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DOI: https://doi.org/10.3897/arphapreprints.e103657

D3.2 Report on gaps and important new areas for monitoring in Europe

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EUROPABON

D3.2 REPORT ON GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE

08/02/2023

Lead beneficiary: BIOPOLIS

This project receives funding from the European Commission's Horizon 2020 research and innovation programme, under Grant Agreement n.101003553

Prepared under contract from the European Commission

Grant agreement No. 101003553

EU Horizon 2020 Coordination and Support Action

Project acronym:	**EuropaBON**
Project full title:	**EUROPA BIODIVERSITY OBSERVATION NETWORK: INTEGRATING DATA STREAMS TO SUPPORT POLICY**
Start of the project:	01.12.2020
Duration:	36 months
Project coordinator:	Prof. Henrique Pereira Martin-Luther Universitaet Halle-Wittenberg (MLU) www.europabon.org
Type:	Coordination and Support Action
Call:	The Sc5-33-2020 Call: "Monitoring ecosystems through innovation and technology"

Project ref. no.	**101003553**
Project title	**EUROPA BIODIVERSITY OBSERVATION NETWORK: INTEGRATING DATA STREAMS TO SUPPORT POLICY**

Deliverable title	Report on gaps and important new areas for monitoring in Europe
Deliverable number	D3.2
Contractual date of delivery	31.11.2022
Actual date of delivery	08.01.2023
Type of deliverable	R
Dissemination level	PU
Work package number	WP3
Institution leading work package	CREAF
Task number	T3.2
Institution leading task	BIOPOLIS
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Deliverable description	The co-design of a European Observatory Observation Network requires information on the existenting monitoring capacity in Europe, including the quantity and quality of the data available to generate the Essential Biodiversity Variables (EBVs) identified in Task 4.1 at the spatial- and temporal resolutions desired by users and policy. In this document, we provide a framework to identify the main monitoring gaps to produce European-wide EBVs. Specifically, we provide a detailed and spatially explicit information (country-level) on monitoring gaps for the production of 44 EBVs by analyzing the data flowing to current and past monitoring integration initiatives according to the defined criteria (country coverage; taxonomic/

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	ecosystem coverage; standardized monitoring; time-series data; long-term monitoring; ongoing monitoring; sampling frequency; spatial coverage density; minimum sampling unit; raw data available). Results are presented in factsheets for each EBV and summarized across EBV classes and realms.
Keywords	Country coverage; data availability; Essential Biodiversity Variable (EBV); geographic monitoring gaps; monitoring gaps; ongoing monitoring; spatial resolution; standardized monitoring; taxonomic gaps; temporal resolution; temporal gaps.

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This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

The team

Joana Santana, Francisco Moreira and Pedro Beja from BIOPOLIS led the analyses, with the support of Miguel Porto (BIOPOLIS). The leading team worked closely with Alejandra Morán Ordóñez, Dani Villero and Lluís Brotons from CREAF on the identification of integration initiatives and workflows considered for the gap analysis, and received valuable input on the overall gap framework from Maria Lumbierres (UvA), W. Daniel Kissling (UvA), Henrique Miguel Pereira (MLU; coordinating team), and Jessica Junker (MLU; coordinating team). The leading team also received valuable data and input on the EBV factsheets from Adrià López-Baucells (Natural Science Museum of Granollers), Ana Cristina Cardoso (JRC), Anne Lyche Solheim (NIVA), Borja Jiménez Alfaro (University of Oviedo), Gabri Miret (CREAF), Jannicke Moe (NIVA), Joana Soares (TERINOV), Judy Shamoun-Baranes (University of Amsterdam), Laurence Carvalho (NIVA), Neftalí Sillero (University of Porto), Nicolas Segebarth (European Commission), Sophie Mentzel (NIVA), Tom Breeze (UReading), Vujadin Kovacevic (European Commission).

Executive Summary

The co-design of a European Observatory Observation Network requires updated information on the monitoring capacity in Europe, including the quantity and quality of the data available to generate the Essential Biodiversity Variables (EBVs) identified in EuropaBON D4.1 at the spatial and temporal resolutions required by users and policy. In this work, considering existing European monitoring programmes providing data to produce the EBVs defined by EuropaBON D4.1, we present a framework to identify the main monitoring gaps to generate EBVs corresponding to the six generic EBV classes identified by the GEOBON network (Genetic composition, Species populations, Species traits, Community composition, Ecosystem function, Ecosystem structure) across the three Earth realms (freshwater, marine and terrestrial). Firstly, we provide a glossary of the terms related to the EBV attributes and the raw monitoring data and sampling that are used to identify the data gaps. Secondly, we build on the Biodiversity Monitoring Database from EuropaBON D3.1 to define criteria to identify thematic (taxonomic/ecosystem representation), geographic, and temporal gaps in EBVs generation. Then, we provide a detailed and spatially explicit information (country-level) on monitoring gaps for the production of EBVs by analysing the data flowing to current and past monitoring integration initiatives according to the defined criteria (country coverage; taxonomic/ ecosystem coverage; standardized monitoring; time-series data; long-term monitoring; ongoing monitoring; sampling frequency; spatial coverage density; minimum sampling unit; raw data available). Finally, we provide a general overview of Europe's main biodiversity monitoring capacities and how they meet user and policy needs as reported in EuropaBON D2.2. By covering the main taxonomic/ecosystem groups across the three Earth realms, this work provides the most comprehensive continental-scale assessment of ongoing monitoring capacities in relation to user and policy needs with implications for the identification of gaps in biodiversity monitoring in Europe and elsewhere.

1. INTRODUCTION

Biodiversity is declining worldwide at an unprecedented rate. The idea that we are experiencing the 6th mass extinction has increasing consensus in the scientific community, supported by evidence of species extinctions, decreases in population ranges and abundance for all taxa, and loss of genetic diversity (Pereira et al. 2012, Ceballos et al. 2015). This idea also has a growing echo in society, leading to a number of global and EU policies and initiatives aimed at reversing biodiversity loss being

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developed. Given the European Union's goals to address the global biodiversity crisis and meet the Sustainable Development Goals (SDGs) for 2030, there is an urgent need to find consistent indicators that can predict variations in biodiversity assets in relation to environmental change and that are meaningful for research, management and policy (Geijzendorffer et al. 2016; Proença et al. 2017). In response to this, the GEOBON network developed the Essential Biodiversity Variables (EBVs) concept that aims to structure biodiversity monitoring globally and to harmonize and standardize biodiversity data to capture a minimum set of critical variables required to study, report and manage biodiversity change (Pereira et al. 2013). EBVs represent harmonised data that are conceptually located on a continuum between primary data observations ('raw data') and synthetic or derived indices ('indicators') categorized in six EBV classes (i.e. genetic composition, species populations, species traits, community composition, ecosystem functioning and ecosystem structure) (Pereira et al. 2013).

EuropaBON builds on the concept of Essential Biodiversity Variables (EBVs) and on a consultation process including a diverse range of stakeholders, to define a set of EBVs at the European level for the freshwater, marine, and terrestrial realms, covering the six EBV classes. EuropaBON's overarching goal is to provide the terms of reference (TOR) for an European Biodiversity Observation Network. The co-design process requires updated information on the monitoring capacity in Europe, including the quantity and quality of the data available to generate the EBVs at the spatial and temporal resolutions required by users and policy identified in EuropaBON D4.1. Despite the efforts to increase biodiversity monitoring in Europe, however, there are still major gaps in the data produced with respect to the definition of geographic coverage, standardized protocols, taxonomic/ecosystem representation, temporal and spatial resolution and extent. The accessibility to raw data and metadata may also hinder the application of FAIR principles ('findable, accessible, interoperable and reusable', Wilkinson et al. 2016) in data access can hinder the production of EBVs at the European scale.

EuropaBON D3.2 aims to identify monitoring gaps in the existing biodiversity-monitoring capacities in Europe regarding the quantity and quality of the data required for the generation of EBVs. Specifically, we aim to identify gaps in terms of: (i) geographic and taxonomic/ecosystem representation, (ii) existence of standardized monitoring, (iii) sampling frequency and level of spatial resolution in the data, (iv) raw data availability, in the assessment of several levels of biodiversity, both scientifically and especially regarding policy-specific requirements. To achieve these goals, we have explored existing monitoring initiatives at the European level to identify gaps in their data production in each country that hinders the generation of EBVs at the European level. Overall, these analyses will provide detailed and spatially explicit information (country-level) on monitoring gaps for the production of EBVs, thus providing guidance for the identification of important new areas and target taxa for monitoring in Europe, as well as the need for further methodological and data management standards.

2. METHODS

2.1. Framework for identifying monitoring gaps

We developed a framework to identify biodiversity monitoring gaps hindering the generation of EBVs at the European level. It is based on four steps detailed below (Figure 1): Step 1 - Set criteria to identify monitoring gaps; Step 2 - Extracting and processing information; Step 3 - Identification of monitoring gaps; Step 4 - Identification of important areas and taxa for monitoring. We focused on a subset of the 70 EBVs defined by EuropaBON D.4.1 (https://github.com/EuropaBON), covering the six generic EBV classes identified by GEOBON (https://geobon.org/; Genetic composition, Species populations, Species traits, Community composition, Ecosystem function, Ecosystem structure), and

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the three Earth realms (freshwater, terrestrial and marine) (Table 1). A glossary of the terms used in this report is provided in Appendix I and available in https://github.com/EuropaBON.

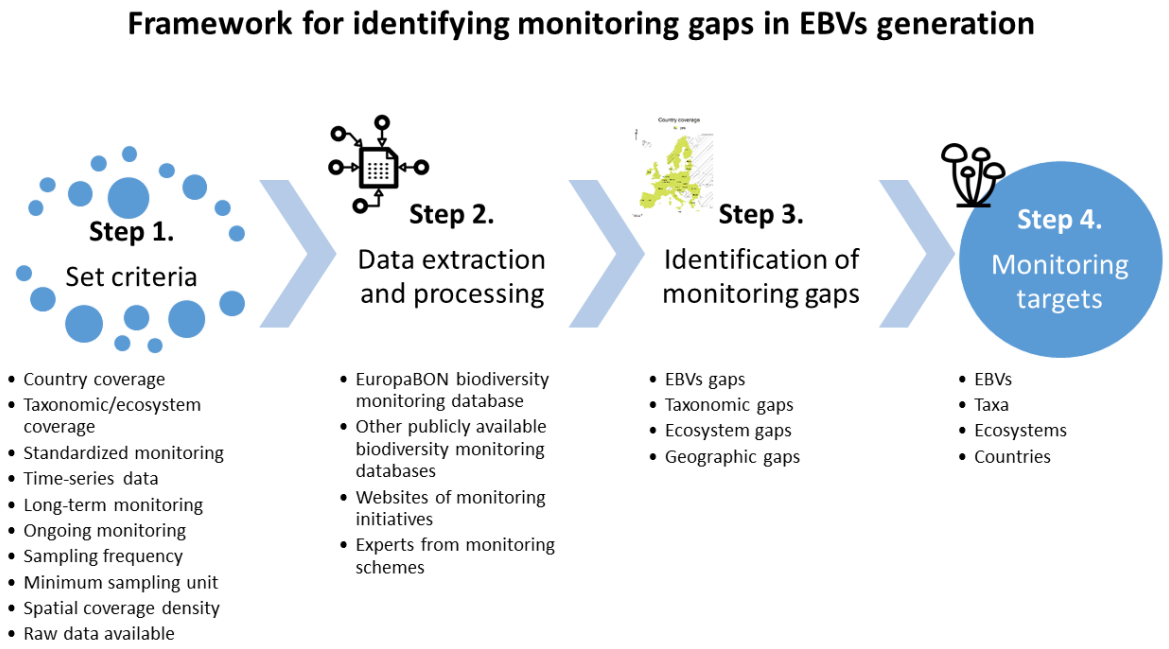

Figure 1. Framework for identifying monitoring gaps in the production of European-wide EBVs.

Table 1. Number of EBVs defined in EuropaBON Task 4.1 and currently covered by the analysis of monitoring gaps (Task 3.2) per EBV classes and realms (Freshwater, Fresh; Marine, Marin, and Terrestrial, Terre). Proportion (% Total) of EBVs covered by the monitoring gaps analyses in relation to the number of EBVs defined in EuropaBON Task 4.1. across EBV classes and realms.

	T4.1 EBVs definition				T3.2 Gap analysis				
EBV classes	**Fresh**	**Marin**	**Terre**	**Total**	**Fresh**	**Marin**	**Terre**	**Total**	**% Total**
Genetic composition	1	1	1	3	1	1	1	3	100%
Species populations	7	7	14	28	6	5	14	25	89%
Species traits	1	1	4	6	1	0	4	5	67%
Community composition	6	1	5	12	6	0	4	10	83%
Ecosystem structure	3	4	3	10	1	0	0	1	10%
Ecosystem function	2	4	5	11	1	0	0	1	9%
Total	20	18	32	70	16	6	22	44	63%
% Total					80%	33%	69%		

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Table 2. Criteria defined to identify monitoring gaps in EBVs generation.

Criteria	Question	Rationale	Description
C1. Country coverage	Q1. Does the country have a national-level monitoring scheme integrated into an EU-level monitoring programme or integration initiative able to generate the EBV?	A gap is assumed to exist in a country if there is no national-level monitoring programme or if monitoring data generated at national levels is not integrated into an EU-level initiative potentially producing an EU-level EBV.	Countries covered by the monitoring scheme.
C2. Taxonomic/ ecosystem coverage	Q2. Does the monitoring programme target the taxonomic (or ecosystem) focus of the EBV?	A gap is assumed to exist If monitoring is focused on just part of the taxonomic (or ecosystem) scope of the EBV (e.g. just some species of fish, rather than the whole fish community).	Level of coverage of taxa or ecosystem types needed for deriving the EBV and covered by the monitoring scheme. Partial gap: not all species are covered (e.g. bivalves and dragonflies are not monitored for WFD): species level identification only for some species.
C3. Standardized monitoring	Q3. Does the monitoring programme follow a specific sampling protocol (i.e. are sites sampled using the same methods)?	A gap is assumed to exist if monitoring is based on non-standardized methodologies (i.e., opportunistic observations or methodologies varying over time and space), in which case data may be difficult to combine for producing an EBV.	Existence of a scheme where a specific field protocol is followed. Partial gap: one of the schemes does not follow standardized protocols.
C4. Time-series data	Q4. Does the monitoring programme encompass sampling for at least two different years?	A gap is assumed to exist if the monitoring programme only involves sampling in a single year (snapshot, one-off monitoring), even if there are multiple sampling occasions in that year. Without this information, it is impossible to derive inter-annual EBV trends.	Repeated measures of a sampling site in least two different years.
C5. Long-term monitoring	Q5. Does the first sampling occasion of the monitoring programme took place 10 years ago or more?	A gap is assumed to exist if only recent (<10 years) data is available because this makes it impossible to estimate long-term EBV trends. The criterion is assumed to be fulfilled if the first	Monitoring data collected over 10 years ago.

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Criteria	Question	Rationale	Description
		monitoring took place before 2012, regardless of whether it was a time-series or one-off monitoring.	
C6. Ongoing monitoring	Q6. Is monitoring data still being collected?	A gap is assumed to exist if the monitoring programme is no longer being implemented. Ongoing monitoring programs represent existing monitoring capacities.	Ongoing one-off monitoring programmes (e.g. atlas targeted monitoring) are considered as ongoing.
C7. Sampling frequency	Q7. Does the monitoring programme involve sampling at time intervals equal to or smaller than the EBV desired temporal resolution?	A gap is assumed to exist if the monitoring frequency is lower than the EBV desired temporal resolution.	Number of samples per unit time (e.g. snapshot/ once-off, annually). Partial gap: the sampling frequency is lower than the higher spatial resolution of the EBV.
C8. Spatial coverage density	Q9. Does the monitoring programme involve sampling at a network of sites sufficiently dense to produce the EBV at the desired spatial resolution?	A gap is assumed to be present if the density of sampling sites is too low to permit the production of the EBV at the desired spatial resolution.	- Definition of an arbitrary threshold for WFD freshwater monitored EBVs: Gap: countries with very low (<20%) proportion of monitored lakes and rivers. Partial gap: countries with the % monitoring water bodies <20% in rivers or lakes. Information based on countries reporting data for the WFD based on monitoring (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no). - Visual inspection of the maps available on the initiatives websites: baseline data have already been used to produce atlases/maps with national coverage matching or exceeding the spatial resolution desired for EBV. Partial gap: the spatial atlas/map of the atlas/map is lower than the higher spatial resolution of the EBV.

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Criteria	Question	Rationale	Description
C9. Minimum sampling unit	Q8. Is the minimum sampling unit equal to or higher than the spatial resolution of the EBV?	A gap is assumed to exist if data is collected at a spatial resolution lower than the EBV desired spatial.	Accuracy at which the location is registered (e.g. exact location, 10x10km grid cells). Gap: the minimum sampling unit is higher than the lower spatial resolution of the EBV; Partial gap: the minimum sampling unit is lower than the lower spatial resolution of the EBV but not than the higher spatial resolution of the EBV.
C10. Raw data available	Q9. Is the monitoring data available in compliance with the FAIR principles (open access or available upon request)?	A gap is assumed to exist if data is not easily available in compliance with the FAIR principles. This gap implies that the generation of EBV is not possible, even when data is collected by a monitoring programme but remains largely inaccessible.	The degree of compliance of the raw data with FAIR principles (Findability, Accessibility, Interoperability, and Reuse, https://www.go-fair.org/fair-principles/). The criterion is fulfilled if raw data is open available or available upon request, or, if it is not available but the EBV is already a product which is available (e.g. EQR values). Partial gap: i) data is available under request but a payment is required; ii) open access only covers part of the data; iii) data request requires authorization of individual data owners; iv) data is available but only at the EBV spatial resolution (e.g. Atlas).

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Step 1 - Criteria to identify monitoring gaps

The definition of criteria to identify geographic and taxonomic monitoring gaps in EBV generation was based on the minimum data requirements for building EBVs at the desired temporal and spatial resolutions in regard to the spatial-, temporal-, and taxonomic- extents and resolutions of the monitoring data, and the degree of accessibility to the data (Kissling et al. 2018). We defined ten criteria for EBV generation reflecting potential gaps related to data collection and data integration that we describe in Table 2.

Step 2 - Extracting and processing information

To obtain the information on gaps, we first extracted data on monitoring programmes from the EuropaBON biodiversity monitoring database including information on pan-national biodiversity monitoring efforts (EuropaBON Deliverable D3.1, https://monitoring.europabon.org). This was complemented whenever possible with the help of experts involved in the initiatives, other publicly available biodiversity monitoring databases (e.g. MarBioMe, Jessop et al. 2022 for marine EBVs), and information on the websites of monitoring initiatives at national and subnational levels. Second, from these data sources, we identified European and regional-level monitoring initiatives that could provide information for producing the 70 EBVs selected in Task 4.1. Third, we built a new database linking each EBV with information on potentially useful monitoring initiatives. Finally, we gathered country-level information on whether biodiversity monitoring data flowing to European-level monitoring initiatives follow the criteria for generating the EBV (Table 2), which were the basis for the identification of monitoring gaps. The identification of monitoring gaps was based on a 'yes' or 'no' alternative for answering a question (Q#) related to each criterion (C#). A "partially" option was selected whenever only part of the monitoring data filled the criteria, if the data that fills the criteria has limited spatial and/or taxonomic/ecosystem coverage, or whenever only part of the criteria is fulfilled by the monitoring scheme (for example, if the desired spatial resolution is 1x1km - 10x10km, and the minimum sampling unit is 10x10km). "Unknown" was attributed whenever the information available was insufficient to answer the question (see Table 2).

Step 3 - Identification of monitoring gaps

Monitoring gaps hindering the generation of each EBV were described in a factsheet containing: i) a summary of the current monitoring and main monitoring gaps; ii) the definition of the EBV (from EuropaBON D4.1, https://github.com/EuropaBON); and ii) the current monitoring and main gaps for different criteria (see Appendices II, III, IV). The identification of monitoring gaps was then represented in the form of 'loading bars', each reflecting the distance to achieve the monitoring requirements for EBVs generation in terms of a specific criterion. In addition, geographic gaps were represented in a form of maps country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV. The loading bars are calculated as the percentage of European Union Member States (EU-MS, n = 27) that fullfil criterion ('yes'). In the case of marine EBVs the calculation of loading bars is restricted to EU-MS that have a coastline (n = 22).

The identification of monitoring gaps across realms and EBV classes in Europe was done by summarizing the monitoring gaps in regard to the different criteria (country coverage; taxonomic/ ecosystem coverage; standardized monitoring; time-series data; long-term monitoring; ongoing monitoring; sampling frequency; spatial coverage density; minimum sampling unit; raw data available). Specifically, we calculated the mean percentage of EU-MS that fulfilled each criterion grouped by EBV classes and EBV realms. Results are reported in five categories reflecting increasing criterion fulfillment ('yes') by EU-MS: Very-Low (<20% of EU-MS); Low [20-40%[; Moderate [40-60%[; High [60-80%[; Very-High (≥80% of EU-MS). This relatively coarse scale was used to account for

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imprecision in parameter estimates. For the identification of geographic gaps, the sum of EBVs that fulfil each criterion per country was mapped.

Step 4 - Identification of important areas and taxa/ ecosystems for monitoring

To identify important areas and taxa/ ecosystems for monitoring, for each EBV, we calculated the mean percentage of EU-MS that fulfilled each criterion (country coverage; taxonomic/ ecosystem coverage; standardized monitoring; time-series data; long-term monitoring; ongoing monitoring; sampling frequency; spatial coverage density; minimum sampling unit; raw data available). Results were represented in four categories reflecting increasing criterion fulfilment by EU-MS: Very-Low (<20%); Low [20-40%[; Moderate [40-60%[; High [60-80%[; Very-High (≥80%). From the analysis of the proportion of EU-MS that fulfil the criteria for assessing the monitoring gaps hindering the production of the EBVs evaluated in this study, we identified the monitoring stage of each EBV (Table 3): a) Nearly non-monitored EBVs (<20% EU-MS); EBVs with major monitoring gaps (20-60% EU-MS); Highly monitored EBVs (60-80% EU-MS); 4) Very-highly monitored EBVs (>80% EU-MS). Lower criterion fulfilment by EU-MS corresponds to important new areas and target taxa for monitoring in Europe. This links to the EuropaBON bottleneck analysis (Task 3.3) as a subsequent step to identify possible causes for the gaps, and the co-design workflows (Task 4.3) in the formulation of solutions to reduce the gaps identified in this report.

3. RESULTS

EuropaBON Task 3.2 provides detailed and country-level information on monitoring gaps for 44 (63%) of the 70 EBVs (16 freshwater, 6 marine, 22 Terrestrial) defined in EuropaBON Task 4.1. (see Table 1, Figure 2). The EBVs analyzed are largely representative of the species populations and community composition EBV classes, and of the freshwater marine and terrestrial realms (Table 1). Specifically, we analysed all the genetic composition EBVs (3); 89% of the species populations EBVs; 83% of the community composition EBVS; and 67% of the species traits EBVs. EBVs related to ecosystem structure and function are less represented (2 EBVs) as these are mostly produced through remote sensing, which was not the main focus of this analysis. Regarding realms, freshwater EBVs were the most analyzed (89%), followed by terrestrial EBVs (69%). EBVs from the marine realm were the less represented (33%), and were related to species populations and genetic composition EBV classes. A detailed analysis per EBV is shown in the Appendices II-IV, and we summarize here the main trends across realms and EBV classes.

3.1. Monitoring gaps across realms and EBV classes

Overall, the main monitoring gaps identified are related to the criteria spatial coverage density and raw data availability, which on average are fulfilled by only a small proportion of EU-MS (around 25%) (Figure 3). Other important criteria met on average by just a moderate proportion of EU-MS (40-60%) are the taxonomic/ ecosystem coverage, long-term monitoring, sampling frequency, ongoing monitoring programmes, time-series data, and minimum sampling unit. The only criteria fulfilled on average by a high proportion of EU-MS are the country coverage and standardized monitoring, while no criteria is fulfilled on average by >80% of EU-MS (Figure 3). Overall, across realms gaps were slightly larger in the freshwater realm (58%), compared to marine and freshwater (43% and 41%, respectively) (Figure 3). Regarding EBV classes, the major gap by far was genetic composition. Species traits, species populations and ecosystem structure EBV classes also had relevant gaps (30%, 48% and 58%, respectively) (Figure 3). The EBVs with less gaps were community composition and ecosystem function, but the latter refers to a single EBV. These general patterns vary, however, across realms and EBV classes, as described below (Figure 3).

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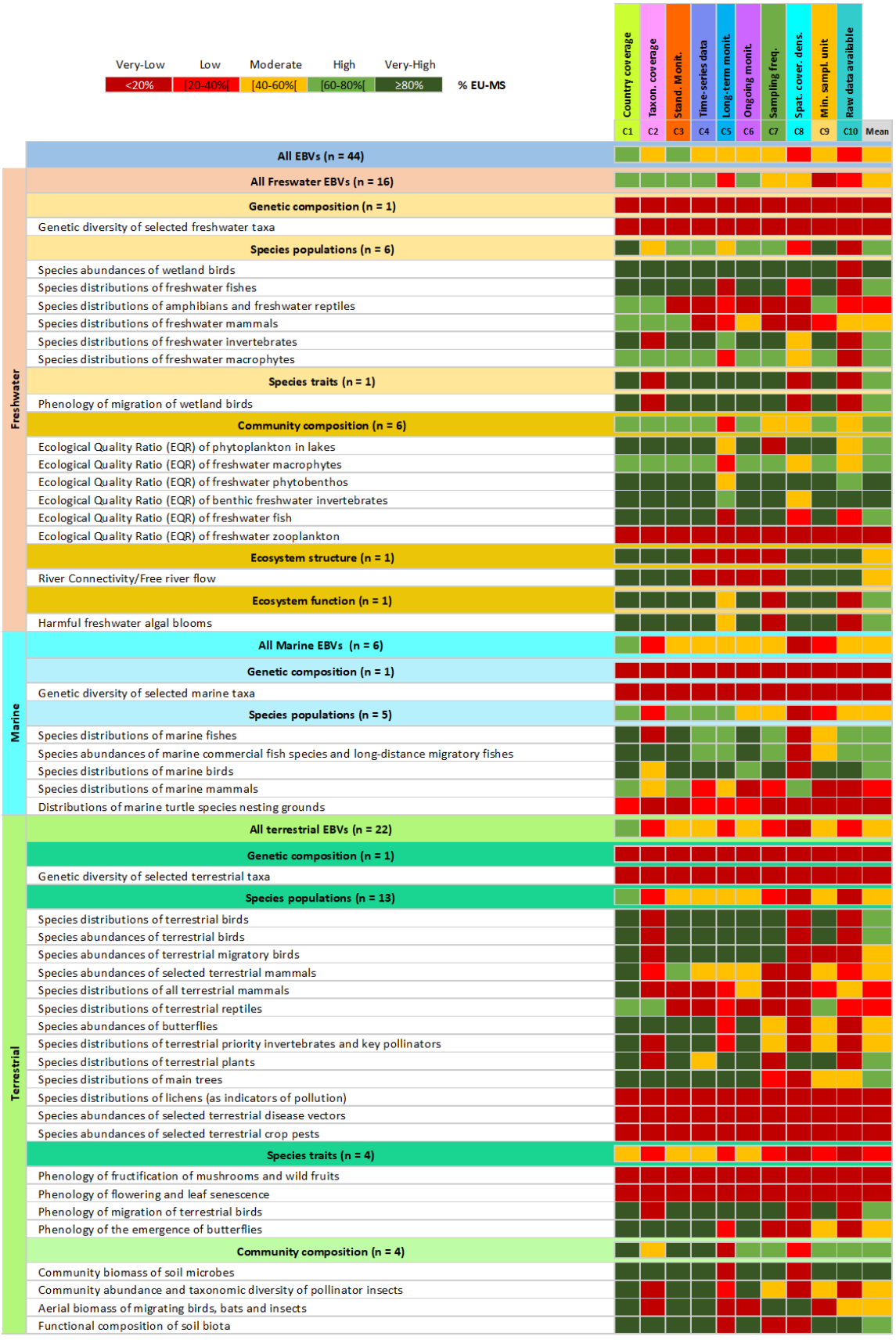

Figure 2. Mean percentage of member states (EU-MS) that meet the criteria for assessing monitoring gaps in the generation of the 44 EBVs. Green-Yellow-Red colour classes indicates increasing monitoring gaps hindering the production of the EBVs.

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Country coverage. This criterion was on average highly fulfilled by 61-77% of EU-MS for all realms. Regarding the EBV classes, there was a particularly large gap for genetic composition, with none (0%) of the EU-MS fulfilling this criterion. Regarding the species traits EBV classes, the proportion of countries fulfilling the criteria is on average 45%. This gapwas less important for community composition, Ecosystem structure and Ecosystem function EBV classes, with 81-96% of the EU-MS fulfilling it.

Taxonomic/ ecosystem coverage. This is a particularly important gap for the Marine and Terrestrial realms, with just a few (25-29%) EU-MS meeting this criterion. In contrast, 64% of EU-MS meet this criterion for the Freshwater realm. Regarding the EBV classes, there was a particularly large gap for genetic composition, species populations, and species traits, with 0-34% of the EU-MS fulfilling this criterion. Regarding the community composition, and the ecosystem structure and function EBV classes, the proportion of countries fulfilling the criteria is on average 63% and 85-96%, respectively.

Criteria	Freshwater	Marine	Terrestrial	Overall
C1. Country coverage	77	61	66	69
C2. Taxonomic/ ecosystem coverage	64	29	25	40
C3. Standardized monitoring	71	58	58	63
C4. Time-series data	62	52	56	58
C5. Long-term monitoring	39	55	37	40
C6. Ongoing monitoring	64	45	55	57
C7. Sampling frequency	51	45	37	43
C8. Spatial coverage density	44	11	9	22
C9. Minimum sampling unit	74	30	46	54
C10. Raw data available	30	40	20	26
Overall	58	43	41	47

Mean % EU-MS fulfil criteria

<20%	Very-Low
[20-40%[	Low
[40-60%[	Moderate
[60-80%[	High
≥80%	Very-High

Criteria	Genetic composition	Species populations	Species traits	Community composition	Ecosystem structure	Ecosystem function	Overall
C1. Country coverage	0	75	45	81	96	85	69
C2. Taxonomic/ ecosystem coverage	0	34	20	63	96	85	40
C3. Standardized monitoring	0	64	44	81	96	85	63
C4. Time-series data	0	58	45	81	0	85	58
C5. Long-term monitoring	0	54	32	26	0	48	40
C6. Ongoing monitoring	0	61	45	71	0	85	57
C7. Sampling frequency	0	47	25	60	0	0	43
C8. Spatial coverage density	0	15	0	41	96	81	22
C9. Minimum sampling unit	0	54	40	69	96	85	54
C10. Raw data available	0	19	1	56	96	15	26
Overall	0	48	30	63	58	66	47

Figure 3. Mean percentage of EU-MS that fulfill each of the 10 criteria across realms (upper painel), and EBV classes (lower painel). Green-Yellow-Red colour classes indicate increasing monitoring gaps hindering EBVs generation.

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Standardized monitoring. This is a particularly important gap for the Marine and Freshwater realms, with just a few (58%) EU-MS meeting this criterion. In contrast, 71% of EU-MS meet this criterion for the Freshwater realm. Regarding the EBV classes, there was a particularly large gap for genetic composition, with none (0%) of the EU-MS fulfilling this criterion. Regarding the species traits EBV classes, the proportion of countries fulfilling the criteria is on average 44%. This criterion was less important for community composition, Ecosystem structure and Ecosystem function EBV classes, with 81-96% of the EU-MS fulfilling it.

Time-series data. This is a particularly important gap for the Marine and Freshwater realms, with just a few (52-56%) EU-MS meeting this criterion. In contrast, 62% of EU-MS meet this criterion for the Terrestrial realm. Regarding the EBV classes, there was a particularly large gap for genetic composition and Ecosystem structure, with none (0%) of the EU-MS fulfilling the criterion. Regarding the species populations and species traits EBV classes, the proportion of countries fulfilling the criteria is on average 45-58%. This criterion was less important for community composition and ecosystem function, with 81-85% of the EU-MS fulfilling it.

Long-term monitoring. This is a particularly important gap for the Freshwater and Terrestrial realms, with just a few (37-39%) EU-MS meeting this criterion. In contrast, 55% of EU-MS meet this criterion for the Marine realm. Regarding the EBV classes, there was a particularly large gap for genetic composition and ecosystem structure, with none (0%) of the EU-MS fulfilling this criterion. Gaps were also relevant for species traits and community composition, with less than 30% of the EU-MS fulfilling it. Regarding the species populations and Ecosystem function EBV classes, the proportion of countries fulfilling the criteria is higher 48-54%.

Ongoing monitoring. This is a particularly important gap for the Marine and Freshwater realms, with ca. half (45-55%) EU-MS meeting this criterion. In contrast, 64% of EU-MS meet this criterion for the Terrestrial realm. Regarding the EBV classes, there was a particularly large gap for genetic composition and Ecosystem structure, with none (0%) of the EU-MS fulfilling this criterion. Regarding the species traits EBV class, the proportion of countries fulfilling the criteria is on average 45%. This gapwas less important for species populations, and for community composition and ecosystem function, as the proportion of countries fulfilling the criteria is on average 61% and 71-85%, respectively.

Sampling frequency. This is a particularly important gap for the Terrestrial realm, with just a few (37%) EU-MS meeting this criterion. In contrast, 45-51% of EU-MS meet this criterion for the Freshwater and Marine realms. Regarding the EBV classes, there was a particularly large gap for genetic composition, ecosystem structure and ecosystem function, with none (0%) of the EU-MS fulfilling this criterion. Regarding the species traits and species populations EBV classes, the proportion of countries fulfilling the criteria is on average 25%. The gap was less important for community composition, with 60% of the EU-MS fulfilling it.

Spatial coverage density. This is a particularly important gap for the Marine and Terrestrial realms, with just a few (9-11%) EU-MS meeting this criterion. In contrast, 44% of EU-MS meet this criterion for the Freshwater realm. Regarding the EBV classes, there was a particularly large gap for genetic composition, species populations, and species traits, with just 0-15% of the EU-MS fulfilling this criterion. Smaller gaps exist forcommunity composition, and ecosystem structure and function EBV classes, where the proportion of countries fulfilling the criteria is on average 41% and 81-96%, respectively.

Minimum sampling unit. This is a particularly important gap for the Marine realm, with just a few (30%) EU-MS meeting this criterion, whereas 46% meet this criterion for the Terrestrial realm. In contrast, 74% of EU-MS meet this criterion for the Freshwater realm. Regarding the EBV classes, there was a particularly large gap for genetic composition, with none (0%) of the EU-MS fulfilling this

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criterion. Regarding the species populations and species traits EBV classes, the proportion of countries fulfilling the criteria is on average 40-54%. This criterion was less important for community composition and ecosystem structure and function EBV classes, with 85-96% of the EU-MS fulfilling it.

Raw data availability. This is a particularly important gap for the Freshwater and Terrestrial realms, with just a few (20-30%) EU-MS meeting this criterion. In contrast, 40% of EU-MS meet this criterion for the Marine realm. Regarding the EBV classes, there was a particularly large gap for genetic composition, species populations, species traits and ecosystem function, with just 0-19% of the EU-MS fulfilling this criterion. Regarding the community composition, and the ecosystem function EBV classes, the proportion of countries fulfilling the criteria is on average 56% and 96%, respectively.

3.2. Geographic monitoring gaps

On average, 30% of the EU-MS do not have a national-level monitoring programme, or monitoring data generated at national levels is not integrated into an EU-level initiative potentially producing an EU-level EBV. While geographic coverage was very-high (>80% EU-MS) for 63% of the EBVs, it was only complete for 20% of the EBVs. The monitoring gaps for the production of the EBVs are heterogeneous across EU-MS for some criteria in each realm (Figures 4-6). For the EBVs of the Freshwater realm, geographic differences among EU-MS are mostly related to the criteria long-term data, spatial coverage density and raw data availability (Figure 4). Overall, some Eastern countries such as Check Republic, Slovakia and Croatia and Malta, generally showed a lower number EBVs that fulfil each criterion (<60%). Geographic patterns in monitoring for the production of EBVs from the Marine realm, are mostly related to the criteria taxonomic/ ecosystem coverage, long-term data and ongoing-monitoring (Figure 5). The coastline countries with a lower number EBVs that fulfil each criterion (<60%) were Bulgary, Greece and Malta. For the Terrestrial realm geographic patterns are mostly related to the criteria long-term data, spatial coverage density and raw data availability (Figure 6). Countries with less that 60% of the Terrestrial EBVs included Cyprus, Denmark, Slovack Republic, Greece and Poland.

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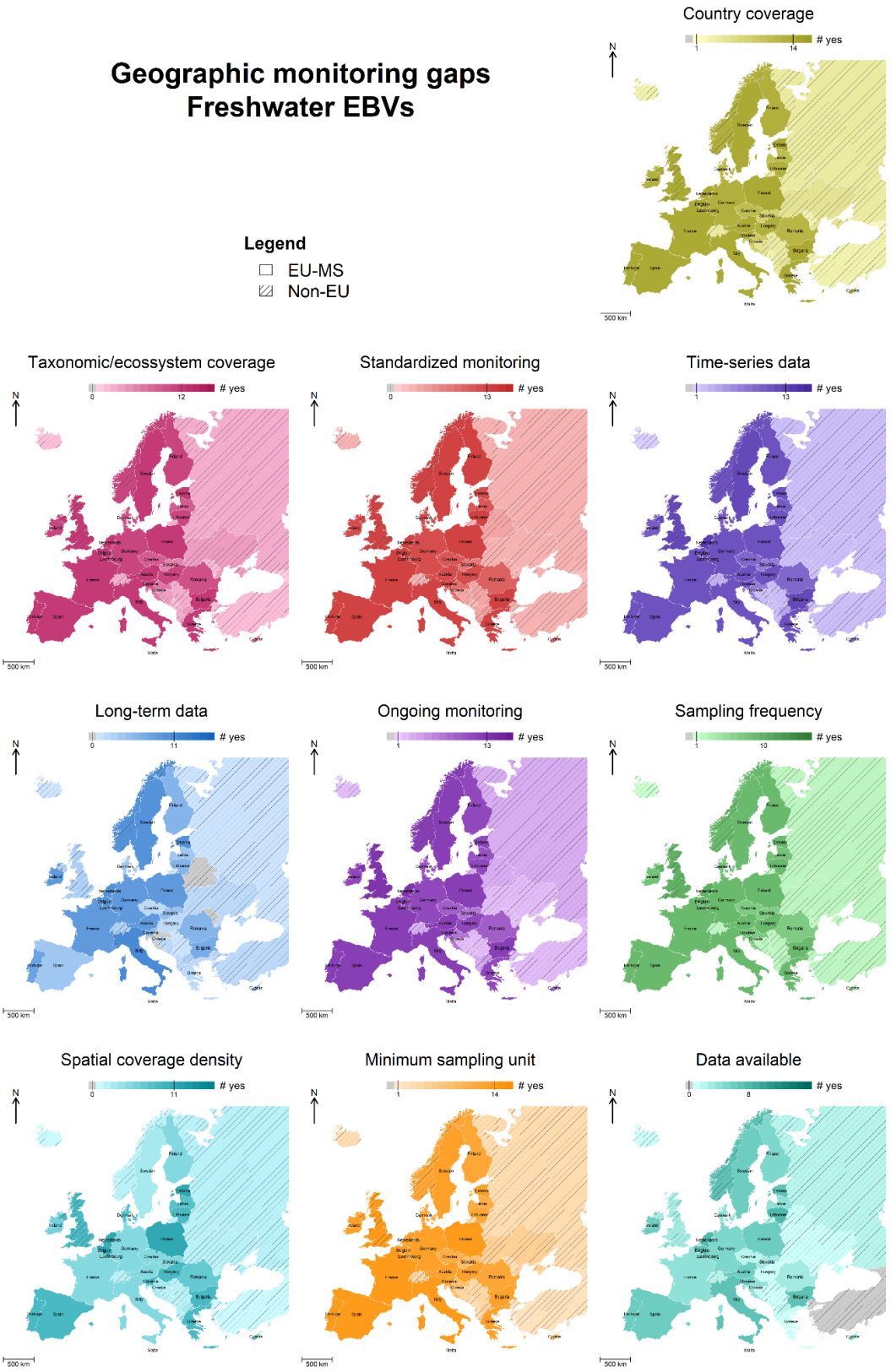

Figure 4. Geographic monitoring gaps for generating freshwater EBVs (n=16). Number of freshwater EBVs that fulfill each criterion in each country (# yes). The color scale shows the range of values (minimum and maximum number of EBVS) across countries, for the total maximum number possible (16).

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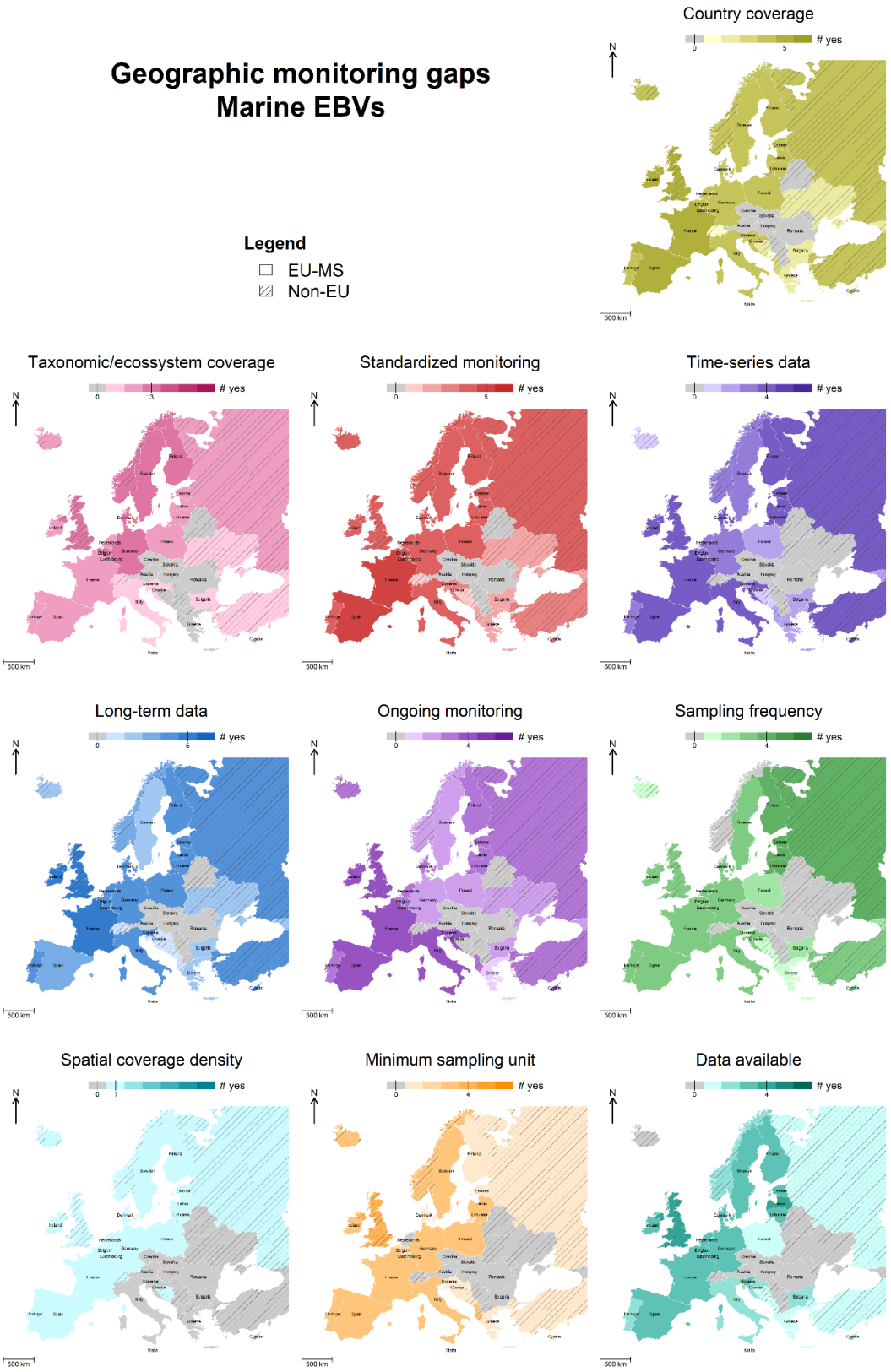

Figure 5. Geographic monitoring gaps for produting marine EBVs. Number of marine EBVs (n=6) that fulfill each criterion in each country (# yes). The color scale shows the range of values (minimum and maximum number of EBVS) across countries, for the total maximum number possible (6).

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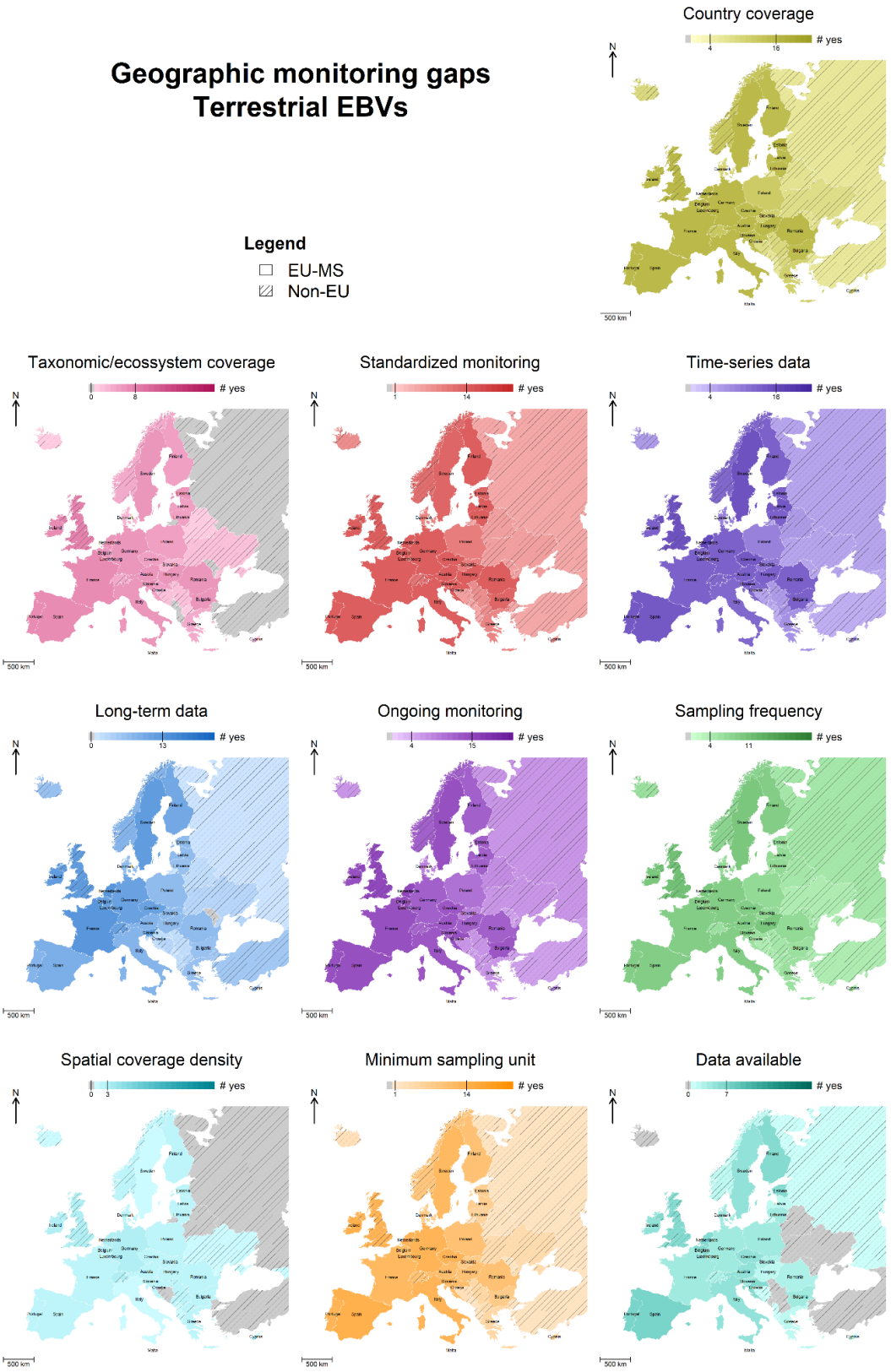

Figure 6. Geographic monitoring gaps for produting terrestrial EBVs. Number of terrestrial EBVs (n=22) that fulfill each criterion in each country (# yes). The color scale shows the range of values (minimum and maximum number of EBVS) across countries, for the total maximum number possible (22).

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3.3. Important areas and taxa/ ecosystems for monitoring

From the analysis of the proportion of EU-MS that fulfill the criteria for assessing the monitoring gaps (Figure 2) we were able to identify the monitoring stage of each EBV (Table 3).

a) Nearly non-monitored EBV's. This group includes 23% of the analysed EBVs (10) to which very few (<20%) EU-MS fulfill the criteria to produce the EBVs (Figure 2): the genetic composition of the three realms; community composition of the freshwater realm; and species population and species traits of the terrestrial realm. To the best of our knowledge, monitoring data of these EBVs is very limited, and there is no initiative integrating monitoring data collected at the national level potentially producing the EBV ('Distributions of marine turtle species nesting grounds') , which low ranking mainly reflects a very reduced country coverage, and from the existing monitoring schemes potentially producing the EBV, most are not targeted on turtles and there is a huge uncertainty around the covered species, whether the spatial coverage density and minimum sampling unit are adequate to provide the EBV at the desired spatial resolution, and in regard to the sampling frequency.

b) EBVs with major monitoring gaps. This group includes 30% of the analysed EBVs (13) to which the average of the proportion of EU-MS that fulfill the criteria to produce the EBVs is 'Low' to 'Moderate' (20-60%) (Figure 2). To the best of our knowledge, there are major gaps hindering the production of nine EBVs related to species population (species distributions and abundances for the three realms); one EBV related to terrestrial species traits; two EBVs related to terrestrial community composition; and one EBV related to ecosystem structure in freshwater realm.

c) Highly monitored EBVs. This group includes 39% of the analysed EBVs (17) to which criteria is on average fulfilled by 60-80% EU-MS (Figure 2): ten EBVs related to species population (species distributions and abundances for the three realms); two EBVs related to freshwater species traits; four EBVs related to community composition; and one EBV related to ecosystem function in freshwater realm.

d) Very-highly monitored EBVs. This group includes 9% of the analysed EBVs (4) to which criteria are on average fulfilled by >80% EU-MS (Figure 2). To the best of our knowledge, only four from the 44 EBVs are in this stage: one EBV related to species populations and three EBV related to community composition.

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Table 3. EBVs classified into four categories reflecting the monitoring gaps based on the proportion of EU-MS that fulfil the criteria for producing European-wide EBVs.

a) Nearly non-monitored EBV's (<20% EU-MS)

Genetic composition
- Genetic diversity of selected freshwater taxa
- Genetic diversity of selected marine taxa
- Genetic diversity of selected terrestrial taxa

Species populations
- Species distributions of lichens (as indicators of pollution)
- Species abundances of selected terrestrial disease vectors
- Species abundances of selected terrestrial crop pests
- Distributions of marine turtle species nesting grounds

Community composition
- Ecological Quality Ratio (EQR) of freshwater zooplankton

Species traits
- Phenology of fructification of mushrooms and wild fruits
- Phenology of flowering and leaf senescence

b) EBVs with major monitoring gaps (20-60% EU-MS)

Species populations
- Species distributions of amphibians and freshwater reptiles
- Species distributions of terrestrial reptiles
- Species distributions of freshwater mammals
- Species distributions of marine mammals
- Species distributions of all terrestrial mammals
- Species distributions of terrestrial priority invertebrates and key pollinators
- Species abundances of selected terrestrial mammals
- Species abundances of terrestrial migratory birds
- Species abundances of butterflies

Species traits
- Phenology of the emergence of butterflies

Community composition
- Community abundance and taxonomic diversity of pollinator insects
- Aerial biomass of migrating birds, bats and insects

Ecosystem structure
- River Connectivity/Free river flow

c) Highly monitored EBVs (60-80% EU-MS)

Species populations
- Species distributions of freshwater fishes
- Species distributions of freshwater invertebrates
- Species distributions of freshwater macrophytes
- Species distributions of marine fishes
- Species abundances of marine commercial fish species and long-distance migratory fishes
- Species distributions of marine birds
- Species distributions of terrestrial birds
- Species abundances of terrestrial birds
- Species distributions of terrestrial plants
- Species distributions of main trees

Species traits
- Phenology of migration of wetland birds

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- Phenology of migration of terrestrial birds

Community composition

- Ecological Quality Ratio (EQR) of phytoplankton in lakes
- Ecological Quality Ratio (EQR) of freshwater macrophytes
- Ecological Quality Ratio (EQR) of freshwater fish
- Functional composition of soil biota

Ecosystem function

- Harmful freshwater algal blooms

d) Very-highly monitored EBVs (>80% EU-MS)

Species populations

- Species abundances of wetland birds

Community composition

- Ecological Quality Ratio (EQR) of freshwater phytobenthos
- Ecological Quality Ratio (EQR) of benthic freshwater invertebrates
- Community biomass of soil microbes

4. DISCUSSION

This study provides the most comprehensive European assessment of ongoing monitoring capacities in relation to user and policy needs, while it develops a framework to identify the main monitoring gaps to generate EBVs corresponding to the generic EBV classes identified by the GEOBON network across the three Earth realms (freshwater, marine and terrestrial). Specifically, we present detailed and spatially explicit information (country-level) on monitoring gaps for a representative sample of the species populations and community composition EBV classes (63% out of the 70 EBVs defined in EuropaBON Task 4.1, 16 freshwater, 6 marine and 22 Terrestrial). Results show that the lack of spatial coverage density, sampling frequency, long-term monitoring and raw data availability, are all particularly important monitoring gaps for the three realms. Other particularly important monitoring gaps for the Marine and Terrestrial realms are related to taxonomic coverage, standardized monitoring, and those hindering to produce the EBVs at the desired temporal and spatial resolutions (sampling frequency and spatial coverage density, respectively). Most of the identified monitoring gaps are taxa specific, with birds, fishes, butterflies and plant trees species being among the more monitored taxa. Less monitored EBVs include genetic composition from all realms, species populations (e.g. lichens, fungi, disease vectors, crop pests, zooplankton, freshwater invertebrates, marine turtles), and the species traits EBVs that are related to the less monitored taxa. Results from this study provide guidance for the identification of important areas and taxa for monitoring in Europe, as well as the need for further methodological and data management standards, to be duly considered for the co-design of the terms of reference (TOR) for a European Biodiversity Observation Network.

4.1. Standardized monitoring

There are only a few initiatives providing standardized monitoring protocols across Europe for terrestrial and freshwater realms. One of such schemes are the European Butterfly Monitoring Scheme (eBMS) collecting data for butterflies; the EU Pollinator Monitoring Scheme (EUPoMS) collecting data for pollinators; the Pan-European Common Bird Monitoring Scheme (PECBMS) collecting data from terrestrial common birds; the African-Eurasian Waterbird Census (AEWC) collecting data from waterbirds; The European Union for Bird Ringing (EURING) collecting data from birds; the Bat Monitoring Programme collecting data from bats; and the European Forest Inventory

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Network (ENFIN) that collecting data from trees; the Water Framework Directive (WFD) collecting data from macroalgae, macrophytes, phytobenthos, benthic invertebrates, and fish in freshwater. However, there is no single European initiative integrating monitoring data on the marine taxa analysed in this study (fishes, mammals, birds and turtles). Biodiversity monitoring in marine realm is very fragmented and mostly integrated at the regional level. For instance, the International Council for the Exploitation of the Sea (ICES) trawling surveys collects data from fishes from North and Northeast Atlantic, the Norwegian Sea, the North See, the Baltic Sea, Mid-Atlantic Ridge, and the Skagerrak; while the European Seabirds At Sea (ESAS) collects data from marine birds from the Northern Sea and NE Atlantic Ocean; and The Fixed Line Transect Mediterranean monitoring Network (FLT Med Net) collects data from one marine turtle species (*Careta careta*) in the Mediterranean Sea. Southern and Eastern marine waters, especially the Black Sea are scarcely monitored, as was also reported by the recent overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters provide by Jessop et al. (2022). Finally, genetic biodiversity for all taxa and realms is not systematic collected or monitored across Europe as reported in a recent review on global genetic diversity status and trends for generate genetic composition EBVs (Hoban et al. 2022).

Standardized monitoring is thus required to combine data collected from different sources for producing the EBVs at the European scale. However, for most taxa, European monitoring across Europe is scattered and the only available information is based on data collected from different sources and monitoring programs based on standardized protocols fails for many taxa, and in most cases, monitoring is based on non-standardized methodologies (i.e., opportunistic observations or methodologies varying over time and space). For instance, species distribution data on amphibians and reptiles is mostly based on historical data, and add doc monitoring not following standardised protocols, citizen science data from online repositories such as GBIF. While much more structured for some selected groups of species (e.g. bats), mammal's species monitoring data is also fragmented and heterogeneous. However, many efforts are being made with the production of the second Atlas of European Mammals based on verified data from national databases by collating dedicated monitoring data, citizens data collected in European and country level Data portals, and historical data available from different sources. Birds are one of the best monitored taxa but even for these a lot of non-standardized monitoring data has been produced. This is the case of data for the EuroBirdPortal that may be used for some species traits EBVs (e.g. 'Phenology of migration of terrestrial birds', 'Phenology of migration of wetland birds'). Standardised monitoring was a particular important monitoring gap for the Marine and Terrestrial realms but not for Freshwater, probably reflecting the efforts for developing standardized protocols to collect metrics inter-calibrated among countries to report water ecological status in freshwater systems to WFD.

4.2. Taxonomic monitoring gaps

European wide monitoring is taxonomic biased. Birds, fishes, butterflies, plant tree species are among the best and more monitored taxa and to which monitoring efforts are closer to potentially producing EBVs at the European scale. Regarding other vertebrate groups such as amphibians, reptiles, and mammals, there is a lack of information based on standardized monitoring protocols enabling the production of European wide EBVs. The few monitoring schemes targeting invertebrates from different realms focus on specific groups (e.g. butterflies, bees) or target threatened species (e.g. *Lucanus cervus*), or species level identification is rarely achieved (e.g. benthic invertebrates monitored for the WFD). In contrast, less monitored taxa include lichens, fungi, disease vectors, crop pests, zooplankton, bivalves, odonata and other priority species listed in the Habitats Directive to which, to the best of our knowledge, monitoring data is very limited, and there is no initiative integrating data collected from these taxa at the national level potentially producing the EBV at the European scale. Also, very little information is available at the European scale for some marine taxa (e.g. marine turtles), most available data is collected by non-targeted monitoring and there is a huge

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uncertainty around the covered species. Fish should be the best monitored taxa in the marine realm, although many monitoring programs are directed to commercial species. These results are in line with the recent overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters provide by Jessop et al. (2022), that reported that fish and benthic invertebrates are the most commonly monitored taxa, with the focus of these taxa being strongest in the North Sea, and the biggest gaps are evident among microbes and turtles. However, according to Jessop et al. (2022), a taxonomic gap should exist for all taxa, but particularly for corals, seagrasses, macroalgae, sea turtles, and microbes due to the lack of monitoring in southern and eastern European waters, pelagic realm and the deep sea.

4.3. Monitoring gaps for produce EBVs at the desired spatial resolution

The spatial coverage density and the minimum sampling unit of the sampling sites are very important monitoring gap for the EBVs from the three realms, hindering the production of the EBVs at the desired spatial resolution. Regarding the Terrestrial realm, the density of sampling sites or the minimum sampling unit is in many cases likely to be enough to produce the EBV at a lower spatial resolution (e.g. 50x50 km grid cells), but it is likely to be too low to produce the EBV at the higher desired spatial resolution (1x1km or 10x10 km grid cells). One of such cases is the data used to produce species distribution atlas such as the European Breeding Bird Atlas 2 (EBBA2) and 2nd European Mammal Atlas (EMMA2), that potentially can produce the EBVs related to species populations (e.g. “Species distributions of terrestrial birds” and “Species distributions of all terrestrial mammals”). While in these cases, existent data is likely to be enough to produce the EBV at the atlas scale (50x50 km), it is likely to be too low to produce the EBV at the higher spatial resolution desired for the EBV, at least for most species. Other example is the European level monitoring programs such as the eBMS or EuPOMs, which aim to identify global population trends across Europe based on country level trends, and thus, the distribution and density of sampling sites is likely to be too low to produce fine-scale information needed for produce the species populations EBVs (e.g. “Species distributions of terrestrial priority invertebrates and key pollinators”) or species traits (e.g. “Phenology of the emergence of butterflies”) at the at the desired spatial resolutions. For the Freshwater realm the minimum sampling unit is unlikely to be an important gap in most cases as monitoring data is collected at the scale of the sampling point or water body which is as a resolution higher than the desired (usually water body or river catchments). However, the density of sampling sites is in many cases too low to provide the EBVs at the desired spatial resolution. This may be the case of the monitoring for WFD. While all EU-MS report to WFD, for many countries only part (or none) is based on monitoring, which in many cases represents less than 20% of the identified water bodies, compromising the production of EBV at the desired spatial resolution. Whether spatial coverage density is enough to produce the EBV at the desired spatial resolution is unclear for many countries particularly for the Marine realm. The evaluation of country-level spatial coverage density was difficult to achieve, as monitoring is mainly made at sea and a dully evaluation would require the definition of specific criteria to this realm (but see Jessop et al. 2022).

4.4. Monitoring gaps for produce EBVs at the desired temporal resolution

The lack of timely updated time-series data is a very important monitoring gap for the EBVs from the three realms, hindering the production of the EBVs at the desired temporal resolution. A few taxa are monitored at an adequate sampling frequency able to produce the EBV with the desired temporal resolution. In most cases, the only European level initiative potentially producing an European wide EBV are snapshots of data collected from different sources and monitoring programs running during a limited time-period to produce European species distribution atlas (e.g. amphibians, reptiles, birds and mammals). These snapshots are produced in 20-30 years intervals which is much lower temporal resolution than required for many EBVs and for Nature Directives reporting (3-6 years). In the case of birds, however, atlas data can be complemented with data collected from target European wide

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initiatives using standardized monitoring programs (e.g. AEWC, PECBMS, EURING,) and citizen science data (EuroBirdPortal) to provide timely estimations of all bird species distributions. Obtaining standardized monitoring data across Europe at the very high temporal resolution desired for some EBVs (real-time, weekly or monthly during a specific season, yearly) is easily for remote sensing related EBVs such as "Aerial biomass of migrating birds, bats and insects" but not for those relying only on in-situ monitoring. Citizen science plays an important role in getting widespread and timely updated in-situ monitoring data for some charismatic groups (e.g. birds, mammals, butterflies) but it fails for other groups and in most cases data cames from simple standardised protocols (e.g. complete bird lists), or in some cases even no protocol (casual observations).

4.5. Raw data access

Difficulties in the access to the raw data may also hinder the production of EBVs at the European scale. Despite the ongoing efforts to increase raw data availability in compliance with the FAIR principles ('findable, accessible, interoperable and reusable', Wilkinson et al. 2016) with the increase of data portals, raw data continues to be in most cases stored in personal and national databases and only the data products are made public available, which is, in most cases, insufficient to produce the EBVs. Raw data availability was thus an important gap for the EBVs from the three realms. One example of such cases is the data collected by EU-MS on composition and abundance of freshwater invertebrates, macrophytes and fish to report ecological status to WFD. However, the huge amount of information collected is stored by each country and not made available. Although a high proportion of EU-MS collects data, raw data is not made available because report relay only on indexes and thus data available cannot be used to produce the species populations related EBVs ("Species distributions of freshwater fishes", "Species distributions of freshwater invertebrates" and "Species distributions of freshwater macrophytes"). One solution would be if the raw data collected under the WFD were reported along with quality status and made available through open repositories, as suggested by Moersberger (2022). In contrast, the data available to produce the EBVs Freshwater community composition EBVs related to Ecological Quality Ratios (EQRs), is reported to Water Information System for Europe, WISE, which collect EQRs from EEA countries. Yet, because the report is voluntary, only some countries report freshwater data to WISE, and thus data is unavailable for the remaining countries collecting data for WFD but that do not report to WISE. Raw data availability in also an important gap for the Terrestrial realm. This include the European wide monitoring initiatives potentially producing European level EBVs, such as the species distribution atlas (e.g. EMMA2, and EBBA2) and monitoring programs (e.g. eBMS), to which difficulties in data access relay in they being largely depend on voluntary work and thus data access need to have permissions from the data owners, hindering the access to all the data. Finally, the continuity of existing European wide monitoring initiatives based on remote sensing may depend on data access. For example, uncleaned polar volume data which can be used to produce the EBV "Aerial biomass of migrating birds, bats and insects" is extracted by the GloBAM program using uncleaned weather radar data provided by the Operational Programme for the Exchange of Weather Radar Information (OPERA). However, the maintenance of the GloBAM program is compromise because the uncleaned polar volume data is no longer made available by OPERA (Shamoun-Baranes et al. 2022) and its continuity is now dependent on agreements with national countries to access data directly from open source pipelines of national meteorological institutes. Many monitoring programs in the marine realm have their data stored in online databases such as DATRAS, the European Marine Observation and Data Network (EMODnet) with access to standard data products access to occurrence data, and Seabirds At Sea (ESAS), however, the raw data is in most cases not public available (Jessop et al. 2022).

4.6. Limitations and future directions

The results presented in this report generally reflect the main existing monitoring gaps for producing EBVs at the spatial and temporal resolutions desired by users and policy, providing the necessary

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background material for advancing subsequent EuropaBON tasks, including the co-design of the workflows (T4.3), and the policy showcases: the Birds Directive (T5.1); the Habitats Directive (T5.2); the Water Framework Directive (T5.3); Restoration and Climate Policy (T5.4); and the Bioeconomy Strategy (T5.5). Still, the study presents some limitations in relation to knowledge gaps and EBVs covered, which will be duly addressed during the development of the subsequent EuropaBON tasks. Specifically, i) EBVs on ecosystem structure and function were underrepresented in our study as they require data from remote sensing, and our main focus was in-situ monitoring EBVs, excluding the variables purely analysed by remote sensing. The exception was the EBV 'Aerial biomass of migrating birds, bats and insects' as it is part of one of the EuropaBON policy showcases (T5.5). ii) Data collection for the identification of monitoring gaps was mainly based on the EuropaBON monitoring database, which was designed for the characterisation of existing workflows in Europe-wide integrated monitoring initiatives. As a result, EBVs whose monitoring is mostly integrated at the regional level (e.g. Marine EBVs) are underrepresented and therefore the information obtained is more limited. Nevertheless, in the case of Marine EBVs, a detailed study of existing monitoring projects and gaps was carried out within the MarBioME project with an overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters (Jessop et al. 2022), and this information will be duly considered during the workflows co-design process (T4.3). iii) The information in the EuropaBON monitoring database is often incomplete leading to country responses to the fulfilment of the criteria being presented as 'unknown' and counted as a gap, although these do not necessarily reflect a monitoring gap, but rather a lack of knowledge by the team. Although there has been some effort to complement the database with existing information from other databases, websites, and experts from the initiatives, complementing the database falls beyond the scope of Task 3.2. These situations are duly identified in the progress bars developed for each EBV and efforts will be made for fill this knowledge gaps during the workflows co-design process (T4.3) and WP5 the policy showcases tasks.

5. CONCLUSIONS

The application of the framework presented here allowed us to identify the main monitoring gaps at the level of data available for the production of 63% of the 70 EBVs defined in EuropaBON Task 4.1 (16 freshwater, 6 marine and 22 Terrestrial). Our study revealed that integration of standardized monitoring data by European-wide initiatives potentially producing European-wide EBVs is very limited. The few that exist fail in at least one criterion for producing the EBVs as desired by policy and uses. Specifically, monitoring data across Europe is taxonomically biased, do not cover all countries or regions; the density of sampled sites is usually insufficient for the production of the EBVs at the desired spatial resolution; there is a lack of long-term time-series data; the sampling frequency is too low for producing the EBV at the desired temporal resolution; and raw data needed to produce the EBVs is hardly accessible. The main source of biodiversity monitoring data at the European scale in terms of quantity and quality of data produced is based on vertebrates, particularly on birds, yet there are no standardized protocols for amphibians and reptiles. To the best of our knowledge monitoring data is lacking for lichens, fungi, disease vectors, crop pests, zooplankton, freshwater invertebrate species, and marine turtles. There is also a large bias in terms of EBV classes and realms. Most of the information concerns populations and communities and there is no information on genetic composition for all taxa and realms due to a lack of systematic data collection and monitoring on genetic biodiversity (Hoban et al. 2022). This work provides support for the challenges identified by stakeholders to biodiversity monitoring (Moersberger 2022) including the need for enhance data gathering, standardization, mobilization, and sharing mechanisms. Below, we summarise key gaps and challenges for biodiversity monitoring for each realm.

Key monitoring challenges for the Freshwater realm:

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- Raw data collected under the Water Framework Directive should be reported along with water quality status.
- Increase country coverage and the proportion of water bodies monitored in each country for WFD.
- Design and implement transnational monitoring programmes with standardized protocols for amphibians, freshwater reptiles, bivalves, odonata, and zooplankton.
- Implement species level identification for invertebrate species in all countries. This may be implemented with the use of new technologies such as eDNA.
- Ensure the maintenance of existing monitoring schemes with the sampling frequency desired for the EBVs.

Key monitoring challenges for the Marine realm:

- European integration of regional monitoring schemes.
- Transnational monitoring programmes with standardized protocols for turtle species nesting grounds.
- Ensure the maintenance of existing monitoring schemes with the sampling frequency desired for the EBVs.
- Implement transnational monitoring programs for different taxa covering in less monitored marine regions such as southern and eastern European waters.

Key monitoring challenges for the Terrestrial realm:

- Implement transnational monitoring programmes with standardized protocols for reptiles, mammals and priority invertebrates listed in Habitats Directive.
- Increase country coverage and spatial coverage density from existing monitoring initiatives.
- Make raw data available from existing monitoring initiatives.
- Ensure the maintenance of existing monitoring schemes with the sampling frequency desired for the EBVs.

6. REFERENCES

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. Sci adv, 1(5), e1400253. https://doi.org/10.1126/sciadv.1400253

Hoban, S., Archer, F. I., Bertola, L. D., Bragg, J. G., Breed, M. F., Bruford, M. W., ... and Hunter, M. E. (2022). Global genetic diversity status and trends: towards a suite of Essential Biodiversity Variables (EBVs) for genetic composition. Biological Reviews, 97(4), 1511-1538.

Jessop, A., Chow, C., Dornelas, M., Pereira, P., Sousa-Pinto, I., Hernández Chan, S., Junker, J., Soares, J., Ratnarajah, L., Fernández, M., Mendo, T. (2022). MarBioME. Overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters. European Commission. Directorate General for Research and Innovation.

Kissling, W. D., Ahumada, J. A., Bowser, A., Fernandez, M., Fernández, N., García, E. A., ... & Hardisty, A. R. (2018). Building essential biodiversity variables (EBV s) of species distribution and abundance at a global scale. Biol Rev, 93(1), 600-625.

Moersberger H, Martin JGC, Junker J, Georgieva I, Bauer S, Beja P, Breeze T, Brotons L, Bruelheide H, Fernández N, Fernandez M, Jandt U, Langer C, Lyche Solheim A, Maes J, Moreira F, Pe'er G, Santana J, Shamoun-Baranes J, Smets B, Valdez J, McCallum I, Pereira HM, Bonn A (2022)

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

Europa Biodiversity Observation Network: User and Policy Needs Assessment. ARPHA Preprints. https://doi.org/10.3897/arphapreprints.e84517

Pereira, H. M., Ferrier, S., Walters, M., Geller, G. N., Jongman, R. H. G., Scholes, R. J., Bruford, M. W., Brummitt, N., Butchart, S. H. M., Cardoso, A. C., Coops, N. C., Dulloo, E., Faith, D. P., Freyhof, J., Gregory, R. D., et al. (2013). Essential biodiversity variables. Science 339, 277–278.

Pereira, H. M., Navarro, L. M., Martins, I. S. (2012). Global biodiversity change: the bad, the good, and the unknown. Annu Rev Environ Resour, 37, 25-50. https://doi.org/10.1146/annurev-environ-042911-093511

Pereira, H. M., Belnap, J., Böhm, M., Brummitt, N., Garcia-Moreno, J., Gregory, R., Martin, L., Peng, C., Proença, V., Schmeller, D. & van Swaay, C. (2017). Monitoring essential biodiversity variables at the species level. In The GEO Handbook on Biodiversity Observation Networks (eds M. Walters and R. J. Scholes), pp. 79– 105. Springer International Publishing, Cham.

Proença, V., Martin, L. J., Pereira, H. M., Fernandez, M., McRae, L., Belnap, J., B¨ohm, M., Brummitt, N., García-Moreno, J., Gregory, R. D., Honrado, J. P., J ¨urgens, N., Opige, M., Schmeller, D. S., Tiago, P. & van Swaay, C. A. M. (2017). Global biodiversity monitoring: from data sources to essential biodiversity variables. Biological Conservation, 213, 256-263. https://doi.org/10.1016/j.biocon.2016.07.014

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., ... & Mons, B. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Scientific data, 3(1), 1-9.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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APPENDIX I. Glossary of terms used in this report.

Term	Description
EBV	Abbreviation for Essential Biodiversity Variable. EBVs are defined as a minimum set of measurements, complementary to one another, that can capture major dimensions of biodiversity change. EBVs are organized in six classes (Genetic composition, Species populations, Species traits, Community composition, Ecosystem functioning, Ecosystem structure) and cover the three realms (Marine, Terrestrial and Freshwater). https://geobon.org/ebvs
EBV attributes	Properties of the biological entities that are being measured.
EBV Class	EBVs are organized in six classes (Genetic composition, Species populations, Species traits, Community composition, Ecosystem functioning, Ecosystem structure).
Genetic composition	This EBV class captures metrics of within-species genetic variation across space and time (Hoban et al 2022). It Includes four generic EBVs (Infraspecific genetic diversity, Genetic differentiation, Effective population size, Inbreeding). https://geobon.org/ebvs
Species populations	EBV class that accesses the spatial and temporal variability in the species populations. This includes two generic EBVs (Species distribution, Species abundance). https://geobon.org/ebvs
Species traits	EBV class that captures the spatial and temporal variation in trait measurements within species. This includes five generic EBVs (Morphology, Physiology, Reproduction, Phenology, Movement). https://geobon.org/ebvs
Community composition	EBV class that assesses inter-specific variability in trait measurements across space and time. This includes four generic EBVs (Community abundance, Taxonomic/phylogenetic diversity, Trait diversity, Interaction diversity). https://geobon.org/ebvs
Ecosystem function	EBV class that captures the spatio-temporal variability of the collective performance of organisms that determines the functioning of an ecosystem. This includes three generic EBVs (Primary productivity, Ecosystem phenology, Ecosystem disturbance). https://geobon.org/ebvs
Ecosystem structure	EBV class capturing the spatial and temporal variability of ecosystem units and the organisms defining these units. This includes three generic EBVs (Live cover fraction, Ecosystem distribution, Ecosystem vertical profile). https://geobon.org/ebvs
EBV Name	One of the standard names listed in https://geobon.org/ebvs
EBV Metric	Name of metric used to measure an EBV (for instance probability of occupancy or relative abundance in relation to a baseline).

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EBV Realm/domain	Three realms (Marine, Terrestrial and Freshwater).
EBV Spatial Extent	Region covered by the EBV (e.g. Europe, EU-MS).
EBV Temporal Extent	Time frame covered by the EBV (e.g. 2018-onwards).
EBV Spatial Resolution Unit	Resolution of the map (e.g. 1x1 km grid cell) obtained by interpolation/extrapolation of the original data collected.
EBV Temporal Resolution Unit	Resolution of the time-series (e.g. 1 year) obtained by interpolation/extrapolation from data collected.
Taxonomic/ ecosystem focus group	Scope of biological entities (the object that is being measured) being monitored with the EBV. It can be a list of species, ecosystem types, or any other biological entity. It may have a standard classification scheme associated (e.g., a standard taxonomy).
EBV entity/ taxonomic classification system	The system that is used to classify the taxonomic/ ecosystem focus group (e.g.The Clements Checklist of Birds of the World, EUNIS habitat classification).
Terms about the raw monitoring data and sampling	
Spatial coverage	The scope of the monitoring scheme (e.g. local, regional, sub-national, national, international).
Taxonomic/ ecosystem coverage	Level of coverage of taxa or ecosystem types needed for deriving the EBV and covered by the monitoring scheme.
Country coverage	Countries covered by the monitoring scheme.
Systematic/ standardised monitoring	Existence of a scheme where a specific field protocol is followed.
Temporal coverage	The length of the time series.
Sampling density	Number of sampling units per area/ region/ country (e.g. XX 10x10km grid cells, XX points distributed randomly).
Sampling Frequency	Number of samples per unit time (e.g. snapshot/ once-off, annually).

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Minimum Sampling Unit Resolution	Accuracy at which the location is registered (e.g. exact location, 10x10km grid).
Minimum Time Unit Resolution	Accuracy at which the time is registered (e.g. second, hour, day, month year).
Raw data	Data collected in the field at the minimum sampling and time unit resolutions.
Raw data access	The degree of compliance of the raw data with FAIR principles (Findability, Accessibility, Interoperability, and Reuse, https://www.go-fair.org/fair-principles/).
Other terms	
Policy targets	European Union action for environmental conservation and protection (e.g. Habitats Directive), and the restoration of habitats and ecosystems (e.g. Nature Restauration Law). This also includes economic policy with implications for biodiversity and ecosystems conservation (e.g. Common Agriculture Policy, CAP).
Monitoring scheme	Systematic/standardised monitoring scheme where a field protocol is followed, and able to provide quantitative data on biodiversity for a given study area. Sampling under monitoring schemes can be carried out once or repeatedly over a given time frame. The former generates once-off estimates whereas the latter generates a time-series of estimates.
European Integration Monitoring Initiatives (captured in the EuropaBON web-based database)	Initiative that integrates biodiversity data from systematic monitoring programs and that are able to generate an EBV /EESV/ Indicator at the European spatial scale. In most cases, these initiatives are associated with monitoring networks coordinated at the supranational level. Occasionally, initiatives also integrate data from non-systematic surveys.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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APPENDIX II. Factsheets describing monitoring gaps for Freshwater EBVs

Genetic composition

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Genetic diversity of selected freshwater taxa**
Summary	There is no initiative integrating monitoring data on the genetic diversity of freshwater taxa potentially producing the EBV “Genetic diversity of selected freshwater taxa” at the European scale.
EBV characteristics (target)	
ID	43b
Realm	Freshwater
Class	Genetic composition
Name	Genetic diversity of selected freshwater taxa
Step in identification process	Internal review process
Definition	Genetic richness (number of alleles in a population) and genetic evenness (expected proportion of heterozygotes in a population at equilibrium) of taxa.
Metric	- Allelic richness - Nucleotide diversity (π) - He = expected heterozygosity under Hardy–Weinberg assumptions - HO = observed heterozygosity (probability of randomly drawing two different alleles from the population)"
Spatial resolution units	Sample sites (populations) across the geographic range of selected taxa
Temporal resolution units	10 years
Taxonomic/ ecosystem focus group	Selected species of birds, mammals, reptiles, amphibians or other taxonomic groups which are categorized as threatened by the European Red List.
Current monitoring	
Integration initiative **[NONE]**	There is no an initiative integrating monitoring data on the genetic diversity of freshwater taxa able to produce the EBV “Genetic diversity of selected freshwater taxa” at the European scale.

This project receives funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003553.

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Species populations

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of wetland birds**
Summary	Monitoring data on wetland birds is currently flowing to a trans-European monitoring initiative - AEWC-IWC - covering all EU-MS. Number of individuals (exact or estimation) of each species is collected during the winter in wetland sites following standardised protocols in all MS. Ongoing long-term time-series data are updated on a yearly basis in most EU-MS. The density of sampling sites and the minimum sampling unit are likely to be adequate to generate the EBV at the defined spatial resolution (wetlands). Main gaps in the generation of the EBV "Species abundances of wetland birds" include unknown temporal extent for a few EU-MS (Croatia, Denmark and Finland), thus reducing the ability of the EBV to establish reliable distribution trends in the short term. In addition, Belgium is currently partly covered by the initiative as monitoring is only ongoing in Flandres. Finally, monitoring data needed to estimate the EBV is made available upon request for most EU-MS but a data-handling fee is normally required.
EBV characteristics (target)	
ID	1
Realm	Freshwater
Class	Species populations
Name	Species abundances of wetland birds
Step in identification process	Expert workshop
Definition	The estimated count of individuals of European wetland bird species within contiguous spatial units (grid cells) over time.
Metric	- Estimated count of individuals in winter - Modelled relative abundance in winter
Spatial resolution units	Wetlands as defined by The Critical Site Network (CSN) Tool which is an online resource for the conservation of 312 species of waterbirds and the important sites upon which they depend in Africa and Western Eurasia (http://criticalsites.wetlands.org/en/sites).
Temporal resolution units	1 year
Taxonomic/ ecosystem focus group	Wetland birds (taxonomy based on the HBW and BirdLife Taxonomic Checklist, with focus on those bird species that are officially recognized in the List of birds of the European Union, and wetland affiliation defined as the linkages of species and habitat types to MAES [wetland] ecosystems)
Current monitoring	
Integration initiative **[AEWC-IWC]**	The AEWC (African-Eurasian Waterbird Census) is an ongoing regional programme of the **IWC** (International Waterbird Census, https://www.wetlands.org/knowledge-base/international-waterbird-census/) to collect information on the numbers of waterbirds at wetland sites, covering all of Africa, Europe and large parts of South-West and Central Asia since 1967. Major outputs from the AEWC include Waterbird population trends and estimates, and Annual National Count Totals. Terrestrial bird species with wetland affiliation are not monitored by the AEWC-IWC bird counts. However, they are covered by the EBV “Species abundance terrestrial birds”. A detailed description of the monitoring gaps in estimating species abundance of terrestrial terrestrial bird species with wetland affiliation are detailed in the factsheet EBV “Species abundance terrestrial birds”.

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Country coverage **Very-High [100% EU-MS]**	41 European countries report species abundance data to AEWC: Albania, Austria, Belarus, Belgium (Flandres & Wallonia), Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom
Taxonomic/ Ecosystem coverage **Very-High [100% EU-MS]**	AEWC-IWC covers all waterbird families defined as "species of bird that are ecologically dependent on wetlands" by the Ramsar Convention on Wetlands (https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/Protocol_for_waterbird_counting_En_.pdf).
Standardised monitoring **Very-High [100% EU-MS]**	Monitoring follows a standardised field protocol with clearly defined waterbird species; site delimitation; equipment and counting techniques; and temporal resolution (https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/Protocol_for_waterbird_counting_En_.pdf). Sampling sites consist of a polygon, transect or point and are identified by an IWC site code or site name. For each site, the following information is collected: site name, date, time of the count, weather, habitat, tidal conditions, and number of individuals (exact or estimation) of each species. More details are available on the initiative webpage: https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/Protocol_for_waterbird_counting_En_.pdf; https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/Digitising-Site-Boundaries-.pdf
Time-series **Very-High [100% EU-MS]**	**Time series [1947-ongoing].**
Long-term monitoring **Very-High [89% EU-MS]**	The longest Time -series are from 1947 (United Kingdom) and 1950 (Austria). Unknown starting date for Belarus, Croatia, Denmark and Finland.
Ongoing monitoring **Very-High [93% EU-MS]**	At least 24 countries have ongoing monitoring schemes. Unknown current monitoring status for Croatia, Denmark and Finland. Partially ongoing in Belgium (Flandres) - **partial gap.**
Sampling frequency **Very-High [96% EU-MS]**	**Annually.** https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/Protocol_for_waterbird_counting_En_.pdf At least 26 MS samples in the same sampling frequency (annually) as the EBV temporal resolution (1-year). Unknown sampling frequency for Cyprus. Bird counts are made during the winter (January).
Spatial Coverage Density **Very-High [100% EU-MS]**	The AEWC involves the sampling of over 12739 sites throughout the covered European countries. The spatial coverage density of baseline data is likely to be adequate to provide the EBV at the desired spatial resolution, as the major wetlands are likely included.
Minimum sampling unit **Very-High [100% EU-MS]**	Number of individuals (exact or estimation) of each species is reported to each sampling site/water body. The minimum sampling unit is likely to be adequate to provide the EBV at the desired spatial resolution (wetlands).
Raw data access	According to information on the website (https://europe.wetlands.org/wp-content/uploads/sites/3/2016/08/DataRequestForm

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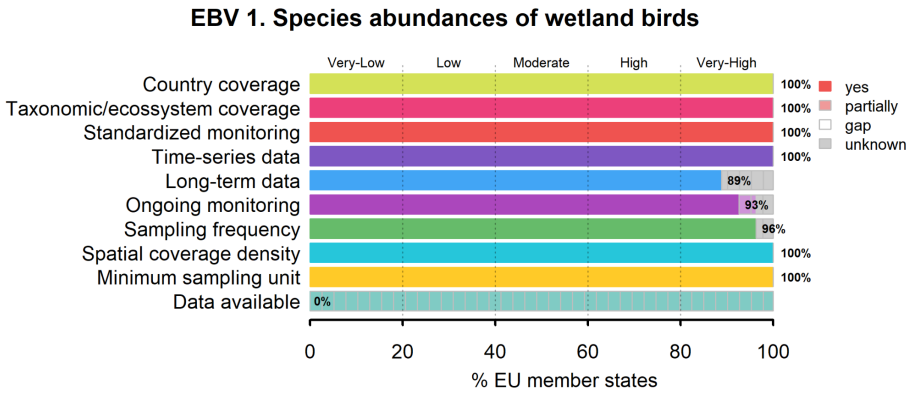
Very-High [0% EU-MS]	28092016.docx), data is available for researchers or students on request, and a data-handling fee is normally applied to cover the staff time required to service the data request. The data remains the property of the national schemes that collected them. Information at a national or sub-national level is only released with the written consent of the relevant national coordinator. The national coordinators will have one month to query the request or to object to the release of their data. EuropaBON database reports open-access data for Spain (1965-2012) and Belgium (Flandres, 1991–2016). **Partial gap for all countries:** data is available under request but a payment is required and open access only covers part of the data.
Monitoring gaps	
Figure 1.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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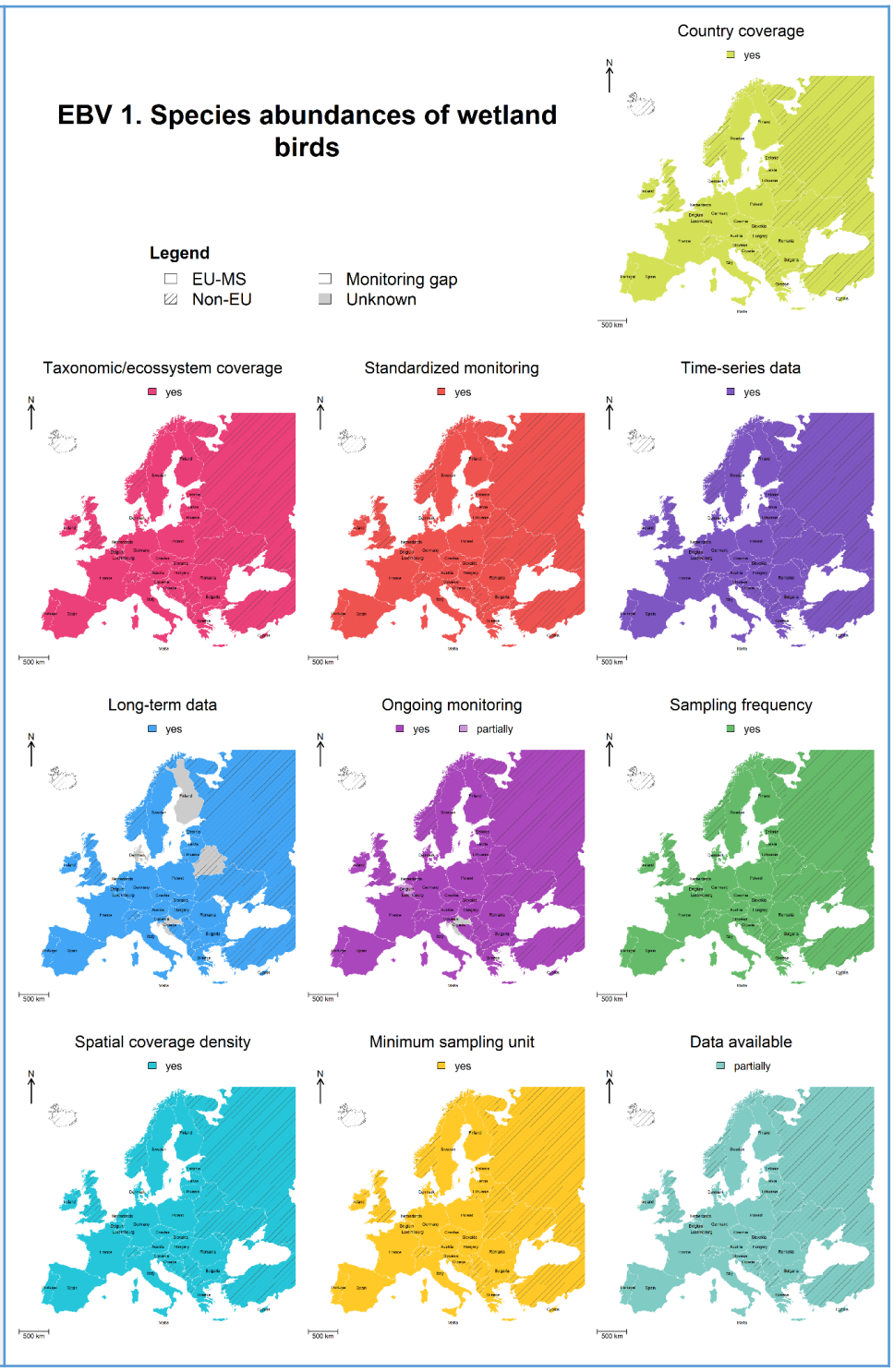

Figure 1.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of freshwater fishes**
Summary	Freshwater fish in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive). Freshwater fish monitoring (composition, abundance, and age structure) is based on standardised protocols using metrics intercalibrated among countries covering 93% of the EU-MS. All countries have time-series data updated every 3 or 6 years, and thus adequate to generate the EBV at the defined temporal resolution (3 to 6 years). Main gaps in the generation of the EBV "Species distributions of freshwater fishes" include lack of long-term data, reduced spatial coverage density, and unavailable raw data. Specifically, long-term data are still lacking for most MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. The proportion of monitored lakes and rivers is very low (<20%) for 74% of the EU-MS. The raw species distribution collected by Member States is not available.
EBV characteristics (target)	
ID	2
Realm	Freshwater
Class	Species populations
Name	Species distributions of freshwater fishes
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of each European freshwater fish species within lakes and river catchments over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	Lakes and river catchments as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	Freshwater fishes listed in the European Red List of Freshwater Fishes (currently 531 native and described European species)
Current monitoring	
Integration initiative **[WFD]**	Freshwater fish in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive). While species distribution data of freshwater fishes in rivers and lakes are collected at each sampling site, raw data is not reported to WFD.
Country coverage **Very-High [93% EU-MS]**	27 countries monitor freshwater fish in rivers and lakes to report ecological quality status under the WFD: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and United Kingdom.
Taxonomic/ Ecosystem coverage **Very-High [93% EU-MS]**	Monitoring is expected to cover all freshwater fish species in each sampling site.

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Standardized monitoring **Very-High [93% EU-MS]**	Freshwater fish are sampled using intercalibrated metrics that include fish composition, abundance and age structure. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD).
Time-series **Very-High [93% of MS]**	Time-series [2015-ongoing].
Long-term monitoring **Low [0% EU-MS]**	Freshwater fish are monitored using intercalibrated metrics since 2015. Long-term data (≥10 years) is thus lacking for all countries.
Ongoing monitoring **Very-High [93% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD.
Sampling frequency **Very-High [93% EU-MS]**	**Every 3 or 6 years.** Freshwater fish are monitored every 3 or 6 years in each sampling site, although ecological status to WFD is reported every 6 years.
Spatial Coverage Density **Low [26% EU- MS]**	WFD identifies 24,453 sites for fish monitoring (2,560 in lakes and 21,893 in rivers), but only 17.5% are actually monitored (9.9% of lakes and 19.2% of rivers). The proportion of monitored water bodies differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_qeMonitoringResults/SWB_qeMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Lithuania, Netherlands, and Poland. **Rivers** (>20%): Denmark, Estonia, Finland, Germany, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, Poland, United Kingdom. The spatial coverage density was assumed to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored waterbodies is higher than >20%. A partial gap was assumed if the % monitoring water bodies <20% in rivers or lakes.
Minimum sampling unit **[Very-High, 93% of MS].**	Freshwater fish composition, abundance and age structure at exact locations. Norway: 0.2x0.2km grid cells for lakes. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier.
Raw data access **Low [0% EU-MS].**	Raw data on fish species distribution is stored by national agencies and is not available. While species distribution data of freshwater fishes in rivers and lakes are collected at each sampling site, raw data is not reported to WFD.
Monitoring gaps	

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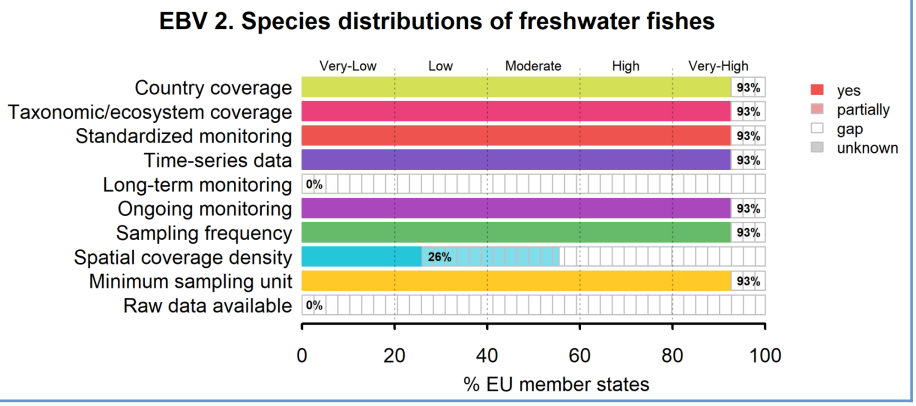
Figure 2.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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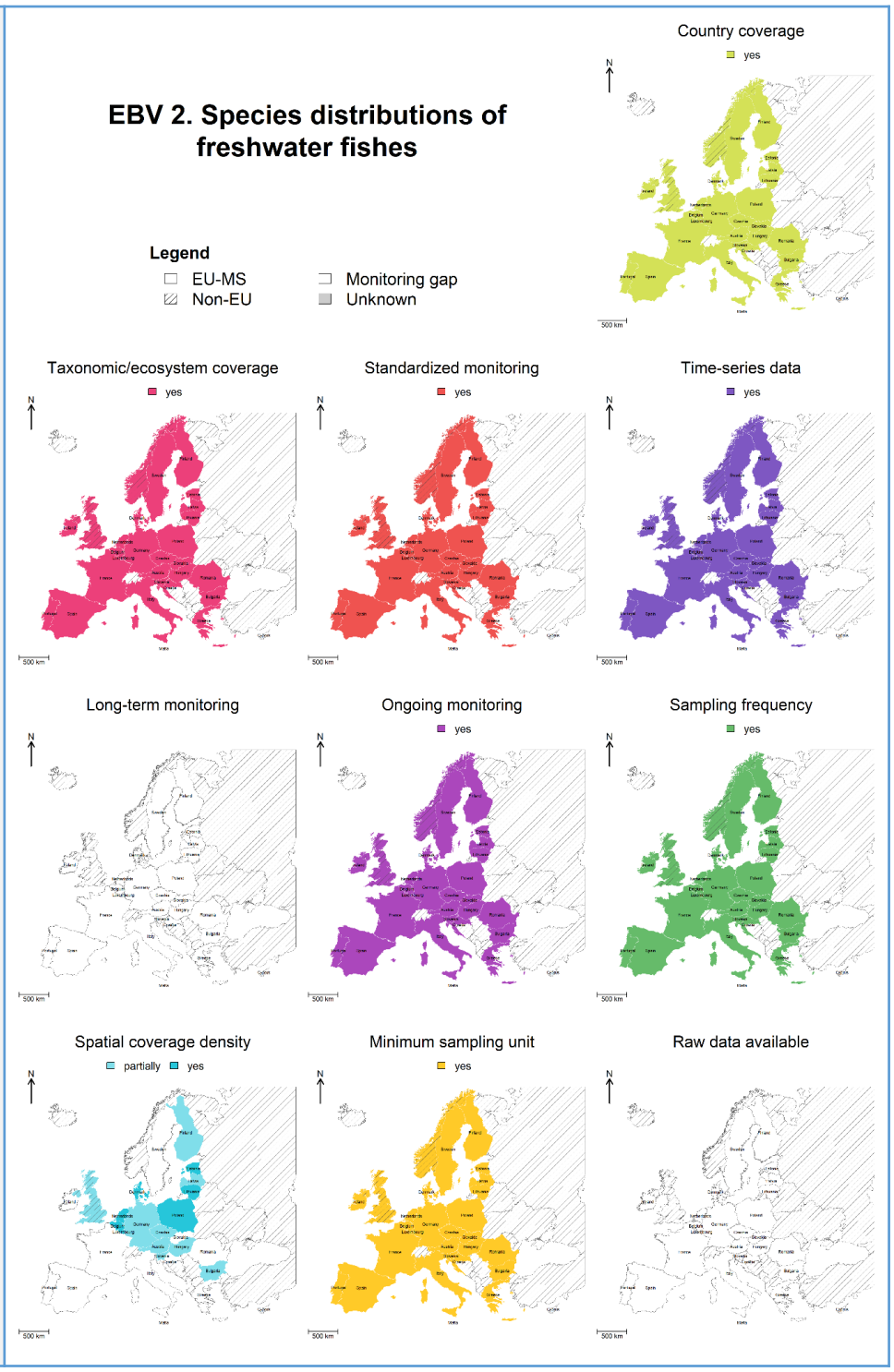

Figure 2.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of amphibians and freshwater reptiles**
Summary	The most recent European initiative on species distributions of amphibian and freshwater reptiles is the New Atlas of European Amphibians and Reptiles (NA2RE). The initiative is a snapshot from 2014 compiling information available for several sources and national and subnational level monitoring schemes, covering 70% of the EU-MS. Data is colected based on opportunistic observations complemented in a some cases by standardized sampling following different field protocols. Data from the first Atlas of European Amphibians and Reptiles in 1997 and the Global Information Facility (GBIF: www.gbif.org) were used when country-level databases were not available. NA2RE builds on the first Atlas of European Amphibians and Reptiles in 1997 and thus some long-term data is available for some EU-MS. The network of sites is likely to be sufficiently dense to produce the EBV at the desired spatial resolution for most countries (10×10km - 50×50km). Main monitoring gaps in the generation of the EBV "Species distributions of amphibians and freshwater reptiles" include the lack of ongoing timely updated standatized monitoring programs with adequate spatial coverage across Europe, and of an ongoing European integration initiative able to produce the EBV. The information on the data available is insufficient with large uncertainty on the sampling frequency, and on the spatial resolution of the baseline data. Only a few countries have standartized monitoring data collected on a regular basis. Data is open and freely available at least at the atlas scale for all countries but some countries have raw data publicly available.
EBV characteristics (target)	
ID	3
Realm	Freshwater
Class	Species populations
Name	Species distributions of amphibians and freshwater reptiles
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of each European amphibian and freshwater reptile species within contiguous spatial units (grid cells) over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10×10km - 50×50km
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	All European amphibians and freshwater reptiles
Current monitoring	
Integration initiative **[NA2RE]**	The NA2RE (New Atlas of European Amphibians and Reptiles, https://www.seh-herpetology.org/distribution-atlas) is the most recent European initiative able to produce an EBV on freshwater Amphibian and Reptiles species distribution across Europe. NA2RE is a snapshot compiling information of over 384,000 grid and exact location records distributed across Europe available from several sources including national and subnational atlases, personal datasets, the first European Atlas, and GBIF. NA2RE was the base to an interactive atlas (https://montobeo.shinyapps.io/NA2RE/) compiles information from the atlas.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

Country coverage **Very-High [70% of EU-MS]**	There are 23 countries with national-level distribution data for the NA2RE: Austria; Belgium; Bosnia and Herzegovina; Bulgaria; Estonia; France; Germany; Greece; Hungary; Ireland; Italy; Luxembourg; Malta; Netherlands; Poland; Portugal; Romania; Slovenia; Spain; Sweden; Switzerland; Ukraine; United Kingdom. In addition, there are 20 countries to which national-level databases were not available and the only available data is from the first Atlas of European Amphibians and Reptiles in 1997 (Gasc et al. 1997) and the Global Information Facility (GBIF: www.gbif.org). This includes: Albania; Andorra; Belarus; Croatia; Czech Republic; Denmark; Finland; Latvia; Liechtenstein; Lithuania; Moldova; Monaco; Montenegro; North Macedonia; Norway; Russia; San Marino; Serbia; Slovakia; Turkey.
Taxonomic/ Ecosystem coverage **High [70% EU-MS]**	NA2RE covers 218 taxa (73 species of amphibians and 145 of reptiles). It includes 13 amphibian and 18 reptile species that were not represented in the 1997 European Atlas (Gasc et al. 1997).
Standardized monitoring **Low [0% of MS]**	NA2RE compiles data from several sources. Distribution data of amphibians and reptiles relies mainly on non-standardised opportunistic data, including historical records. Although some data may came from monitoring programmes, these have usualy limited spatial coverage, focusing on grid cells with less data (**partial gap**). At least partial standardised monitoring data is reported in the EuropaBON T3.1 database for 8 countries: Austria, Belgium, France, Netherlands, Portugal, Spain, Switzerland and the United Kingdom. Standardised monitoring is unknown for the remaining countries.
Time-series **Very-low [4% EU-MS]**	Two snapshots: [1997]: 1st atlas; and [2014]: NA2RE Time-series [1960-ongoing]. There are at least 3 countries with time-series data: the Netherlands, Switzerland and the United Kingdom.
Long-term monitoring **Very-low [26% EU-MS]**	There are at least 9 countries with long-term data (≥10 years): Austria, Belgium, France, Italy, Netherlands, Portugal, Spain, Switzerland and the United Kingdom. Long-term data (>17 years) is likely to exist for the countries covered by the first Atlas of European Amphibians and Reptiles.
Ongoing monitoring **Very-low [7% EU-MS]**	There are at least 4 countries with ongoing monitoring schemes: Austria, Netherlands, Switzerland, and the United Kingdom.
Sampling frequency **Very-low [4% EU-MS]**	NA2RE is a snapshot. The previous/first Atlas of European Amphibians and Reptiles was in 1997 (17 years interval). **Annually** data is produced in at least two countries: the Netherlands and the United Kingdom. The sampling frequency is unlikely to be adequate to generate the EBV at the desirable temporal resolution (3-6 years) for most countries (**gap**) except the Netherlands and the United Kingdom. However, the information on the data available is insufficient with large uncertainty on the sampling frequency of the baseline data.
Spatial Coverage Density **Very-High [0% EU-MS]**	The NA2RE involves the compilation of 384,609 records (241,163 for Amphibians and 143,446 for Reptiles). The spatial coverage density of baseline data is likely to be adequate to provide the EBV at least at the spatial resolution of 50x50 km as they were used to produce the European scale species distribution atlas at this spatial resolution. However, the

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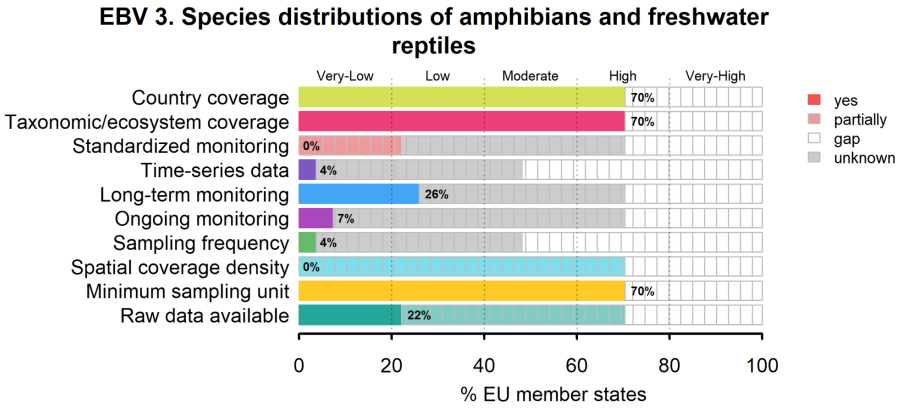
	density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km) (**partial gap**).
Minimum sampling unit **Very-High [70% of EU-MS]**	**NA2RE and first Atlas:** Presence/Absence data at 50x50-km resolution. **Raw data with different spatial resolutions:** Exact locations, 1x1 km - 50×50 km grid cells. There are at least 20 countries with a minimum sampling unit ≤10x10km which is likely to be adequate to provide the EBV at the desired spatial resolution (10x10km - 50x50km): Austria, Belgium, Bosnia and Herzegovina; Bulgaria; Estonia; Germany; Greece; Hungary; Ireland; Italy; Luxembourg; Netherlands; Poland; Portugal; Romania; Slovenia; Spain; Sweden; Switzerland; Ukraine; and the United Kingdom. For the remaining countries, the minimum sampling unit is >10x10km resolution and likely to be adequate to provide the EBV at least at the spatial resolution of 50x50 km (the spatial resolution of the atlas) (**partial gap**).
Raw data access **Very-High [22% of EU-MS]**	Species distribution data is open and freely available for the countries covered by NA2RE at the atlas scale (50x50 km) (**partial gap**). Raw data is open available or available under request at least for Austria, Italy, Netherlands, Portugal, Slovenia, Spain, Switzerland, and the United Kingdom. Unknown raw data access for the remaining countries.
Monitoring gaps	
Figure 3.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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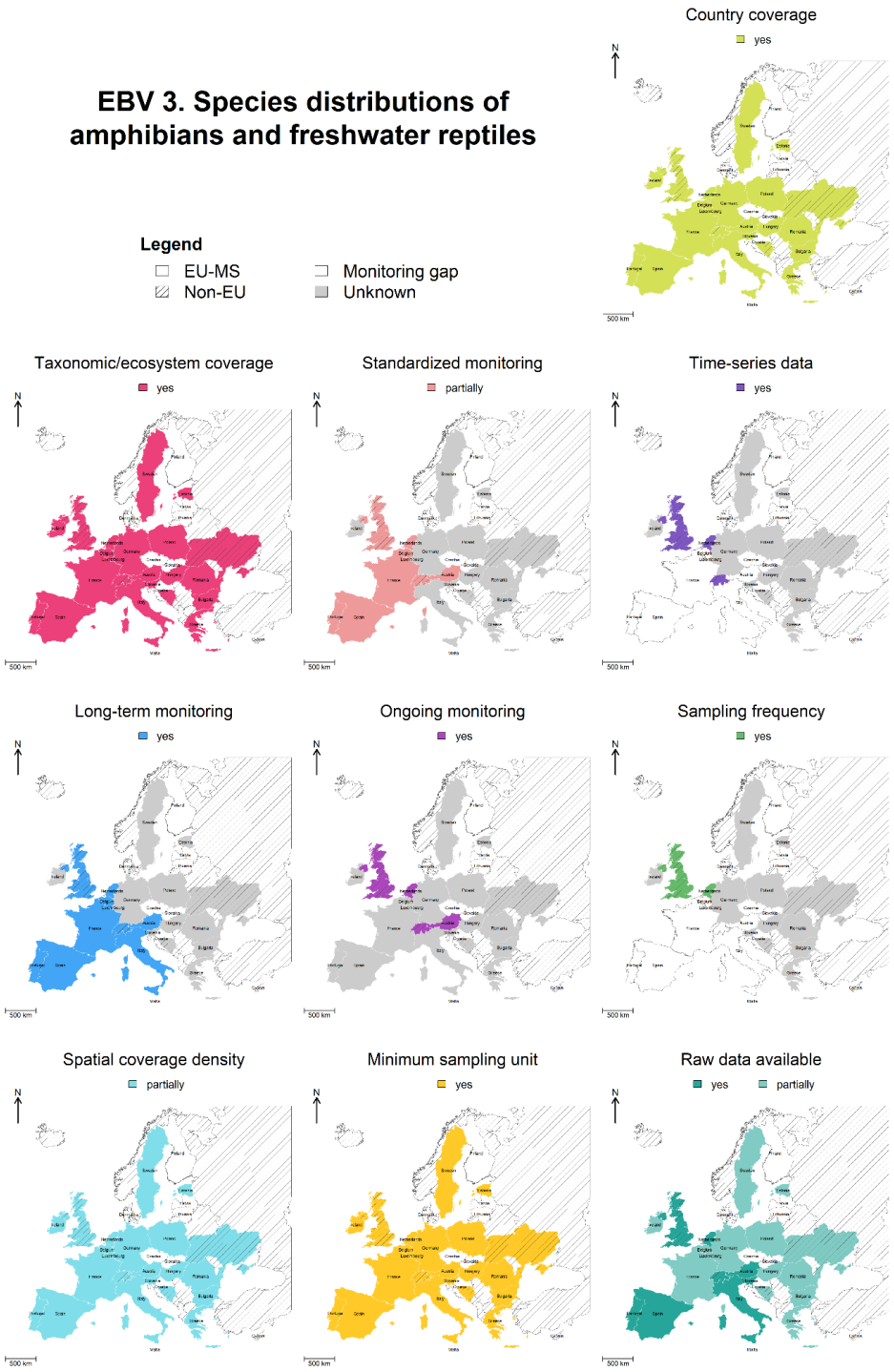
Figure 3.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.



REFERENCES

Gasc, J.-P., Cabela, A., Crnobrnja-Isailovi´c, J., Dolmen, D., Grossenbacher, K., Haffner, P., Lescure, J., Martens, H., Martínez-Rica, J.P., Maurin, H., Oliveira, M.E., Sofi anidou, T.S., Veith, M., Zuiderwijk, A. (1997): Atlas of Amphibians and Reptiles in Europe. Societas Europaea Herpetologica and Muséum national d'Histoire.

Sillero, N., J. Campos, A. Bonardi, C. Corti, R. Creemers, P.-A. Crochet, J. Crnobrnja Isailovic, M. Denoël, G. F. Ficetola, J. Gonçalves, S. Kuzmin, P. Lymberakis, P. de Pous, A. Rodríguez, R. Sindaco, J. Speybroeck, B. Toxopeus, D.R. Vieites, M. Vences (2014): Updated distribution and biogeography of amphibians and reptiles of Europe. Amphibia-Reptilia 35: 1-31. (download PDF with all supplements - 40 MB)

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of freshwater mammals**
Summary	The most recent European initiative on species distributions of freshwater mammals is the EMMA2. By 2023, EMMA2 will provide the second snapshot of the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (1999). EMMA2 is based on verified data from national databases including both standardized and opportunistic observations, and citizen science data. Although EMMA2 covers all European countries, information based on monitoring data is only available for 78% of the EU-MS. Yet, only a few countries have time-series data collected at a regular basis. The spatial coverage density of baseline data is likely to be adequate to provide the EBV at the spatial resolution of 50x50 km as this is the spatial resolution of the atlas. Data will be open and freely available at least at the atlas scale (50x50 km) to all countries. Main gaps in the generation of the EBV "Species distributions of freshwater mammals" include the lack of timely updated time-series data able to produce the EBV at the desired temporal resolution and the lack of long-term data, although it is expected to be available for the countries covered by the first atlas. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km).
EBV characteristics (target)	
ID	4
Realm	Freshwater
Class	Species populations
Name	Species distributions of freshwater mammals
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of each European freshwater mammal species within contiguous spatial units (grid cells) over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10 km - 50x50km
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	Freshwater mammal species listed in the Habitats Directive (*Lutra lutra*, *Galemys pyrenaicus*, *Mustela lutreola*)
Current monitoring	
Integration initiative **[EMMA2]**	The EMMA2 (Second European Mammal Atlas, https://discovermammals.org/projects/the-2nd-european-mammal-atlas/) realised by the European Mammal Foundation (the successor of the Societas Europaea Mammalogy that published the first Atlas). EMMA2 is the second edition of the Atlas of European Mammals published in 1999, updating information for the area already covered and extending the area to the whole of Europe. EMMA2 will provide by 2023 the second snapshot of the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (1999). EMMA2 is based on verified data from national databases including both standardized and opportunistic observations and citizen science data.
Country coverage **High [78% EU-MS]**	The new atlas involve the participation of all European countries but Cyprus, Georgia and Vatican City.

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Taxonomic/ Ecosystem coverage **High [78% EU-MS]**	Monitoring is expected to cover all freshwater mammal species listed in the Habitats Directive. However, because many data came from opportunistic surveys a partial gap was assumed to all countries.
Standardized monitoring **High [67% EU-MS]**	EMMA2 sets up the national databases by collating dedicated monitoring data and historical data available in museums, scientific literature, notebooks, and project databases. Additional fieldwork is being done to gather new data and citizens are encouraged to pass on observations of mammals in European and country level Data portals (https://discovermammals.org/mammal-portals/). There are 23 countries with web portals dedicated for uploading mammal observations: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Netherlands, Norway, Romania, Russia, Spain, Sweden, Switzerland, United Kingdom, Ukraine. Standardised monitoring programs are reported in the EuropaBON database for 27 coountries: Albania, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Lithuania, Luxemburg, Netherlands, North Macedonia, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Turkey, United Kingdom.
Time-series **Very-low [11% EU-MS]**	Two snapshots: [1999]: EMMA; and [2023]: EMMA2 Time-series [2006-ongoing]. The EuropaBON database refers to 4 countries with time-series data: Albania, Netherlands, North Macedonia, and Kosovo.
Long-term monitoring **Low [33% EU-MS]**	Two snapshots: [1999]: EMMA; and [2023]: EMMA2 he EuropaBON database refers to 4 countries with Albania, Estonia, Norway, Slovenia, and Sweden.
Ongoing monitoring **Very-low [48% EU-MS]**	The EuropaBON database refers to 4 countries with ongoing monitoring schemes: Albania, Netherlands, North Macedonia, and Kosovo.
Sampling frequency **Very-low [0% EU-MS]**	**24 years interval between the two atlases [1999 - 2023].** **>10 years:** Albania, North Macedonia, Kosovo. **Seasonal:** Netherlands.
Spatial Coverage Density **High [0% EU-MS]**	The spatial coverage density of baseline data is likely to be adequate to provide the EBV at the spatial resolution of 50x50 km as this is the spatial resolution of the atlas. However, the density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km) (**partial gap**).
Minimum sampling unit **Low [33% EU-MS]**	**Exact location (abundance/presence-absence data):** Bulgaria, Czech Republic, France, Iceland, Netherlands, North Macedonia, Norway, and Sweden. **10x10km grid cells (abundance/presence-absence data):** Denmark, Ireland, Italy, North Macedonia, Poland, Portugal, Serbia, Spain, and the United Kingdom. **50x50km grid cells (presence-absence data):** Romania and Ukraine. **Unknown sampling unit** for the remaining countries. The minimum sampling unit is ≤10x10 km at least for 17 countries (Bulgaria, Czech Republic, Denmark, France, Iceland, Ireland, Italy, Netherlands, North Macedonia, Norway, Poland, Portugal, Serbia, Spain, Sweden, and the United Kingdom), and likely to be adequate to provide the EBV at the higher spatial resolution (10x10 km). For the remaining countries, the minimum sampling 50x50km grid cells or unknown is likely to provide the EBV at the lower spatial resolution (50x50 km) which is the spatial resolution of the EMMA2 atlas (**partial gap**).

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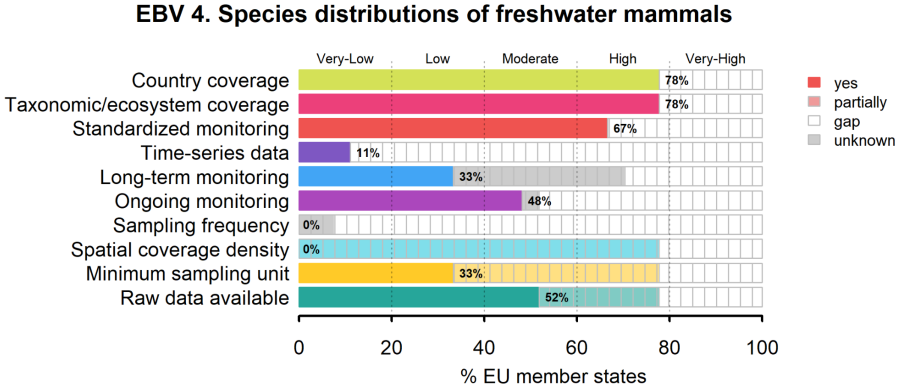
Raw data access **Moderate [52% EU-MS]**	Data will be made open at least at the atlas resolution to all countries (50x50 km) (**partial gap**). Yet, national coordinators are been encouraged to make the majority of records freely accessible at a higher resolution than in the Atlas, with the appropriate safeguards for sensitive records (https://www.european-mammals.org/public-documents?task=download.send&id=81&catid=2&m=0). **Raw data open:** Czech Republic, Denmark, Ireland, Luxembourg, Netherlands, Portugal, Romania (partially), Sweden **Raw data available on-demand:** Albania (partially), Austria, Belgium, Bulgaria, Croatia, Estonia, Italy (partially), Lithuania, Netherlands, Russia, Spain, United Kingdom **Raw data not available for** Serbia, Slovenia and **unknown raw data access** for the remaining countries (**partial gap**).
Monitoring gaps	
Figure 4.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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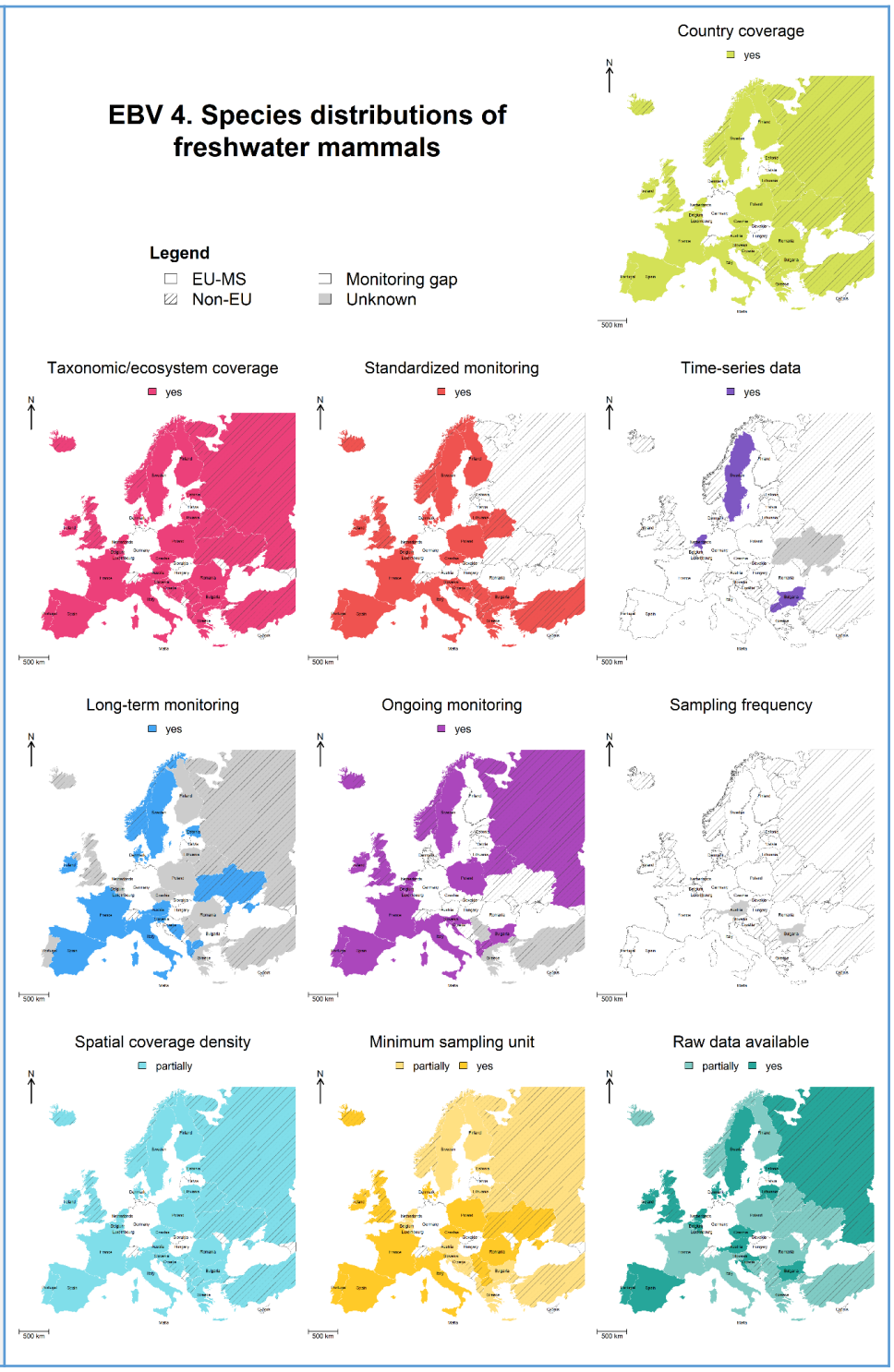

Figure 4.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of freshwater invertebrates**
Summary	Pollution-sensitive benthic invertebrates in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive), however, dragonflies and bivalves are not being monitored at the European level. Pollution-sensitive benthic invertebrates monitoring (composition and abundance) in lakes and rivers is based on standardised protocols using metrics intercalibrated among countries covering 96% of the EU-MS. All countries have time-series data updated every 2 or 3 years, and thus adequate to generate the EBV at the desired temporal resolution (3 to 6 years); and many have long-term data series (>10 years). Main gaps in the generation of the EBV "Species distributions of freshwater invertebrates" include lack of taxonomic coverage, low spatial coverage density, and unavailable raw data. Specifically, invertebrates are likely to be identified mostly at the family level (not species), and bivalves and dragonflies are not monitored. The proportion of monitored lakes and rivers is very low (<20%) for 44% of the EU-MS. While invertebrates composition and abundance data is collected, it is not available.
EBV characteristics (target)	
ID	5
Realm	Freshwater
Class	Species populations
Name	Species distributions of freshwater invertebrates
Step in identification process	Internal review process
Definition	The presence/absence or probability of occurrence of invertebrate species within lakes and river catchments over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	Lakes and river catchments as delineated in ECRINS (European catchments and Rivers network system)
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	- Freshwater invertebrate species listed in the Habitats Directive Annex II: Dragonflies: *Coenagrion hylas*, *C. mercuriale, Cordulegaster trinacriae, Gomphus graslinii, Leucorrhina pectoralis, Lindenia tetraphylla, Macromia splendens, Ophiogomphus cecilia, Oxygastra curtisii* Bivalves: *Margaritifera margaritifera* and *Unio crassus* - Freshwater invertebrate species listed in the Habitats Directive Annex IV: Dragonflies: *Aeshna viridis, Cordulegaster trinacriae, Gomphus graslinii, Leucorrhina albifrons, L. caudalis, L. pectoralis, Lindenia tetraphylla, Macromia splendens, Ophiogomphus cecilia, Oxygastra curtisii, Stylurus flavipes* and *Sympecma braueri* Bivalves: *Lithophaga lithophaga, Pinna nobilis, Margaritifera auricularia* and *Unio crassus* - Pollution-sensitive benthic invertebrates that are monitored for the Water Framework Directive: Mayflies (Ephemeroptera) Stoneflies (Plecoptera) Caddisflies (Trichoptera)
Current monitoring	

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Integration initiative **[WFD]**	Freshwater pollution-sensitive benthic invertebrates (composition and abundance) in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive). While composition and abundance data of freshwater pollution-sensitive benthic invertebrates is collected at each sampling site, raw data is not reported to WFD. Dragonflies and bivalves are not monitored to WFD, and they are not monitored at the European level.
Country coverage **Very-high [96% EU-MS]**	28 countries reporting ecological quality status for the WFD based on freshwater pollution-sensitive benthic invertebrates monitoring in rivers and lakes (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and United Kingdom.
Taxonomic/ Ecosystem coverage **Very-high 0% EU-MS]**	Monitoring for WFD covers freshwater pollution-sensitive benthic invertebrates but not bivalves and dragonflies. In addition, freshwater pollution-sensitive benthic invertebrates are often identified at the family level, although genus or species level may be achieved in some countries for important indicator taxa (**partial gap**).
Standardized monitoring **Very-high [96% EU-MS]**	Freshwater pollution-sensitive benthic invertebrates are sampled using intercalibrated metrics that include invertebrates' composition and abundance. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD).
Time-series **Very-high [96% EU-MS]**	**Time-series [2004-ongoing].** Freshwater invertebrates are monitored using intercalibrated metrics since 2004.
Long term monitoring **High [78% EU-MS]**	Long-term data (≥10 years) exists at least for 78% of the EU-MS.
Ongoing monitoring **Very-high [96% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD.
Sampling frequency **Very-high [96% EU-MS]**	**Every 2 or 3 years.** Freshwater invertebrates are monitored every 2 or 3 years in each sampling site, although ecological status to WFD are reported every 6 years.
Spatial Coverage Density **High [56% EU-MS]**	WFD identifies 40,742 sites for invertebrates monitoring (2,622 in lakes and 38,120 in rivers), but only 29.1% are actually monitored (10.2% in lakes and 33.4% in rivers). The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Belgium, Bulgaria, Estonia, Greece, Hungary, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and United Kingdom. **Rivers** (>20%): Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and the United Kingdom. The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. A partial gap was assumed if the % monitoring site <20% in rivers or lakes.

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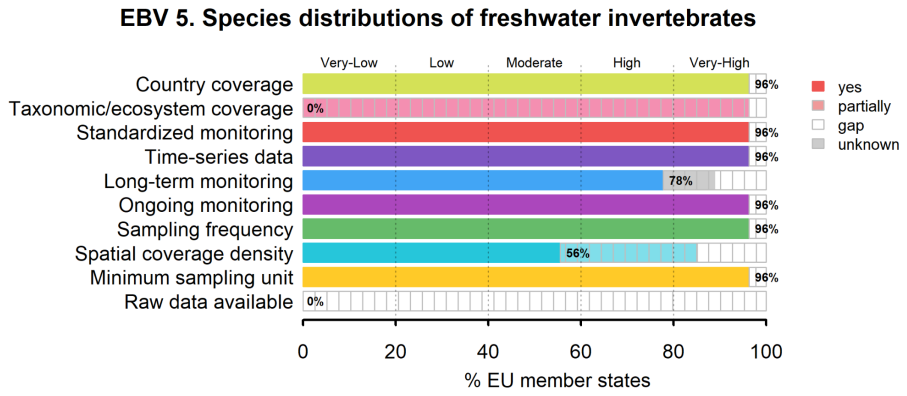
Minimum sampling unit **Very-high [96% EU-MS]**	Benthic invertebrates composition and abundance at exact locations. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier.
Raw data access **Very-low [0% EU-MS]**	Raw data on Freshwater pollution-sensitive benthic invertebrates species is collected and likely to be stored by the national agencies, but is not available (**gap**).
Monitoring gaps	
Figure 5.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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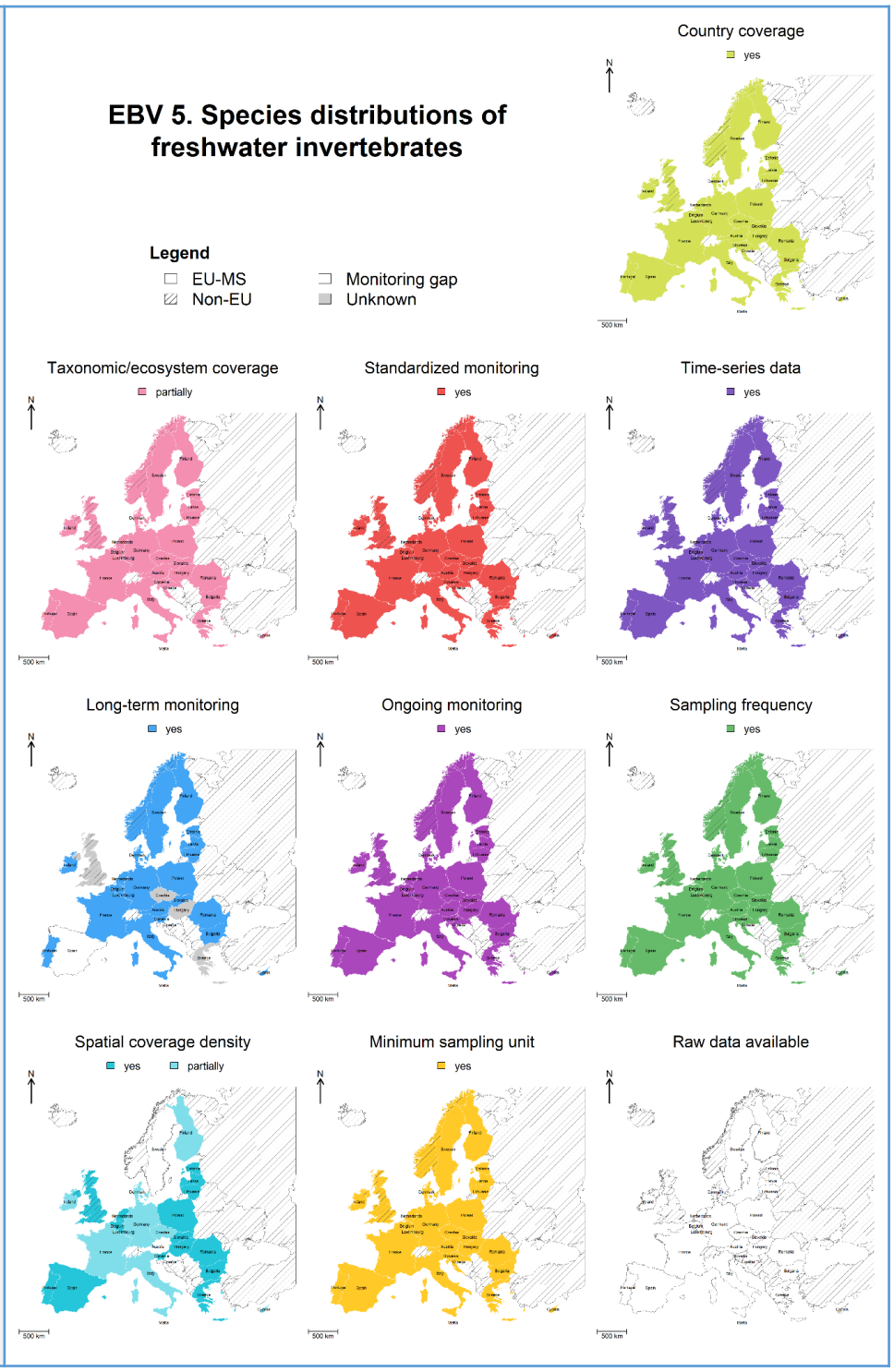

Figure 5.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of freshwater macrophytes**
Summary	Freshwater macrophytes in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive). Freshwater macrophytes monitoring is based on standardized protocols using intercalibrated metrics among countries (composition and abundance) in lakes covering 74% of the EU-MS. All countries have time-series data updated every 6 years, and thus adequate to generate the EBV at the defined temporal resolution (3 to 6 years). Main gaps in the generation of the EBV "Species distributions of freshwater macrophytes" include reduced country coverage, lack of long-term data, unknown spatial coverage, and unavailable raw data. Specifically, long-term data are still lacking for most MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. The proportion of monitored lakes and rivers is very low (<20%) for 59% of the EU-MS. While species distribution is collected, it is not available.
EBV characteristics (target)	
ID	6
Realm	Freshwater
Class	Species populations
Name	Species distributions of freshwater macrophytes
Step in identification process	Internal review process
Definition	The presence/absence or probability of occurrence of European freshwater macrophyte species within lakes over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	Lakes as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	European macrophytes
Current monitoring	
Integration initiative **[WFD]**	Freshwater macrophytes in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive). While species distribution data of freshwater macrophytes in lakes is collected at each sampling site, raw data is not reported.
Country coverage **High [74% EU-MS]**	22 countries reporting ecological quality status for the WFD based on freshwater macrophytes monitoring in lakes (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Netherlands, Poland, Poland, Slovenia, Spain, Sweden, and the United Kingdom.
Taxonomic/ Ecosystem coverage **High [74% EU-MS]**	Monitoring covers all freshwater macrophytes in lakes.
Standardized monitoring **High [74% EU-MS]**	Freshwater macrophytes are sampled using intercalibrated metrics that include macrophytes composition and abundance. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD).

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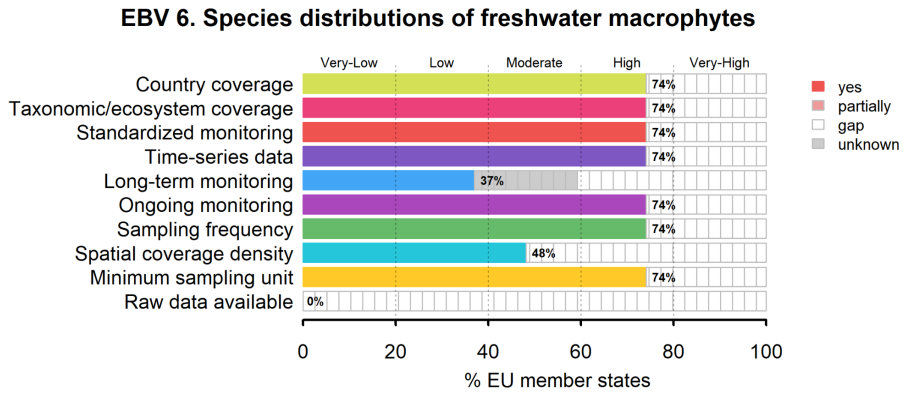
Time-series **Low [74% EU-MS]**	**Time-series [2007-ongoing]** Freshwater macrophytes are monitored using intercalibrated metrics since 2007.
Long-term monitoring **High [37% EU-MS]**	Long-term data (≥10 years) on freshwater macrophytes are available at least for 11 countries: Belgium, Bulgaria, Estonia, Finland, Germany, Ireland, Italy, Netherlands, Norway, Poland, and Sweden.
Ongoing monitoring **Very-high [74% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD.
Sampling frequency **Very-high [74% EU-MS]**	**Every 6 years.** Freshwater macrophytes are monitored once every 6 years in each sampling site.
Spatial Coverage Density **Moderate [48% EU-MS]**	WFD identifies 2,541 sites for macrophytes monitoring in lakes, but only 9.8% are actually monitored. The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Belgium, Bulgaria, Denmark, Estonia, Greece, Hungary, Ireland, Latvia, Poland, Portugal, and United Kingdom. The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%.
Minimum sampling unit **Very-high [74% EU-MS]**	Freshwater macrophytes composition and abundance at exact locations. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier.
Raw data access **Very-low [0% EU-MS]**	Raw data on macrophyte species distribution is stored by national agencies and but not available.
Monitoring gaps	
Figure 6.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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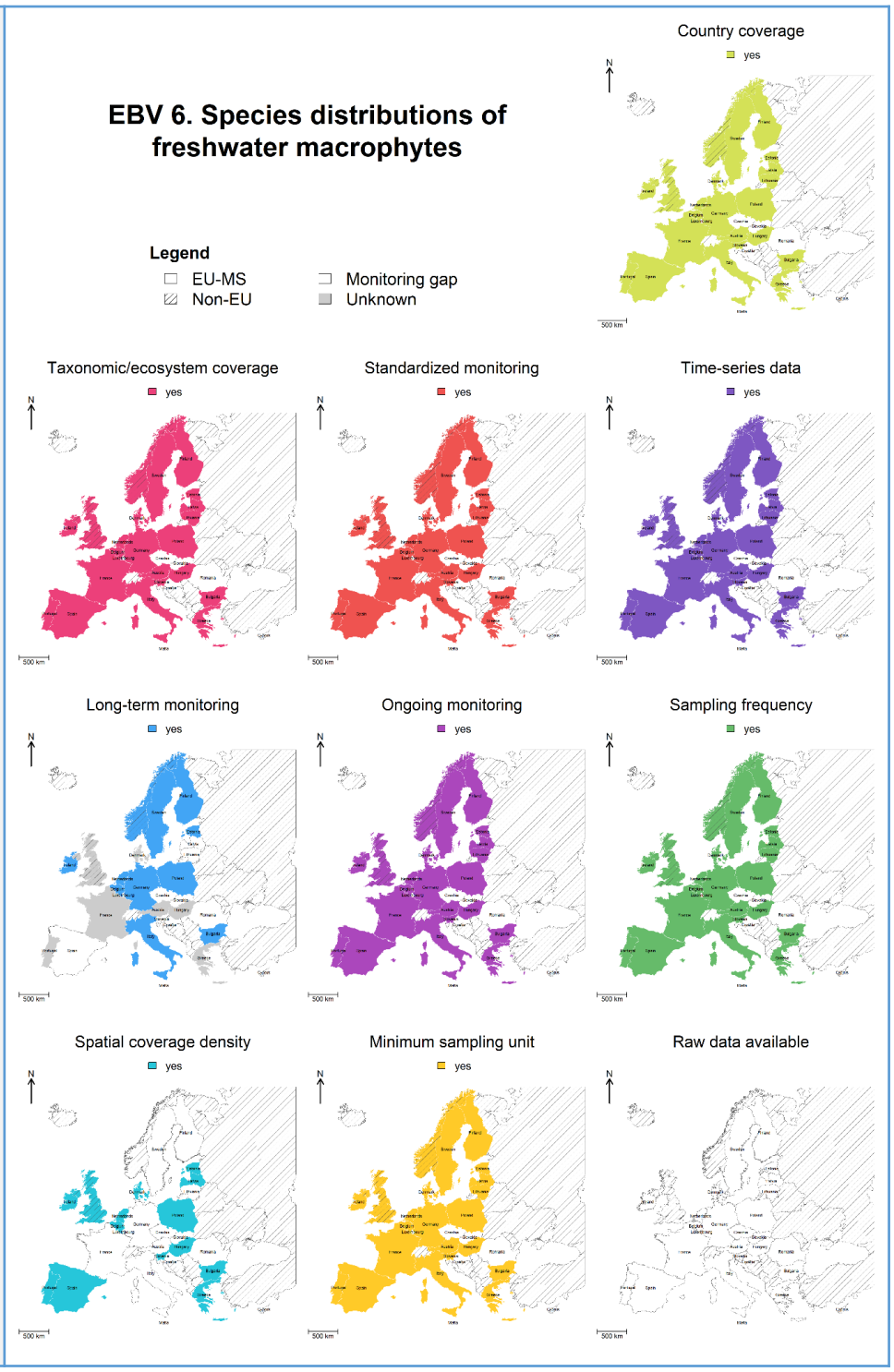

Figure 6.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of invasive alien freshwater taxa of European concern**
Summary	There is an initiative to collect and harmonise invasive alien species data across Europe, including freshwater species from Union Concern - **EASIN** (European Alien Species Information Network). EASIN facilitates the exploration of existing Alien Species information from a variety of sources through freely available tools and interoperable web services, compliant with internationally recognized standards. The EASIN GeoDatabase (v9.0- 19.07.22, https://easin.jrc.ec.europa.eu/easin/GeoDatabase) contains occurrence records for more than 14,000 species, across 40 countries (https://easin.jrc.ec.europa.eu/easin/Catalogue), including 740 freshwater alien species, of which 39 are Invasive Alien Species of Union Concern (https://easin.jrc.ec.europa.eu/spexplorer/map/mapselectedspecies), across all European countries but Andorra. EASIN species mapping tool (https://easin.jrc.ec.europa.eu/spexplorer/search/) shows the distribution of species at the country level, river basin districts, or at 10x10 km grid cells. Data in the EASIN GeoDatabase can be easily accessed and downloaded from the website, while ownership of the data remains within its source, which is properly cited and linked. However, EASIN is not a monitoring network and its data come from a variety of sources, including standardized monitoring programs, occasional observations, data portals, and iterature review, making it difficult to collect the country-level information needed to identify monitoring gaps in the generation of the EBV "Species distributions of invasive alien freshwater taxa of European concern" at the European level. Information on monitoring gaps of invasive alien freshwater taxa of European concern to generate this EBV can be partially inferred from several European initiatives covering different taxa and described in detail for other EBVs: “Species distribution of freshwater fishes”; “Species distribution of freshwater macrophytes”; Species distribution of freshwater benthic invertebrates”; “Species distribution of amphibians and freshwater reptiles”; and “Species distribution of freshwater mammals”.
EBV characteristics (target)	
ID	7
Realm	Freshwater
Class	Species populations
Name	Species distributions of invasive alien freshwater taxa of European concern
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of invasive freshwater species within lakes and river catchments over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	Lakes and river catchments as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	Freshwater species specified in the Consolidated List of Invasive Alien Species of Union Concern
Current monitoring	
Integration initiative **[EASIN, others]**	There is an initiative to collect and harmonise invasive alien species data across Europe, including freshwater species from Union Concern - **EASIN** (European Alien Species Information Network). EASIN facilitates the exploration of existing Alien Species information from a variety of sources through freely available tools and

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	interoperable web services, compliant with internationally recognized standards. The EASIN GeoDatabase (v9.0- 19.07.22, https://easin.jrc.ec.europa.eu/easin/GeoDatabase) contains occurrence records for more than 14,000 species, across 40 countries (https://easin.jrc.ec.europa.eu/easin/Catalogue), including 740 freshwater alien species, of which 39 are Invasive Alien Species of Union Concern (https://easin.jrc.ec.europa.eu/spexplorer/map/mapselectedspecies), across all European countries but Andorra. EASIN species mapping tool (https://easin.jrc.ec.europa.eu/spexplorer/search/) shows the distribution of species at the country level, river basin districts, or at 10x10 km grid cells. Data in the EASIN GeoDatabase can be easily accessed and downloaded from the website, while ownership of the data remains within its source, which is properly cited and linked. However, EASIN is not a monitoring network and its data come from a variety of sources, including standardized monitoring programs, occasional observations, data portals, and iterature review, making it difficult to collect the country-level information needed to identify monitoring gaps in the generation of the EBV "Species distributions of invasive alien freshwater taxa of European concern" at the European level. Information on monitoring gaps of invasive alien freshwater taxa of European concern to generate this EBV can be partially inferred from several European initiatives covering different taxa and described in detail for other EBVs: “Species distribution of freshwater fishes”; “Species distribution of freshwater macrophytes”; Species distribution of freshwater benthic invertebrates”; “Species distribution of amphibians and freshwater reptiles”; and “Species distribution of freshwater mammals”.

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Species traits

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Phenology of migration of wetland birds**
Summary	Monitoring data on phenology of migration of terrestrial birds able to produce the EBV "Phenology of migration of terrestrial birds" at the European scale is currently flowing to **EURING** and **EuroBirdPortal** to produce **The Eurasian African Migration Atlas** and the **Migration Mapping Tool 2022**. The Eurasian African Migration Atlas provides interactive migration maps for 300 species using ringing data collected all year round by EURING following standardized protocols at exact locations and involves ongoing long-term time-series updated on a yearly basis in most EU-MS. The Migration Mapping Tool is a joint initiative by EURING, EBP, EFSA to provide information of the migratory connectivity of 50 bird species in Europe, primarily to inform management of Avian Influenza outbreaks and the risks of another disease transmission by birds. EBP data is stored in the EBP central data repository aggregated at 10x10 km resolution. Main monitoring gaps in the generation of the EBV "Phenology of migration of terrestrial birds" include lack of: taxonomic coverage, standardised monitoring, spatial coverage density, and data availability. While the EURING data is based on well stablished standirtised field protocols, only a small part of the EBP data is collected following standardized monitoring protocols. Monitoring does not cover all migratory species. The network of sites is likely to be sufficiently dense to produce the EBV at the desired spatial resolution (10x10km) but only for a subset of species. EURING and EBP data are available upon request, but EBP dada access requires authorization from national owners.
EBV characteristics (target)	
ID	58c
Realm	Freshwater
Class	Species traits
Name	Phenology of migration of wetland birds
Step in identification process	Expert workshop
Definition	The annual timing of arrival and departure of European wetland migratory bird species at breeding, staging and wintering sites over time.
Metric	Migration phenology metrics such as: - Day of arrival - Day of departure - Length of stay"
Spatial resolution units	10x10km
Temporal resolution units	1 week (traits derived from weekly distribution data)
Taxonomic/ ecosystem focus group	Migratory bird species defined as full migrants in the European Red List
Current monitoring	
Integration initiative **[EURING, EuroBirdPortal]**	Monitoring data on phenology of phenology of migration of wetland birds is currently flowing to **EURING** and **EuroBirdPortal** to produce **The Eurasian African Migration Atlas** and the **Migration Mapping Tool 2022**. The **EURING** (https://euring.org/) is the coordinating organisation for European bird ringing schemes. The organization collects data in the EURING Data Bank (**EDB**, https://euring.org/node/4), which holds a high proportion of the ringing recovery data

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	that have been gathered by bird ringing schemes throughout Europe and along the Eurasian African flyway. The databank is hosted by the British Trust for Ornithology. The data are computerised according to standard protocols that are used by all EURING schemes. EURING data was used to produce the Eurasian African Migration Atlas (https://migrationatlas.org/about), encompassing the flyways between Eurasia and Africa. Movements in time and space of **300 bird species** are mapped and analysed drawing on data gathered by European Ringing Schemes over more than a century and collated by the EURING databank. The **EuroBirdPortal** (**EBP**, https://eurobirdportal.org/) is a European integration initiative gathering data from online portals to map large-scale spatio-temporal patterns of bird distributions within 30x30 km grid cells on a weekly basis. EBP obtains year-round data from unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases even no protocol (casual observations). However, data is stored in the EBP central data repository aggregated at 10x10 km resolution. Data from **EURING** Ringing Schemes and bird recording portals contributing to EuroBirdPortal are used to build The Migration Mapping Tool 2022 (https://euring.org/research/migration-mapping) is a joint initiative by EURING, EBP, EFSA to provide information of the migratory connectivity of 50 bird species in Europe, primarily to inform management of Avian Influenza outbreaks and the risks of another disease transmission by birds.
Country coverage **Very-High [100% EU-MS]**	41 European countries report species abundance data to **EURING:** Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and United Kingdom. All European countries report species abundance data to **EBP.**
Taxonomic/ Ecosystem coverage **Very-High [0% EU-MS]**	Movements in time and space of 300 bird species are mapped and analysed by the **Eurasian African Migration Atlas**. Migratory connectivity of 50 bird species in Europe are available through the **Migration Mapping Tool 2022.** **EBP** has the potential to collect data on all bird species occurring in Europe but, by 2023, data was only available for 137 species. It is possible that not all species detected in a given square are reported (e.g. incomplete lists) **(partial gap).**
Standardized monitoring **Very-High [96% EU-MS]**	**EURING** monitoring is based on standardised fieldwork protocols to collect count data on a seasonal basis (breeding, wintering and migration). **EBP** monitoring is based on unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases, even no protocol (casual observations) obtained year-round. Only a small part of the data is collected following standardized monitoring protocols (**partial gap**).
Time-series **Very-High [100% EU-MS]**	**EURING:** Times-series [1889-ongoing]. **EBP:** Times-series [2003-ongoing].
Long-term monitoring **Very-High [93% EU-MS]**	The first modern bird ringing took place in Denmark in 1889. The first national ringing schemes developed over the following 20 years and there are now some 49 European Ringing Schemes that are members of EURING. EBP longest time-series is from 2003.

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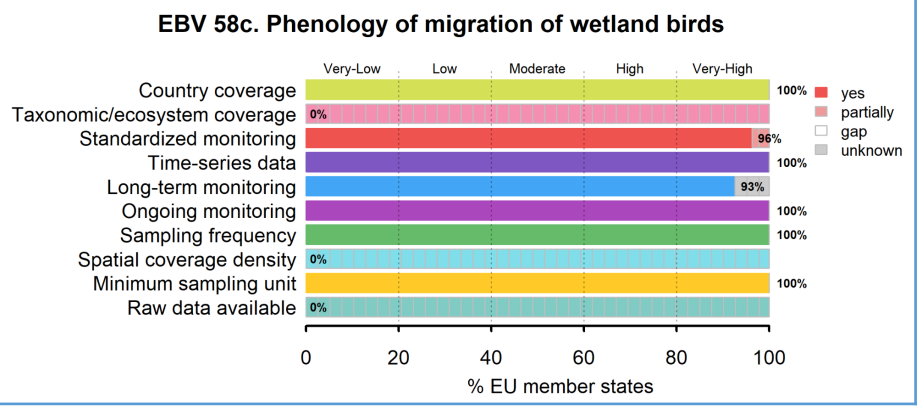
Ongoing monitoring **Very-High [100% EU-MS]**	**EURING** and **EBP** are both ongoing.
Sampling frequency **Very-High [100% EU-MS]**	Seasonally/Annually. **EURING:** higher than the EBV temporal resolution (3 or 6 years) Daily. **EBP.** The local online portals collect most of their data through mobile apps in near-real time or shortly after it has been recorded in the field and the data is transferred to the EBP on a daily basis. Altogether, EURING and EBP data can be used to provide a timely estimation the phenology of migratory terrestrial bird species across Europe.
Spatial Coverage Density **Very-High [0% EU-MS**	**EURING:** Bird abundance data are collected in sampling points unevenly distributed in each country. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km). **EBP:** Bird count data of ca. 137 are collected in transects or sampling points. Although the maps featured in the EBP viewer (www.eurobordportal.org) are aggregated by week and 30x30 km, data is stored in the EBP central data repository aggregated at 10x10 km resolution. The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km). Altogether, the network of sites is likely to be sufficiently dense to produce the EBV at the desired spatial resolution (10x10km) but only for a subset of species (**partial gap**).
Minimum sampling unit **Very-High [96% EU-MS]**	**EURING:** Exact location. **EBP:** 10x10km. Data is aggregated at 10x10 km grid cells. Altogether, monitoring data collected from the different schemes are likely to be adequate to generate the EBV at the desired spatial resolution 10x10km.
Raw data access **Very-Low [0% EU-MS]**	**EURING** data are available upon request. **EBP** is available upon request and subject to agreement by National coordinators who hold the ownership of data, but just one centralized data request to should be done as data is already centralized in the EBP databank (authorizations by national owners are coordinated by EBP) (**partial gap**). Overall, data is only partially available.
Monitoring gaps	
Figure 58c.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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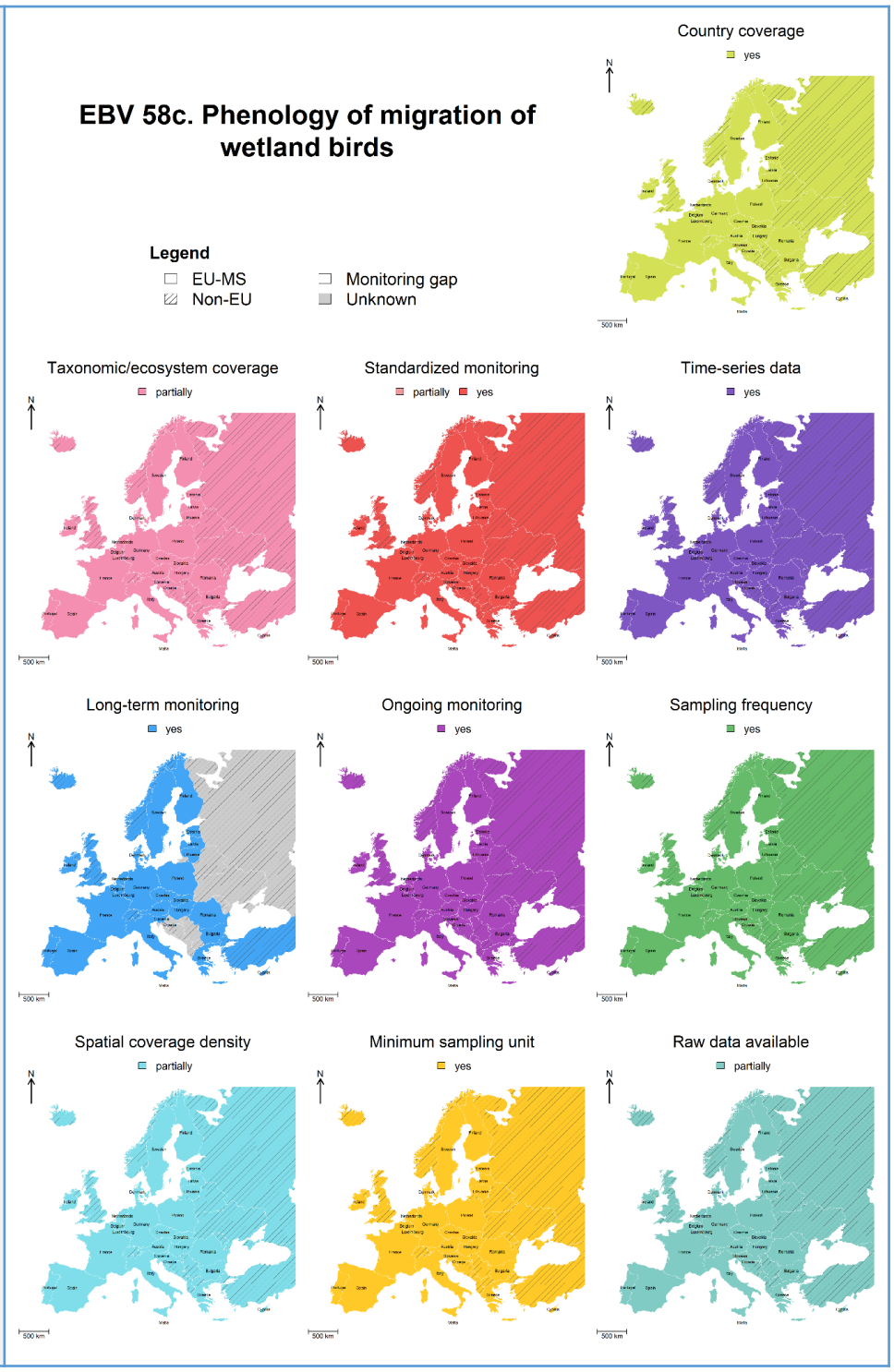

Figure 58c.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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Community composition

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of phytoplankton in lakes**
Summary	Freshwater phytoplankton in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to WISE-2 (Water Information System for Europe - Biology data). Freshwater phytoplankton monitoring (composition, abundance, and biomass) in lakes is based on standardized protocols using intercalibrated metrics among countries covering 85% of the EU-MS. Yet, because the report is voluntary, only 59% of the EU-MS report freshwater phytoplankton EQRs to WISE-2. All countries reporting to WISE-2 have time-series data updated annually, and thus adequate to generate the EBV at the defined temporal resolution (1 year). Main gaps in the generation of the EBV "Ecological Quality Ratio (EQR) of phytoplankton in lakes" include reduced country coverage, lack of long-term data and insufficient sampling frequency. Specifically, just over half of the MS report on EQR of phytoplankton in lakes (59%). The proportion of monitored lakes and rivers is very low (<20%) for 19% of the EU-MS. Long-term data is only available for 44% of the MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. Finally, the current sampling frequency (annually) is adequate to produce the EBV at a 1-year temporal resolution, yet it is not enough to update the EBV at a weekly-monthly basis during the growing season (partial gap). EQRs values on lake phytoplankton are available upon request for all the countries reporting for WISE-2 but not for the WFD.
EBV characteristics (target)	
ID	9
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of phytoplankton in lakes
Step in identification process	User & Policy Needs Assessment
Definition	Community composition and total biomass of phytoplankton in lakes (Ecological Quality Ratio) based on total abundance (biovolume), taxonomic composition index across all species based on biovolume per indicator species, and bloom intensity, e.g. maximum biomass of cyanobacteria or percentage of cyanobacteria of the total biomass for all taxa
Metric	The Ecological Quality Ratio (EQR) of phytoplankton in European lakes, expressed as a numerical value between zero (low) and one (high), quantifying the ecological status of phytoplankton community composition and its deviation from a reference condition. The metric describes the deviation from natural phytoplankton communities.
Spatial resolution units	Lakes as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	1 year, weekly-monthly during growing season
Taxonomic/ ecosystem focus group	Phytoplankton indicator taxa and reference taxa as described in the Water Framework Directive Intercalibration Technical Reports (Part 2, Lakes)
Current monitoring	
Integration initiative **[WFD, WFD-WISE-2]**	Phytoplankton in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to Water Information System for Europe - Biology data (WISE-2). The WISE-2

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	(https://water.europa.eu/freshwater, https://cdr.eionet.europa.eu/help/WISE_SoE/wise2) is an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Ecological Quality Ratios (EQRs) from all surface water categories; rivers, lakes, transitional and coastal waters. By 2021, 26 countries reported data to WISE-2: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.
Country coverage **Very-High [85% EU-MS]**	25 countries reporting ecological quality status for the WFD based on freshwater phytoplankton monitoring in lakes (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, and the United Kingdom. 18 countries report EQR on lake phytoplankton to WISE-2 based on monitoring: Austria, Belgium, Bulgaria, Cyprus, Estonia, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania and Sweden.
Taxonomic/ Ecosystem coverage **Very-High [85% EU-MS]**	Monitoring covers all lake phytoplankton species with indicator values.
Standardized monitoring **Very-High [85% EU-MS]**	Phytoplankton in lakes are sampled using intercalibrated metrics that include phytoplankton composition, abundance and biomass. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology). The EQR values are calculated by MS based on biological indicator values defined by their national classification systems (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology; http://dd.eionet.europa.eu/dataelements/latest/procedureClassificationSystem).
Time-series **Very-High [85% EU-MS]**	Freshwater phytoplankton are monitored using intercalibrated metrics since 1990.
Long term monitoring **Moderate [48% EU-MS]**	Long-term time-series on EQR on lake phytoplankton are available for 13 countries: Austria, Belgium, Estonia, Germany, Ireland, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, and Sweden.
Ongoing monitoring **Very-High [85% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, 6 countries have not reported EQR values to WISE-2 at least since 2015: Cyprus, Estonia, Germany, Netherlands, Portugal, and France.
Sampling frequency **Very-Low [0% EU-MS]**	**Annually.** Sampling sites are monitored annually. EQR values on phytoplankton in lakes are reported annually. Current sampling frequency (annually) in adequate to produce the EBV at a 1-year temporal resolution, yet it is not enough to update the EBV at a weekly-monthly basis during the growing season (**partial gap**).

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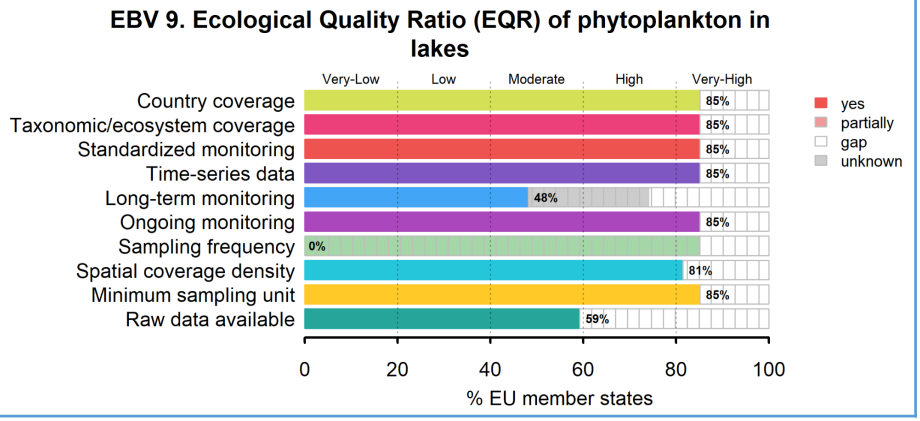
Spatial Coverage Density **Very-High [81% EU-MS]**	WFD identifies 7,747 sites for phytoplankton monitoring in lakes, and 30% are actually monitored. The proportion of monitored sites differs among countries but was >20% in all countries except Sweden (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no). The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. From the WFD monitored sites, 5,597 sites have EQR values on freshwater phytoplankton in lakes reported to WISE-2.
Minimum sampling unit **Very-High [85% EU-MS]**	Freshwater phytoplankton composition, abundance and biomass at exact locations. Norway: 0.2x0.2km grid cells for lakes. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Moderate [59% EU-MS]**	EQRs values on lake phytoplankton are available upon request for all the countries reporting for WISE-2 but not for the WFD (**gap**).
Monitoring gaps	
Figure 9.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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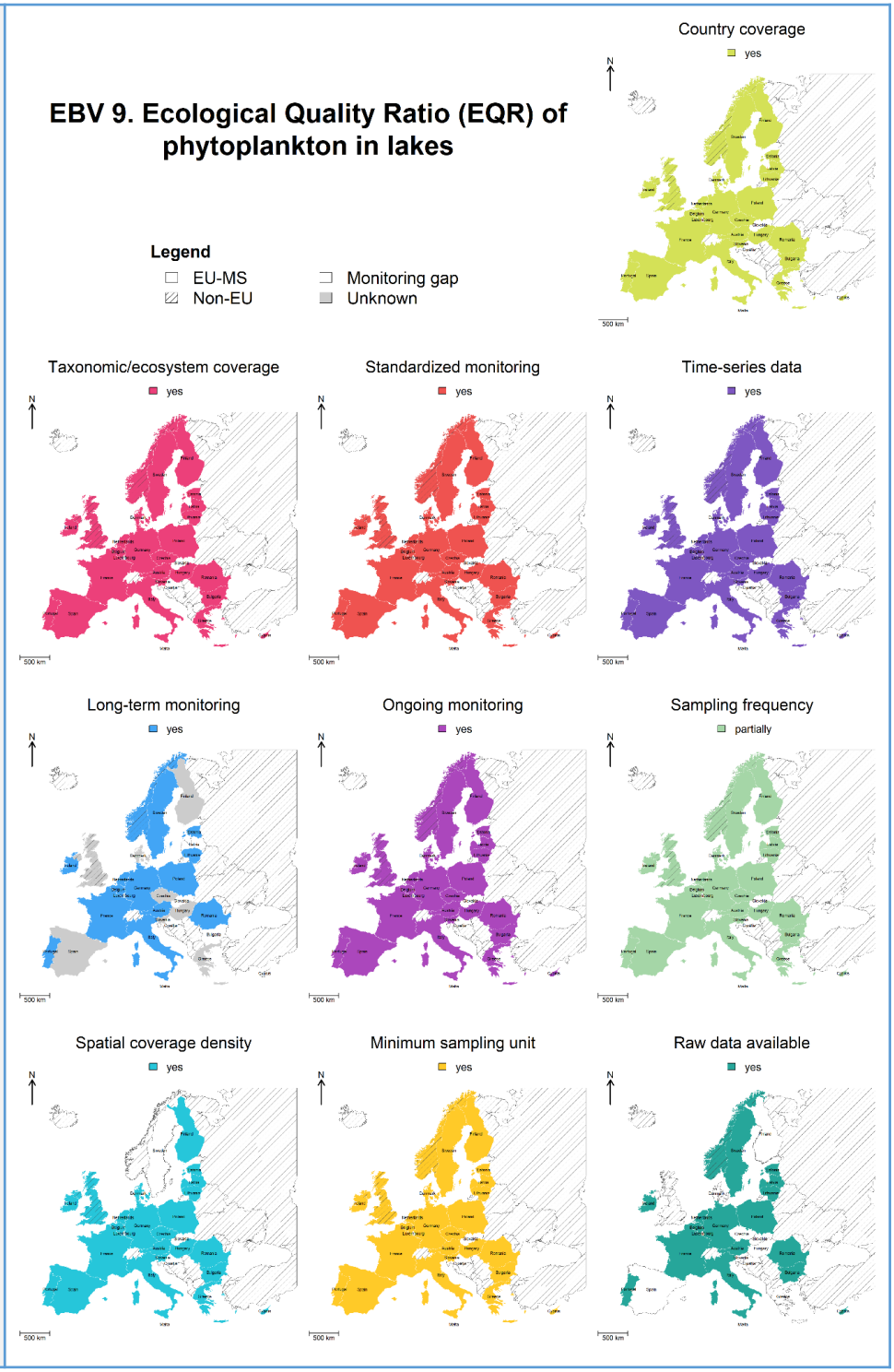

Figure 9.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of freshwater macrophytes**
Summary	Freshwater macrophytes in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to WISE-2 (Water Information System for Europe - Biology data). Freshwater macrophytes monitoring (composition and abundance) in lakes is based on standardized protocols using intercalibrated metrics among countries covering 74% of the EU-MS. Yet, because the report is voluntary, only 52% of the EU-MS report freshwater macrophytes EQRs to WISE-2. All countries reporting to WISE-2 have time-series data updated every 6 years, and thus adequate to generate the EBV at the defined temporal resolution (3 to 6 years). Main gaps in the generation of the EBV "Ecological Quality Ratio (EQR) of freshwater macrophytes" include reduced country coverage, lack of long-term data, unknown spatial resolution, and unavailable raw data. The proportion of monitored lakes is very low (<20%) for 59% of the EU-MS. Long-term data are still lacking for most MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. EQRs values on freshwater macrophytes in lakes are available upon request for all the countries reporting for WISE-2 but not to the WFD.
EBV characteristics (target)	
ID	10
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of freshwater macrophytes
	User & Policy Needs Assessment
Definition	Community composition of macrophytes (Ecological Quality Ratio) based on presence-absence data
Metric	The Ecological Quality Ratio (EQR) of macrophytes in European lakes, expressed as a numerical value between zero (bad) and one (very good), quantifying the ecological status of macrophyte community composition and its deviation from a reference condition.
Spatial resolution units	Lakes as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	6 years
Taxonomic/ ecosystem focus group	All macrophytes species with indicator values as defined in the Water Framework Directive Intercalibration Technical Reports (Part 2, Lakes)
Current monitoring	
Integration initiative **[WFD, WFD-WISE-2]**	Freshwater macrophytes in lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to Water Information System for Europe - Biology data (WISE-2). The WISE-2 (https://water.europa.eu/freshwater, https://cdr.eionet.europa.eu/help/WISE_SoE/wise2) is an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Ecological Quality Ratios (EQRs) from all surface water categories; rivers, lakes, transitional and coastal waters. By 2021, WISE-2 database has data for 26 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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Country coverage **High [74% EU-MS]**	22 countries reporting ecological quality status for the WFD based on freshwater macrophytes monitoring in lakes to report ecological status to WFD (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, and the United Kingdom. Only 18 countries report EQR values on lake macrophytes to WISE-2 based on monitoring: Belgium, Bulgaria, Estonia, Finland, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Spain, Slovenia, and Sweden.
Taxonomic/ Ecosystem coverage **High [74% EU-MS]**	Monitoring covers all freshwater macrophytes in lakes.
Standardized monitoring **High [74% EU-MS]**	Monitoring data on freshwater macrophytes are sampled using metrics intercalibrated among countries that include macrophytes composition and abundance. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology).
Time-series **Low [37% EU-MS]**	**Time-series [2007-ongoing]** Freshwater macrophytes are monitored using intercalibrated metrics since 2007.
Long term monitoring **High [74% EU-MS]**	Long-term data (≥10 years) on EQR on macrophytes are available for 11 countries: Belgium, Bulgaria, Estonia, Finland, Germany, Ireland, Italy, Netherlands, Norway, Poland, and Sweden.
Ongoing monitoring **High [74% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, 5 countries have not reported EQR values to WISE-2 at least since 2012: Belgium, Bulgaria, Estonia, Finland, and the Netherlands.
Sampling frequency **High [74% EU-MS]**	**Every 6 years.** Freshwater macrophytes are monitored every 6 years in each sampling site. Yet, EQR values on freshwater macrophytes are reported annually.
Spatial Coverage Density **Moderate [48% EU-MS]**	WFD identifies 2,541 sites for macrophytes monitoring in lakes, but only 9.8% are actually monitored. The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Belgium, Bulgaria, Denmark, Estonia, Greece, Hungary, Ireland, Latvia, Poland, Portugal, and United Kingdom. The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. From the WFD monitored sites, 1,472 sites have EQR values on freshwater macrophytes in lakes reported to WISE-2.
Minimum sampling unit **High [74% EU-MS]**	Freshwater macrophytes composition and abundance at exact locations. Norway: 0.2x0.2km grid cells. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a

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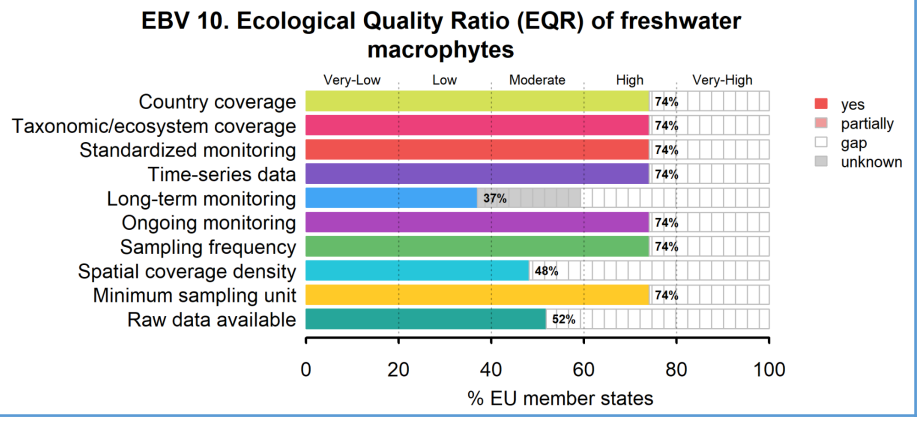
	monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Moderate [52% EU-MS]**	EQRs values on lake macrophytes are available upon request for all the countries reporting for WISE-2 but not for the WFD.
Monitoring gaps	
Figure 10.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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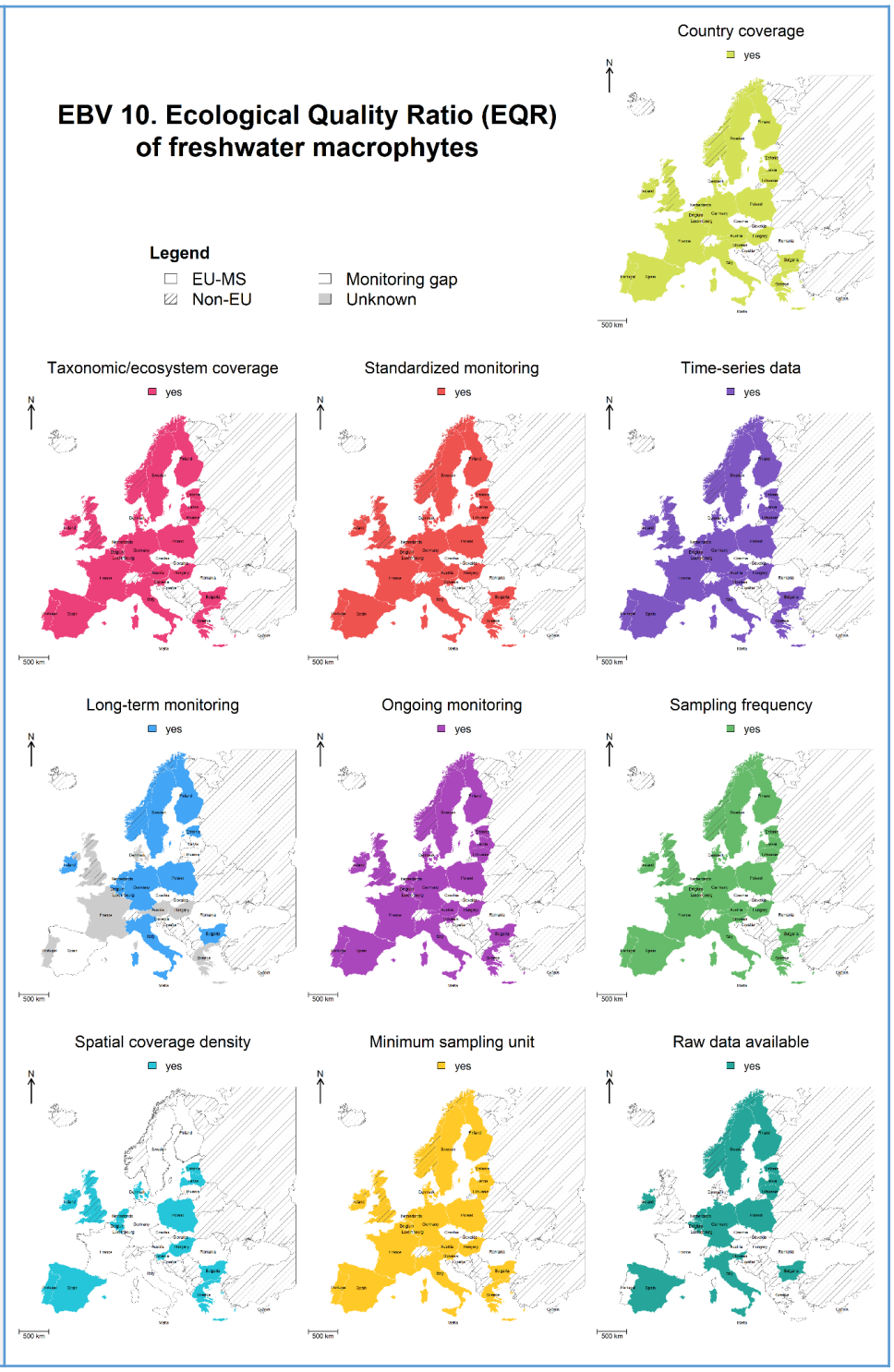

Figure 10.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of freshwater phytobenthos**
Summary	Freshwater phytobenthos in rivers are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to WISE-2 (Water Information System for Europe - Biology data). Freshwater phytobenthos monitoring (composition and abundance) in rivers is based on standardized protocols using intercalibrated metrics among countries covering 85% of the EU-MS. Yet, because the report is voluntary, only 70% of the EU-MS report freshwater phytobenthos EQRs to WISE-2. All countries reporting to WISE-2 have time-series data updated every 2 or 3 years, and thus adequate to generate the EBV at the defined temporal resolution (1 to 3 years). Main gaps in the generation of the EBV "Ecological Quality Ratio (EQR) of freshwater phytobenthos" include lack of country and spatial coverage and long-term data. Specifically, although with a moderate country coverage, 26% of the MS do not report on EQR of phytobenthos. The proportion of monitored lakes and rivers is very low (<20%) for 15% of the EU-MS. Long-term monitoring is still lacking for most MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. EQRs values on river phythobentos are available upon request for all the countries reporting for WISE-2 but not to the WFD.
EBV characteristics (target)	
ID	11
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of freshwater phytobenthos
Step in identification process	User & Policy Needs Assessment
Definition	The ecological status of phytobenthos in European rivers, measured as Ecological Quality Ratio (EQR).
Metric	The Ecological Quality Ratio (EQR) of phytobenthos in European rivers, expressed as a numerical value between zero (bad) and one (very good), quantifying the ecological status of phytobenthos community composition and its deviation from a reference condition.
Spatial resolution units	River catchments as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	1-3 years
Taxonomic/ ecosystem focus group	Phytobenthic species with indicator values as defined in the Water Framework Directive Intercalibration Technical Reports (Part 1, Rivers)
Current monitoring	
Integration initiative **[WFD, WISE-2]**	Freshwater phytobenthos in rivers are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to Water Information System for Europe - Biology data (WISE-2). The WISE-2 (https://water.europa.eu/freshwater, https://cdr.eionet.europa.eu/help/WISE_SoE/wise2) is an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Ecological Quality Ratios (EQRs) from all surface water categories; rivers, lakes, transitional and coastal waters. By 2021, WISE-2 database has data for 26 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy,

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	Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.
Country coverage **Very-High [85% EU-MS]**	25 countries reporting ecological quality status for the WFD based on freshwater Phytobenthos monitoring in rivers (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom. 20 countries report EQR on river Phytobenthos to WISE-2 based on monitoring: Austria, Belgium, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden.
Taxonomic/ Ecosystem coverage **Very-High [85% EU-MS]**	Monitoring covers all river phytobenthos species with indicator values.
Standardized monitoring **Very-High [85% EU-MS]**	Monitoring data on phytobenthos in rivers are sampled using intercalibrated metrics that include macrophytes composition and abundance. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology).
Time-series **Very-High [85% EU-MS]**	Freshwater phytobenthos in rivers are monitored using intercalibrated metrics since 1992.
Long term monitoring **Very-High [59% EU-MS]**	Long-term data (≥10 years) on EQR on river phytobenthos are available for 17 countries: Austria, Belgium, Bulgaria, Cyprus, Estonia, Finland, France, Germany, Italy, Luxemburg, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, and Sweden.
Ongoing monitoring **Very-High [85% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, 6 countries have not reported EQR values to WISE-2 at least since 2015: Finland, France, Germany, Netherlands, Norway, and Portugal.
Sampling frequency **Very-High [85% EU-MS]**	**Every 2 or 3 years.** Freshwater phytobenthos in rivers are monitored every 2 to 3 years in each sampling site. Yet, EQR values on freshwater macrophytes are reported annually.
Spatial Coverage Density **High [85% EU-MS]**	WFD identifies 20,280 sites for phythobentos monitoring in rivers, but only 17.8% are actually monitored. The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Luxembourg, Poland, Portugal, Romania, Slovakia, Spain, Sweden, and the United Kingdom.

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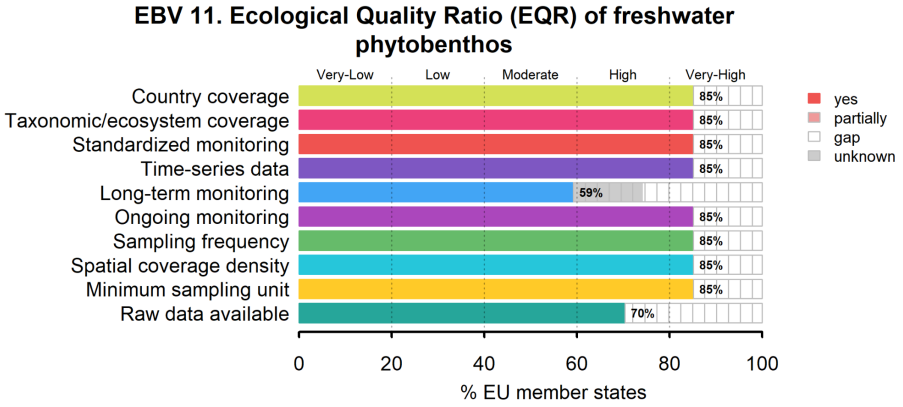
	The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. From the WFD monitored sites, 17,794 sites have EQR values on freshwater phythobentos in rivers reported to WISE-2.
Minimum sampling unit **Very-High [85% EU-MS]**	Freshwater phythobentos composition and abundance at exact locations. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Very-High [70% EU-MS]**	EQRs values on river phythobentos are available upon request for all the countries reporting for WISE-2 but not to the WFD.
Monitoring gaps	
Figure 11.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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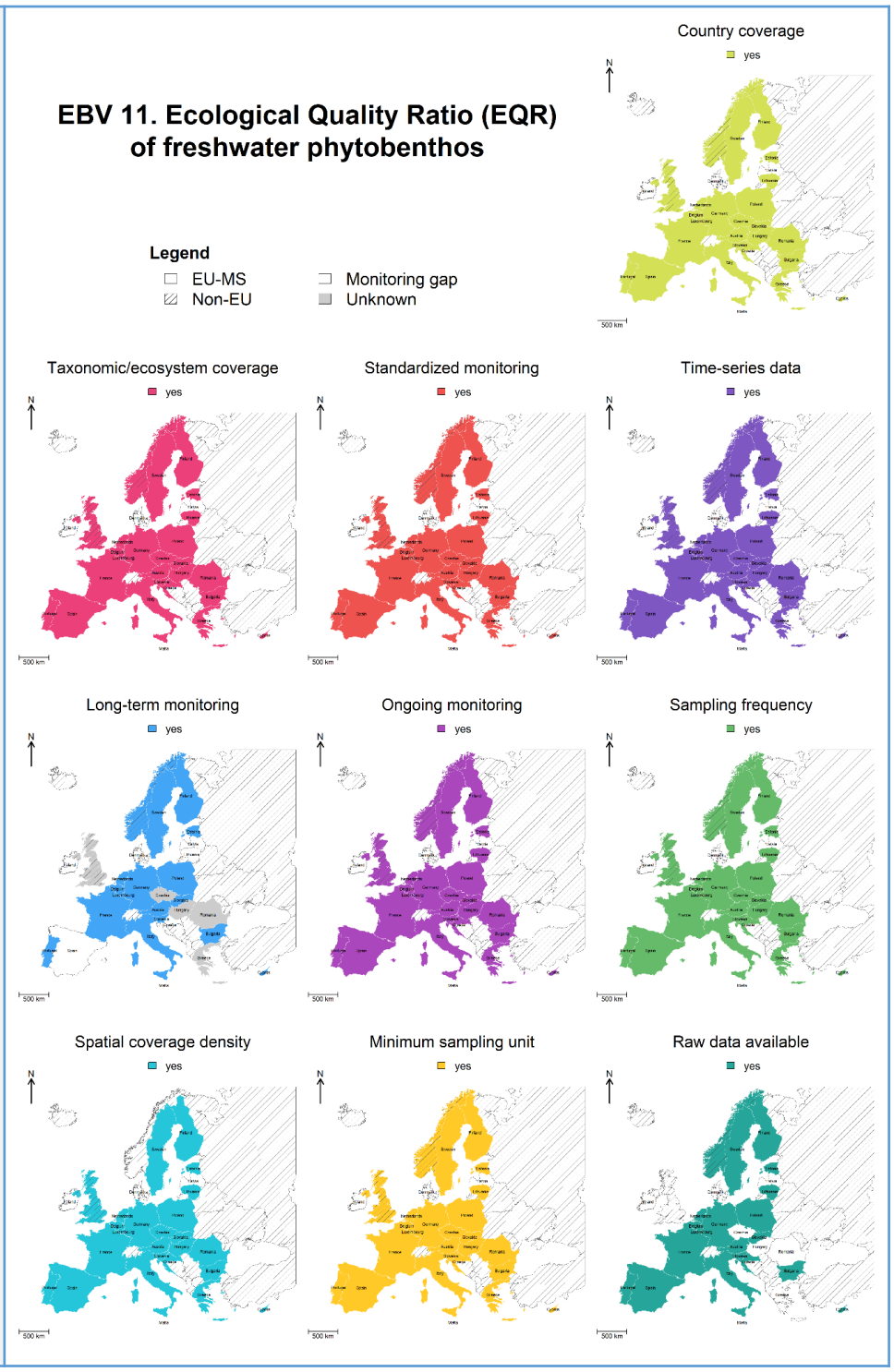

Figure 11.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of benthic freshwater invertebrates**
Summary	Freshwater benthic invertebrates in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to WISE-2 (Water Information System for Europe - Biology data). Freshwater benthic invertebrates monitoring (composition and abundance) in lakes and rivers is based on standardized protocols using intercalibrated metrics among countries covering 96% of the EU-MS. Yet, because the report is voluntary, only 85% of the EU-MS report freshwater invertebrates EQRs to WISE-2. All countries reporting to WISE-2 have time-series data updated every 2 or 3 years, and thus adequate to generate the EBV at the defined temporal resolution (3 to 6 years); and many have long-term data series (>10 years). Main gaps in the generation of the EBV "Ecological Quality Ratio (EQR) of benthic freshwater invertebrates" include lack of spatial coverage as only two EU-MS report on lakes. The proportion of monitored lakes and rivers is very low (<20%) for only one EU-MS. EQRs values on benthic invertebrates in rivers and lakes are available upon request for all the countries reporting for WISE-2 but not to the WFD.
EBV characteristics (target)	
ID	12
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of benthic freshwater invertebrates
Step in identification process	User & Policy Needs Assessment
Definition	The ecological status of benthic invertebrates in European rivers, measured as Ecological Quality Ratio (EQR).
Metric	The Ecological Quality Ratio (EQR) of benthic invertebrates in European rivers, expressed as a numerical value between zero (bad) and one (very good), quantifying the ecological status of benthic invertebrate community composition and its deviation from a reference condition.
Spatial resolution units	River catchments as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	2-3 years
Taxonomic/ ecosystem focus group	Benthic invertebrate species with indicator values as defined in the Water Framework Directive Intercalibration Technical Reports (Part 1, Rivers)
Current monitoring	
Integration initiative **[WFD, WFD-WISE-2]**	Freshwater benthic invertebrates in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to Water Information System for Europe - Biology data (WISE-2). The WISE-2 (https://water.europa.eu/freshwater, https://cdr.eionet.europa.eu/help/WISE_SoE/wise2) is an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Ecological Quality Ratios (EQRs) from all surface water categories; rivers, lakes, transitional and coastal waters. By 2021, 26 countries reported data to WISE-2: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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Country coverage **Very-High [96% EU-MS]**	28 countries reporting ecological quality status for the WFD based on freshwater pollution-sensitive benthic invertebrates monitoring in rivers and lakes (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and United Kingdom. 24 countries report EQR on benthic Invertebrates to WISE-2: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and Sweden.
Taxonomic/ Ecosystem coverage **Very-High [96% EU-MS]**	Monitoring covers all freshwater benthic invertebrate species with indicator values.
Standardized monitoring **Very-High [96% EU-MS]**	Monitoring data on benthic invertebrates are sampled using intercalibrated metrics that include invertebrates' composition and abundance. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology).
Time-series **Very-High [96% EU-MS]**	**Time-series [2004-ongoing].** Benthic invertebrates are monitored using intercalibrated metrics since 2004.
Long term monitoring **Very-High [78% EU-MS]**	Long-term data (≥10 years) exists for 78% of the EU-MS.
Ongoing monitoring **Very-High [96% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, there are 8 countries that have not reported EQR values to WISE-2 at least since 2015: Austria, Estonia, Finland, France, Germany Netherlands, and Portugal.
Sampling frequency **Very-High [96% EU-MS]**	**Every 2 or 3 years.** Benthic invertebrates are monitored every 2 or 3 years in each sampling site.
Spatial Coverage Density **Very-High [56% EU-MS]**	WFD identifies 40,742 sites for benthic invertebrates monitoring (2,622 in lakes and 38,120 in rivers), but only 29.1% are actually monitored (10.2% in lakes and 33.4% in rivers). The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Belgium, Bulgaria, Estonia, Greece, Hungary, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and United Kingdom. **Rivers** (>20%): Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and United Kingdom.

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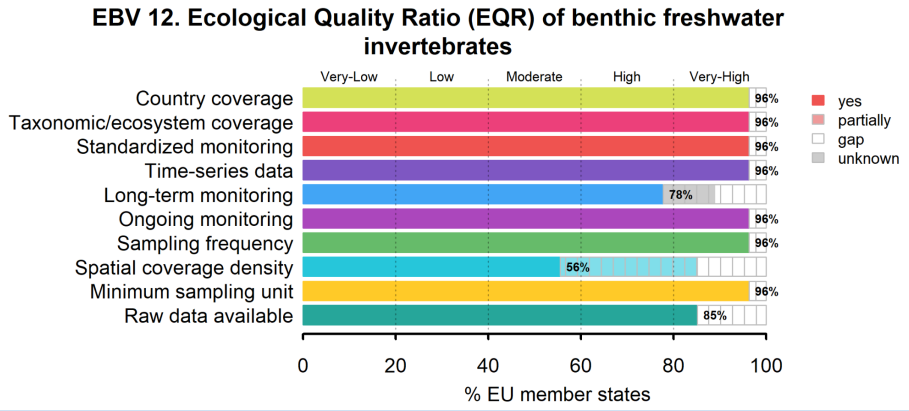
	The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. A partial gap was assumed if the % monitoring site <20% in rivers or lakes. From the WFD monitored sites, 17,630 sites (186 in lakes and 17,434 in rivers) have EQR values on freshwater fishes reported to WISE-2. Most countries only report data to WISE-2 for rivers.
Minimum sampling unit **Very-High [96% EU-MS]**	Benthic invertebrates composition and abundance at exact locations. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Very-High [85% EU-MS]**	EQRs values on benthic invertebrates in rivers and lakes are available upon request for all the countries reporting for WISE-2 but not to the WFD (**gap**).
Monitoring gaps	
Figure 12.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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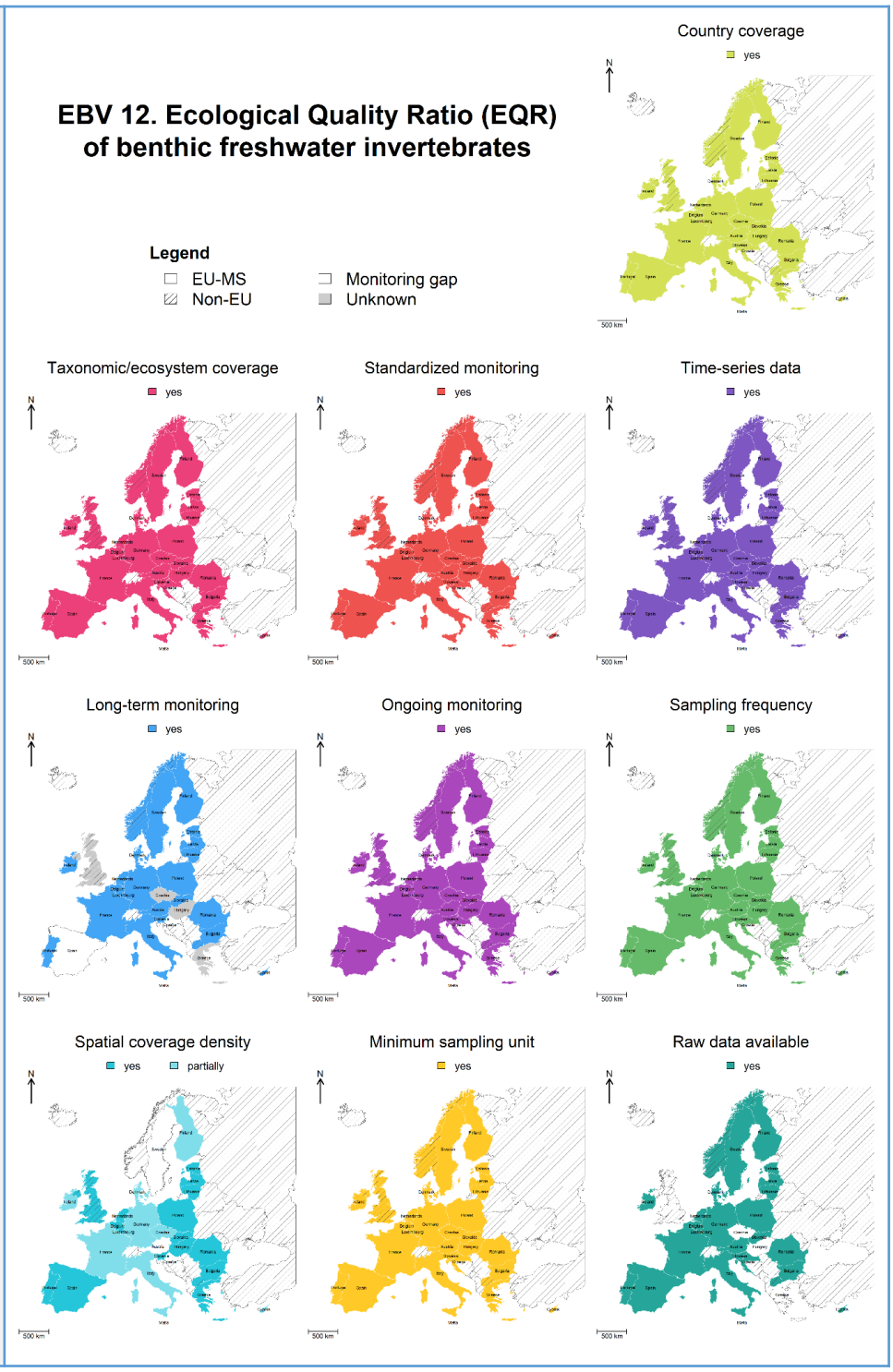

Figure 12.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of freshwater fish**
Summary	Freshwater fish in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to WISE-2 (Water Information System for Europe - Biology data). Freshwater fish monitoring (composition, abundance, and age structure) in lakes and rivers is based on standardized protocols using inter-calibrated metrics among countries covering 93% of the EU-MS. Yet, because the report is voluntary, only 33% of the EU-MS report freshwater invertebrates EQRs to WISE-2. All countries reporting to WISE-2 have time-series data updated every 3 or 6 years, and thus adequate to generate the EBV at the defined temporal resolution (3 to 6 years). Main gaps in the generation of the EBV "Ecological Quality Ratio (EQR) of freshwater fish" include reduced country coverage, lack of long-term data, and reduced spatial coverage density. While 93% of the EU-MS monitor freshwater fishes under WFD, very few EU-MS report on EQRs of freshwater fishes (33%) to WISE-2. Long-term data are still lacking for most MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. The proportion of monitored lakes and rivers is very low (<20%) for 74% of the EU-MS. EQRs values on freshwater fishes are available upon request for all the countries reporting for WISE-2 but not to the WFD only.
EBV characteristics (target)	
ID	13
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of freshwater fish
Step in identification process	User & Policy Needs Assessment
Definition	The ecological status of fish in European freshwater systems (lakes and rivers), measured as Ecological Quality Ratio (EQR).
Metric	The Ecological Quality Ratio (EQR) of fish in European lakes and rivers, expressed as a numerical value between zero (low) and one (high), quantifying the ecological status of fish community composition and abundance and its deviation from a reference condition.
Spatial resolution units	Lakes and river catchments as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	3-6 years
Taxonomic/ ecosystem focus group	Freshwater fish species with indicator values defined in the Water Framework Directive Intercalibration Technical Reports (Part 1, Rivers; Part 2, Lakes)
Current monitoring	
Integration initiative **[WFD, WISE-2]**	Freshwater fish in rivers and lakes are currently monitored by EU-MS to report ecological status to WFD (Water Framework Directive) and report Ecological Quality Ratios (EQRs) to Water Information System for Europe - Biology data (WISE-2). The WISE-2 (https://water.europa.eu/freshwater, https://cdr.eionet.europa.eu/help/WISE_SoE/wise2) is an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Ecological Quality Ratios (EQRs) from all surface water categories; rivers, lakes, transitional and coastal waters. By 2021, WISE-2 database has data for 26 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy,

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	Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.
Country coverage **Very-High [93% EU-MS]**	27 countries monitor freshwater fish in rivers and lakes to report ecological status to WFD: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, and United Kingdom. Only 10 countries report EQR values on freshwater fish: Belgium; Bulgaria; Ireland; Italy; Lithuania; Luxembourg; Netherlands; Poland; Slovak Republic; Slovenia; and Norway.
Taxonomic/ Ecosystem coverage **Very-High [93% EU-MS]**	Monitoring covers all freshwater fish species.
Standardized monitoring **Very-High [93% EU-MS]**	Monitoring data on freshwater fish are sampled using intercalibrated metrics that include fish composition, abundance and age structure. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology).
Time-series **Very-High [93% EU-MS]**	**Time-series [2015-ongoing].** Freshwater fish are monitored using intercalibrated metrics since 2015.
Long term monitoring **Very-Low [0% EU-MS]**	Long-term data (≥10 years) is thus lacking for all countries.
Ongoing monitoring **Very-High [93% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, the Netherlands stop reporting EQR values to WISE-2 in 2015.
Sampling frequency **Very-High [93% EU-MS]**	**Every 3 or 6 years.** Freshwater fish are monitored every 3 or 6 years in each sampling site. Yet, EQR values on freshwater fishes are reported annually.
Spatial Coverage Density **Low [26% EU-MS]**	WFD identifies 24,453 sites for fish monitoring (2,560 in lakes and 21,893 in rivers), but only 17.5% are actually monitored (9.9% of lakes and 19.2% of rivers). The proportion of monitored sites differs among countries (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_qeMonitoringResults/SWB_qeMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): **Lakes** (>20%): Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Lithuania, Netherlands, and Poland. **Rivers** (>20%): Denmark, Estonia, Finland, Germany, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, Poland, United Kingdom. The spatial coverage density is likely to be adequate to provide the EBV at the desired spatial resolution in the countries where the proportion of monitored sites is higher than >20%. A **partial gap** was assumed if the % monitoring site <20% in rivers or lakes. From the WFD monitored sites, 2,975 sites (347 in lakes and 1268 in rivers) have EQR values on freshwater fishes reported to WISE-2. Most countries only report data to WISE-2 for rivers.

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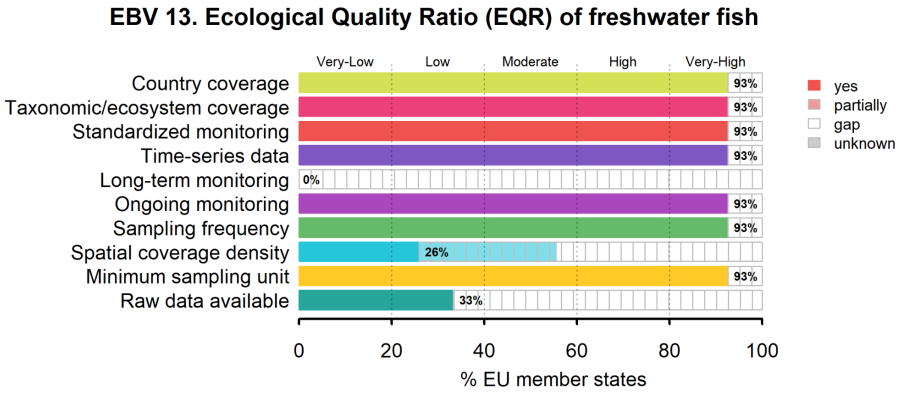
Minimum sampling unit **Very-High [93% EU-MS]**	Freshwater fish composition, abundance and age structure at exact locations. Norway: 0.2x0.2km grid cells for lakes. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Very-High [33% EU-MS]**	EQRs values on freshwater fish are available upon request for all the countries reporting for WISE-2 but not to the WFD.
Monitoring gaps	
Figure 13.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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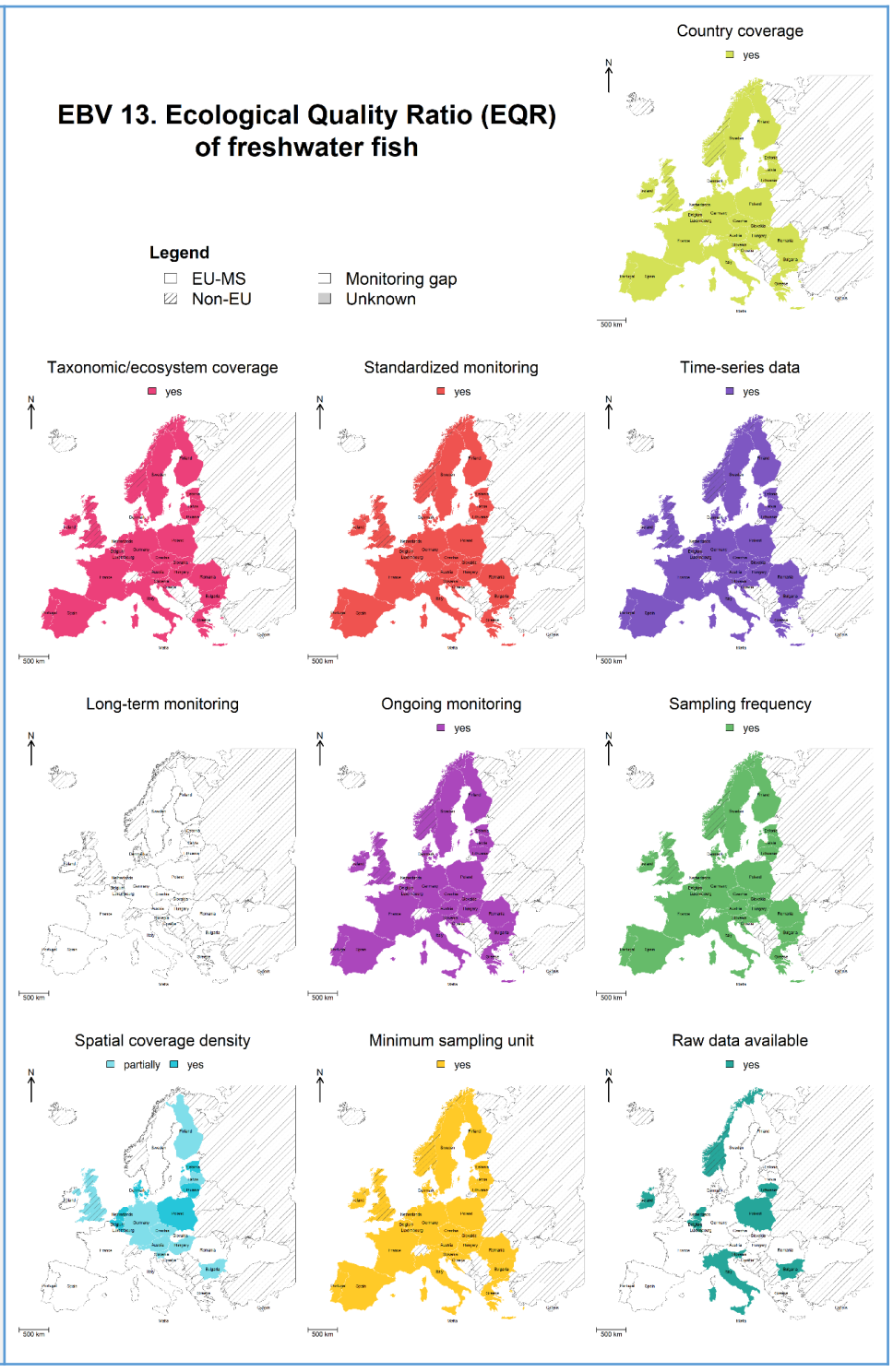

Figure 13.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Ecological Quality Ratio (EQR) of freshwater zooplankton**
Summary	There is no initiative integrating trans-national data on lake zooplankton able to produce the EBV Ecological Quality Ratio (EQR) of zooplankton at the European scale.
EBV characteristics (target)	
ID	14
Realm	Freshwater
Class	Community composition
Name	Ecological Quality Ratio (EQR) of freshwater zooplankton
Step in identification process	Internal review process
Definition	The ecological status of zooplankton in European lakes, measured as Ecological Quality Ratio (EQR).
Metric	The Ecological Quality Ratio (EQR) of zooplankton in European lakes, expressed as a numerical value between zero (bad) and one (very good), quantifying the ecological status of zooplankton community composition and its deviation from a reference condition.
Spatial resolution units	Lakes as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	1-3 years
Taxonomic/ ecosystem focus group	Lake zooplankton species with indicator values
Current monitoring	
Integration initiative **[NONE]**	There is no initiative integrating trans-national data on lake zooplankton able to produce the EBV Ecological Quality Ratio (EQR) of zooplankton at the European scale.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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Ecosystem structure

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**River Connectivity/Free river flow**
Summary	Monitoring data on river connectivity/free river flow have been collected under a Pan-European monitoring scheme – the AMBER Barriers Atlas. Monitoring is based on standardized protocols in rivers across Europe, covering 96% of the MS. Monitoring is ongoing based on a citizen science-monitoring programme mapping the river barriers using validated records at the exact location. Data is open and freely available on the initiative website. Main gaps in the generation of the EBV "River Connectivity/Free river flow" is the absence of long-term data that reduces the ability of the EBV to establish reliable distribution trends in the near future.
EBV characteristics (target)	
ID	15
Realm	Freshwater
Class	Ecosystem structure
Name	River Connectivity/Free river flow
Step in identification process	Internal review process
Definition	The length of free-flowing rivers (without barriers) and the natural longitudinal and lateral connectivity of rivers and lakes.
Metric	- The percentage of free-flowingfree flowing river length per sub-catchment - The presence, number and location of artificial barriers in river segments - The connectivity between rivers, lakes and pond
Spatial resolution units	0.1×0.1km - 1×1km or per river segment
Temporal resolution units	6 years
Taxonomic/ ecosystem focus group	Broad types of rivers or level 3 EUNIS river habitats
Current monitoring	
Integration initiative **[AMBER]**	The AMBER (AMBER Barriers Atlas, https://amber.international/) is a project that joins 20 partners from large hydropower businesses, rivers authorities, non-governmental organisations, universities and the European Joint Research Centre to provide the first European map of river barriers which is the first assessment of stream connectivity across Europe. The continuity of the initiative is ensured by a Citizen Science real-time monitoring program to Record Barriers in European Rivers using the smartphone application 'Barrier Tracker'.
Country coverage **Very-High [96% EU-MS]**	46 countries are covered by the AMBER project: Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.
Taxonomic/ Ecosystem coverage **Very-High [96% EU-MS]**	The initiative covers rivers of broad sizes width and height and flow conditions (low, medium, high).

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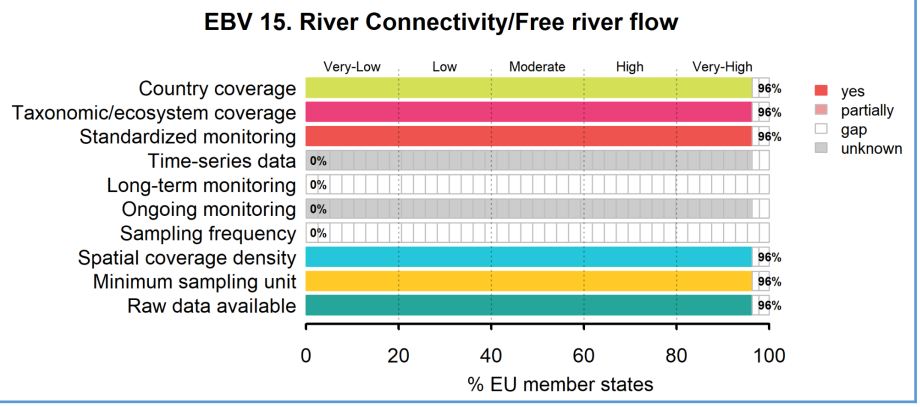
Standardized monitoring **Very-High [96% EU-MS]**	The monitoring is based on a standardized protocol clearly defined and described in https://amber.international/amber-field-manual/.
Time-series **Very-Low [0% EU-MS]**	Unknown time-series
Long term monitoring **Very-Low [0% EU-MS]**	Monitoring started in 2017
Ongoing monitoring **Very-Low [0% EU-MS]**	Unknown ongoing monitoring
Sampling frequency **Very-Low [0% EU-MS]**	Unknown sampling frequency.
Spatial Coverage Density **Very-High [96% EU-MS]**	Adequate spatial coverage density (https://amber.international/european-barrier-atlas/)
Minimum sampling unit **Very-High [96% EU-MS]**	Exact location.
Raw data access **Very-High [96% EU-MS]**	Data is open and freely available in the initiative website.
Monitoring gaps	
Figure 15.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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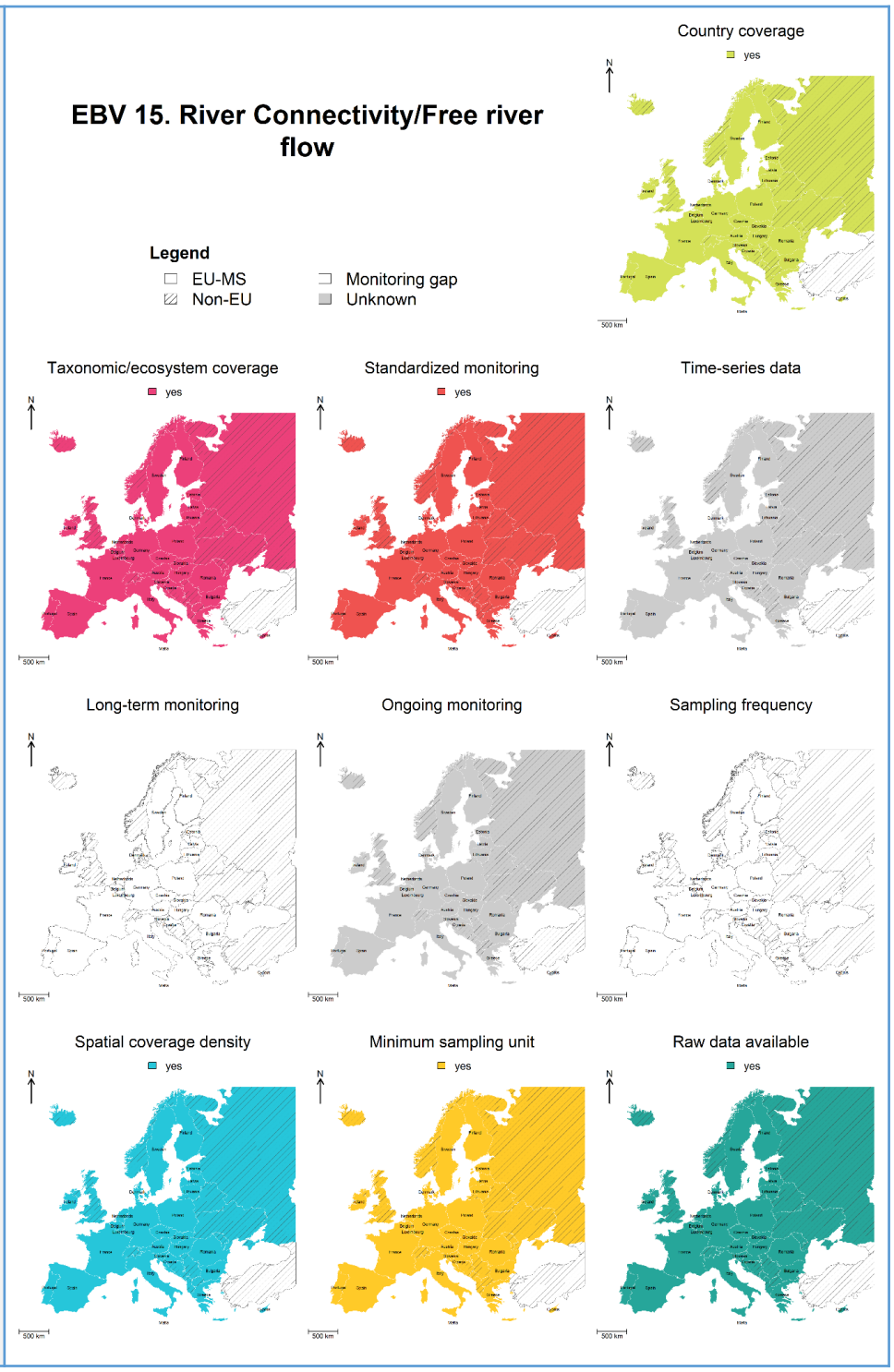

Figure 15.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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Ecosystem function

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Harmful freshwater algal blooms**
Summary	Cyanobacteria density in lakes are monitored by EU-MS to report phytoplankton water quality status to WFD (Water Framework Directive) and report Cyanobacteria biovolume to the Water Information System for Europe - Water Quality (WISE-6). There is no initiative integrating trans-national data on the location and intensity of algal blooms derived from satellite imagery (e.g. Copernicus Sentinel-3) able to produce the EBV at the European scale. Cyanobacteria monitoring (biovolume or % of total biovolume) in lakes is currently based on standardised protocols developed for the WFD using intercalibrated metrics among countries covering 85% of the EU-MS. Yet, because reporting is voluntary, only 5 countries report cyanobacteria biovolume to WISE-6. All countries reporting to WISE-2 have time-series data updated annually, and thus adequate to generate the EBV at the defined temporal resolution (1 year). Main gaps in the generation of the EBV "Harmful freshwater algal blooms" include reduced country coverage by WISE-6, lack of long-term data, insufficient sampling frequency and lack of data availability. Specifically, while 89% of the EU-MS monitor Cyanobacteria to assess phytoplankton status class under WFD, only 15% MS report Cyanobacteria biovolume to WISE-2. Long-term data is only available for 48% of the MS, thus reducing the ability of the EBV to establish reliable distribution trends in the short term. Finally, the current sampling frequency (annually) is adequate to produce the EBV at a 1-year temporal resolution to assess general status and trends, although it is not frequent enough to update the EBV onat a weekly-monthly basis during the growing season if needed to alert for public health risks. Cyanobacteria areis not reported as a separate metric to the WFD, but is part of the metrics used to assess lake phytoplankton status class.
EBV characteristics (target)	
ID	19
Realm	Freshwater
Class	Ecosystem function
Name	Harmful freshwater algal blooms
Step in identification process	User & Policy Needs Assessment
Definition	Distribution, intensity, frequency and position of harmful algal blooms in European lakes which occur when cyanobacteria accumulate in water, with the potential to harm the health of humans, livestock, and wild animals.
Metric	- Observed location and intensity of algal blooms as derived from satellite imagery (e.g. Copernicus Sentinel-3) or regulatory monitoring - Modeled cyanobacterial density based on hydrodynamic models and satellite imagery
Spatial resolution units	Lakes as delineated in ECRINS (European catchments and rivers network system)
Temporal resolution units	Real-time, weekly-monthly during the growing season
Taxonomic/ ecosystem focus group	ECRINS lakes
Current monitoring	

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Integration initiative **[WFD, WFD-WISE-6]**	- Regulatory monitoring of algal blooms (Cyanobacteria) is made as part of WFD (Water Framework Directive) lake phytoplankton monitoring to assess phytoplankton status class. Cyanobacteria biovolume (in mg L-1 or mm3 L-1) or the % of total biovolume in lakes are reported to the Water Information System for Europe - Water Quality (WISE-6, https://water.europa.eu/freshwater https://cdr.eionet.europa.eu/help/WISE_SoE/wise6) - an ongoing European monitoring scheme established by the European Environment Agency (EEA) to obtain a harmonised flow of biology data from all EEA member states reported as Water Quality Ratios from all surface water categories; rivers, lakes, transitional and coastal waters. - Observed location and intensity of algal blooms derived from satellite imagery (e.g. Copernicus Sentinel-3) is possible, but public services are still under-development (this is an area "under development" for GEO AQuaWatch (https://www.geoaquawatch.org/) and the Copernicus Global Land Service (CGLS) for lake water quality Lake Water Quality | Copernicus Global Land Service) - Modelled cyanobacteria density in European lakes based on lake type, climate and water quality (total phosphorus) data is possible using published statistical models (Richardson et al., 2018). - Citizen science data are available in 5 countries in Europe (Belgium, Ireland, Netherlands, Norway and the UK) using the Bloomin' Algae app (https://www.ceh.ac.uk/our-science/projects/bloomin-algae). Data provide high spatial resolution (10-20 m) and potentially high frequency (daily data), but data are qualitative (presence/absence of blooms judged by experts on photographic evidence) and do not provide quantitative information on biovolume or % abundance. The data are viewable and raw data (location, date) can be made available in real-time through an API from iRecord (https://irecord.org.uk/bloomin-algae-app-summary) - Modelled cyanobacterial density based on hydrodynamic models, citizen science and satellite imagery is a possible future approach for high coverage and high-frequency data.
Country coverage **Very-High [85% EU-MS]**	25 countries reporting ecological quality status for the WFD based on freshwater phytoplankton monitoring in lakes (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_qeMonitoringResults/SWB_qeMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no): Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, and the United Kingdom. Only 5 countries report Cyanobacteria biovolume to WISE-6: Denmark, Estonia, Finland, Lithuania and Norway.
Taxonomic/ Ecosystem coverage **Very-High [85% EU-MS]**	Monitoring covers Cyanobacteria in lakes.
Standardized monitoring **Very-High [85% EU-MS]**	Algae blooms monitoring (Cyanobacteria) is made as part of WFD lake phytoplankton monitoring. Monitoring data on Cyanobacteria are sampled using intercalibrated metrics that include biovolume (in mg L-1 or mm3 L-1) or the % of total biovolume. Data is collected at the level of the monitoring site or water body within monitoring programs defined under the Water Framework Directive (WFD). Whenever possible, the countries should use WFD monitoring sites and WFD water bodies. The use of EIONET monitoring sites and EIONET water bodies should be restricted to exceptional situations: small water bodies that are not WFD waterbodies (https://dd.eionet.europa.eu/datasets/latest/WISE-SoE_Biology).

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Time-series **Very-High [85% EU-MS]**	Cyanobacteria are monitored using intercalibrated metrics since 1990.
Long-term monitoring **Moderate [48% EU-MS]**	Long term monitoring exists at least for all countries reporting to WISE-6.
Ongoing monitoring **Very-High [85% EU-MS]**	Monitoring is expected to be ongoing in all countries reporting to WFD. Yet, Denmark and Estonia stopped reporting Cyanobacteria biovolume to WISE-6 in 2012.
Sampling frequency **Very-Low [0% EU-MS]**	**Annually.** Sampling sites are monitored annually. Cyanobacteria biovolume in lakes are reported annually to WISE-6. Regulatory monitoring for WFD is currently available monthly for summer months (July to September) for one or two years every six years. Current sampling frequency (annually) is not enough to update the EBV at real-time and at a weekly-monthly basis during the growing season. Near real-time or weekly monitoring may become available in future years through satellite EO (CGLS) and citizen science.
Spatial Coverage Density **Very-High [81% EU-MS]**	WFD identifies 7,747 sites for phytoplankton monitoring in lakes, and 30% are actually monitored. The proportion of monitored sites differs among countries but was >20% in all countries except Sweden (https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_geMonitoringResults/SWB_geMonitoringResults?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no). From the WFD monitored water bodies, 304 reports of cyanobacteria biovolumes to WISE-6.
Minimum sampling unit **Very-High [85% EU-MS]**	Cyanobacteria biovolume or % of total biovolume at exact locations. Norway: 0.2x0.2 km grid cells. Monitoring data is linked to a monitoring site or to a water body (for data aggregated by water body), using a unique identifier. The location, identification and characteristics of the spatial objects are provided via the WISE Spatial data flow. If a monitoring site or water body is reported also under the WFD, then the WFD identifiers are used as the unique identifier.
Raw data access **Very-Low [15% EU-MS]**	Cyanobacteria biovolume is available upon request for all the countries reporting for WISE-6. Cyanobacteria is not reported as a separate metric to the WFD, but is part of the metrics used to assess lake phytoplankton status class.
Monitoring gaps	

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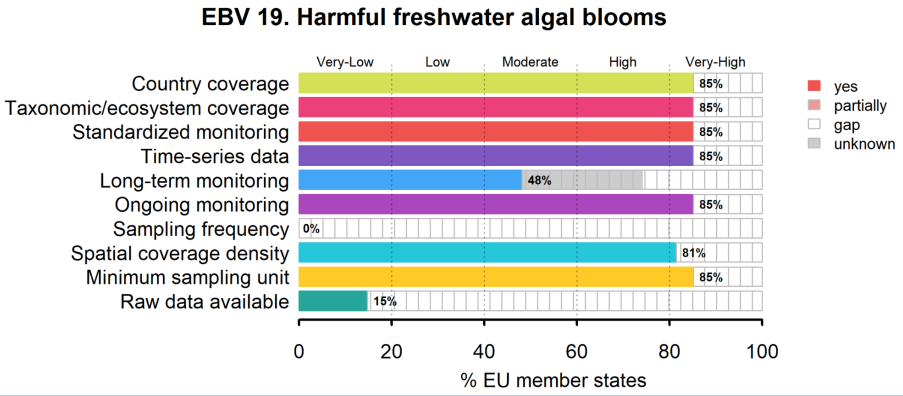
Figure 19.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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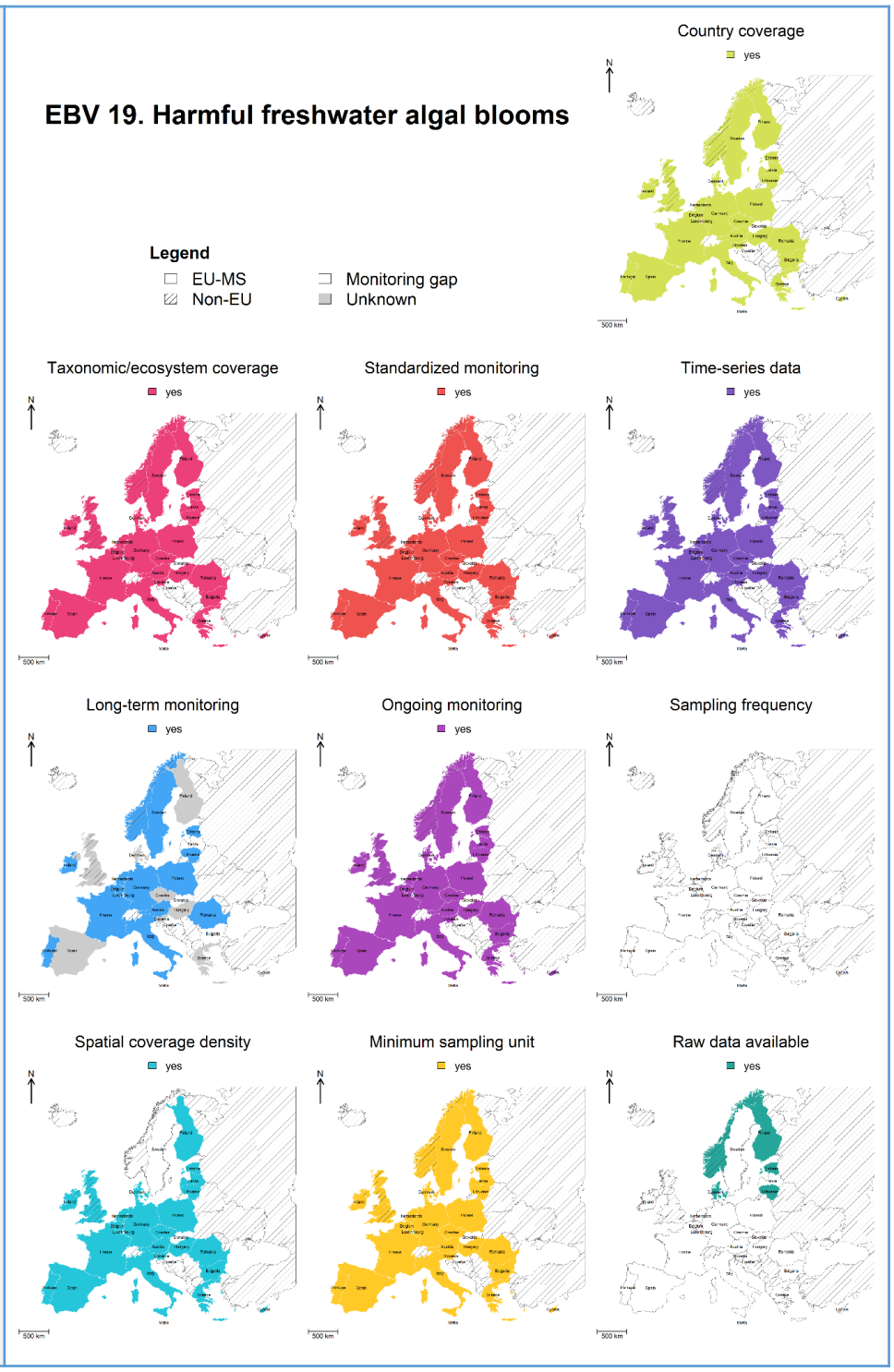

Figure 19.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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APPENDIX III. Factsheets describing monitoring gaps for Marine EBVs

Genetic composition

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Genetic diversity of selected marine taxa**
Summary	There is no a European initiative integrating national data on genetic diversity of marine taxa able to produce the EBV "Genetic diversity of selected marine taxa" at the European scale.
EBV characteristics (target)	
ID	42c
Realm	Terrestrial
Class	Genetic composition
Name	Genetic diversity of selected marine taxa
Step in identification process	Internal review process
Definition	Genetic richness (number of alleles in a population) and genetic evenness (expected proportion of heterozygotes in a population at equilibrium) of taxa.
Metric	- Allelic richness - Nucleotide diversity (π) - He = expected heterozygosity under Hardy–Weinberg assumptions - HO = observed heterozygosity (probability of randomly drawing two different alleles from the population)
Spatial resolution units	Sample sites (populations) across the geographic range of selected taxa
Temporal resolution units	10 years
Taxonomic/ ecosystem focus group	Selected species of birds, mammals, reptiles, amphibians or other taxonomic groups which are categorized as threatened by the European Red List.
Current monitoring	
Integration initiative	There is not a European initiative integrating national data on genetic diversity of marine taxa able to produce the EBV "Genetic diversity of selected marine taxa" at the European scale.

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Species populations

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of marine fishes**
Summary	Monitoring data on species distributions of marine fishes in EU's marine waters is integrated by a few regional monitoring schemes (e.g. ICES and OSPAR Trawling surveys) covering the North and Northeast Atlantic, the Norwegian Sea, the North See, the Baltic Sea, Mid-Atlantic Ridge, and the Skagerrak, and involving at least 9 European countries. In addition, there are a number of national and sub-national level ongoing monitoring programs running by 17 European countries, collecting marine fishes data in their coastal and transitional waters and the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subareas 6 and 7, parts of the Mediterranean Sea. Many os these programs have their data stored in online databases such as DATRAS and the European Marine Observation and Data Network (EMODnet) with access to standard data products. Main gaps in the regeneration of the EBV "Species distributions of marine fishes" include the lack of a European initiative integrating monitoring data on marine fishes and unknown spatial resolution, and lack of data acess. There is a huge uncertain on whether the spatial coverage density and minimum sampling unit are adequate to provide the EBV at the desired spatial resolution across the EU's marine waters.
EBV characteristics (target)	
ID	23
Realm	Marine
Class	Species populations
Name	Species distributions of marine fishes
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of European marine fish species in EU's marine waters within contiguous spatial units (grid cells) over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	50x50km - 200x200km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Marine fish species indicated in the Review and analysis of Member States' 2018 reports Descriptor 1: Species biological diversity
Current monitoring	
Integration initiative **[DATRAS (ICES) and others]**	There is not a European initiative integrating monitoring data on marine fishes able to produce the EBV "Species distributions of marine fishes" in EU's marine waters. However, there are a number of **regional monitoring schemes** (e.g. the International Council for the Exploitation of the Sea (ICES) trawling surveys) covering the North and Northeast Atlantic, the Norwegian Sea, the North See, the Baltic Sea, Mid-Atlantic Ridge, and the Skagerrak, and involving at least 9 European countries. In addition, there are a number of **national and sub-national** level ongoing monitoring programs running by 17 European countries, collecting marine fishes data in their coastal and transitional waters and the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subareas 6 and 7, parts of the Mediterranean Sea. Many os these programs have their data stored in online databases such as **DATRAS** and the European Marine Observation and Data Network (**EMODnet**) with access to standard data products. See MarBioMe

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	marine biodiversity monitoring database for details on monitoring schemes covering marine fishes (Jessop et al. 2022).
Country coverage **Very-High [86% EU-MS]**	Regional monitoring schemes involving at least 8 European countries: France, Iceland, Ireland, Norway, Portugal, Spain, Sweden, United Kingdom. National monitoring programes running by at least 17 European countries: Albania, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, Germany, Italy, Latvia, Lithuania, Netherlands, Poland, Russia, Slovenia, Ukraine, covering, among others, the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subareas 6 and 7, parts of the Mediterranean Sea, coastal and transitional areas of the covered countries.
Taxonomic/ Ecosystem coverage **Low [0% EU-MS]**	All fish species are expected to be recorded in each monitoring program, although many programs are mostly directed to commercial species (**partial gap**).
Standardized monitoring **Very-High [86% EU-MS]**	Monitoring is mostly based on a monitoring protocols.
Time-series **High [77% EU-MS]**	Time-series [early 90's-onwards] Most countries have time-series data [early 90's-onwards] . Unknown time series data for Albania, Iceland, Poland, Slovenia and Ukraine.
Long term monitoring **High [77% EU-MS]**	Most countries have data with more that 10 years [early 90's-onwards] Unknown monitoring starting date for Albania, Croatia, Iceland and Spain.
Ongoing monitoring **Very-High [86% EU-MS]**	All countries have ongoing monitoring programs.
Sampling frequency **High [77% EU-MS]**	The sampling frequency is likely to be adequate to provide the EBV at the desired temporal resolution for most countries except Norway. Unknown sampling frequency for Albania, Iceland, Poland, Slovenia and Ukraine.
Spatial Coverage Density **Low [0% EU-MS]**	It is unknown whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution in the EU's marine waters.
Minimum sampling unit **Moderate [50% EU-MS]**	Exact location or Unknown. The minimum sampling unit is likely to be adequate to provide the EBV at the desired spatial resolution in the EU's marine waters for part of countries.
Raw data access **High [68% EU-MS]**	Most programs have their data stored in online databases such as DATRAS and the European Marine Observation and Data Network (EMODnet) with access to standard data products. EMODnet only provides access to occurrence data. Raw data is partially available for Ukraine. Unknown data availability for Albania, Croatia, Cyprus, Georgia, Iceland, Poland, Turkey.
Monitoring gaps	

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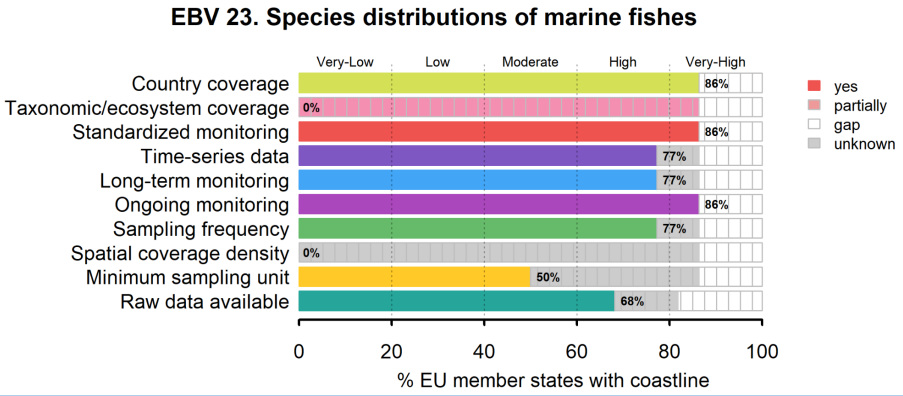
Figure 23.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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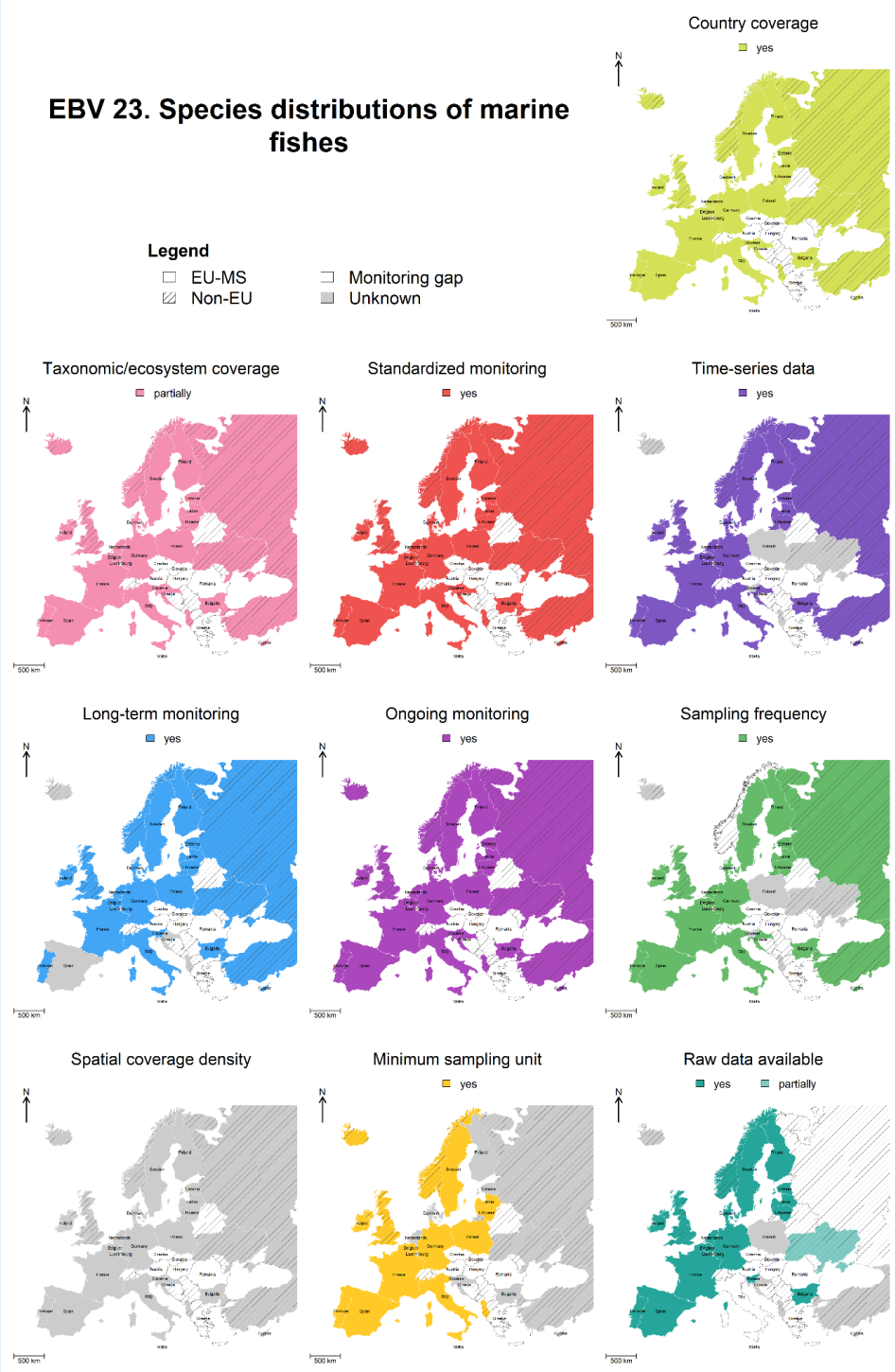

Figure 23.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

REFERENCES

Jessop, A., Chow, C., Dornelas, M., Pereira, P., Sousa-Pinto, I., Hernández Chan, S., Junker, J., Soares, J., Ratnarajah, L., Fernández, M., Mendo, T. (2022). MarBioME. Overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters. European Commission. Directorate General for Research and Innovation.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of marine commercial fish species and long-distance migratory fishes**
Summary	Monitoring data on species abundances of marine commercial fish species and long-distance migratory fishes in EU's marine waters is integrated by a few regional monitoring schemes (e.g. ICES and OSPAR Trawling surveys) covering the North and Northeast Atlantic, the Norwegian Sea, the North See, the Baltic Sea, Mid-Atlantic Ridge, and the Skagerrak, and involving at least 9 European countries. In addition, there are a number of national and sub-national level ongoing monitoring programs running by 16 European countries, collecting marine fishes data in their coastal and transitional waters and the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subareas 6 and 7, parts of the Mediterranean Sea. Many os these programs have their data stored in online databases such as DATRAS and the European Marine Observation and Data Network (EMODnet) with access to standard data products. Main gaps in the regeneration of the EBV "Species abundances of marine commercial fish species and long-distance migratory fishes" include the lack of a European initiative integrating monitoring data on marine fishes and unknown spatial resolution, and lack of data acess. There is a huge uncertain on whether the spatial coverage density and minimum sampling unit are adequate to provide the EBV at the desired spatial resolution across the EU's marine waters.
EBV characteristics (target)	
ID	24
Realm	Marine
Class	Species populations
Name	Species abundances of marine commercial fish species and long-distance migratory fishes
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of commercially relevant marine fish species and long-distance migratory fishes in EU's marine waters within contiguous spatial units (grid cells) over time.
Metric	- Estimated count of individuals - Modeled relative abundance
Spatial resolution units	50x50km - 200x200km
Temporal resolution units	1 year
Taxonomic/ ecosystem focus group	Commercial marine fish species listed in the Common Fisheries Policy.
Current monitoring	
Integration initiative **[DATRAS (ICES) and others]**	There is not a European initiative integrating monitoring data on marine fishes able to produce the EBV "Species distributions of marine fishes" in EU's marine waters. However, there are a number of **regional monitoring schemes** (e.g. the International Council for the Exploitation of the Sea (ICES) trawling surveys) covering the North and Northeast Atlantic, the Norwegian Sea, the North See, the Baltic Sea, Mid-Atlantic Ridge, and the Skagerrak, and involving at least 9 European countries. In addition, there are a number of **national and sub-national** level ongoing monitoring programs running by 16 European countries, collecting marine fishes data in their coastal and transitional waters and the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES

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	Subareas 6 and 7, parts of the Mediterranean Sea. Many os these programs have their data stored in online databases such as **DATRAS** and the European Marine Observation and Data Network (**EMODnet**) with access to standard data products. See MarBioMe marine biodiversity monitoring database for details on monitoring schemes covering marine fishes (Jessop et al. 2022).
Country coverage **Very-High [86% EU-MS]**	Regional monitoring schemes involving at least 8 European countries: France, Iceland, Ireland, Norway, Portugal, Spain, Sweden, United Kingdom. National Subnational monitoring programes running by at least 16 European countries: Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, Germany, Italy, Latvia, Lithuania, Netherlands, Poland, Russia, Slovenia, Ukraine, covering, among others, the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subareas 6 and 7, parts of the Mediterranean Sea, coastal and transitional areas of the covered countries.
Taxonomic/ Ecosystem coverage **Very-High [86% EU-MS]**	All commercial marine fish species are expected to be recorded particularly because many programs are mostly directed to commercial species.
Standardized monitoring **Very-High [86% EU-MS]**	Monitoring is mostly based on standardized monitoring protocols.
Time-series **High [77% EU-MS]**	Time series [early 90's-onwards] Most countries have time series data [early 90's-onwards] . Unknown time series data for Albania, Iceland, Poland, Slovenia and Ukraine.
Long term monitoring **High [77% EU-MS]**	Most countries have data with more that 10 years [early 90's-onwards] Unknown monitoring starting date for Albania, Croatia, Iceland and Spain.
Ongoing monitoring **Very-High [86% EU-MS]**	All countries have ongoing monitoring programs.
Sampling frequency **High [77% EU-MS]**	The sampling frequency is likely to be adequate to provide the EBV at the desired temporal resolution for most countries except Norway. Unknown sampling frequency for Albania, Iceland, Poland, Slovenia and Ukraine.
Spatial Coverage Density **Low [0% EU-MS]**	It is unknown whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution in the EU's marine waters.
Minimum sampling unit **Moderate [50% EU-MS]**	Exact location or Unknown. The minimum sampling unit is likely to be adequate to provide the EBV at the desired spatial resolution in the EU's marine waters for part of countries.
Raw data access **Moderate [68% EU-MS]**	Most programs have their data stored in online databases such as DATRAS and the European Marine Observation and Data Network (EMODnet) with access to standard data products. EMODnet only provides access to occurrence data. Raw data is partially available for Ukraine. Unknown data availability for Albania, Croatia, Cyprus, Georgia, Iceland, Poland, Turkey.
Monitoring gaps	

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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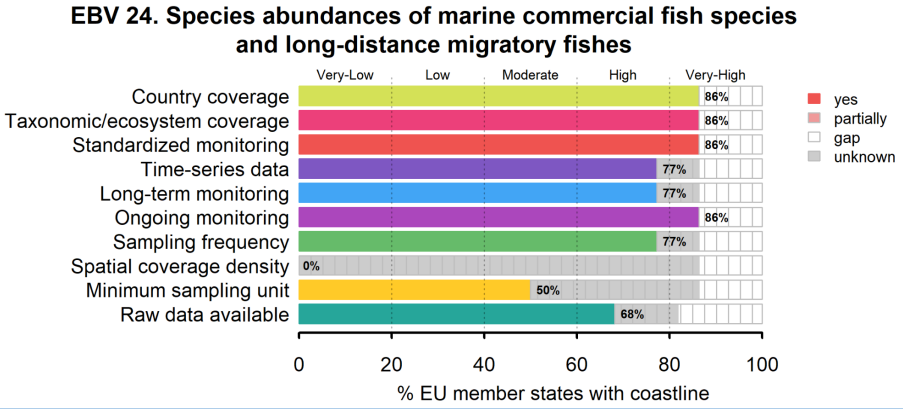
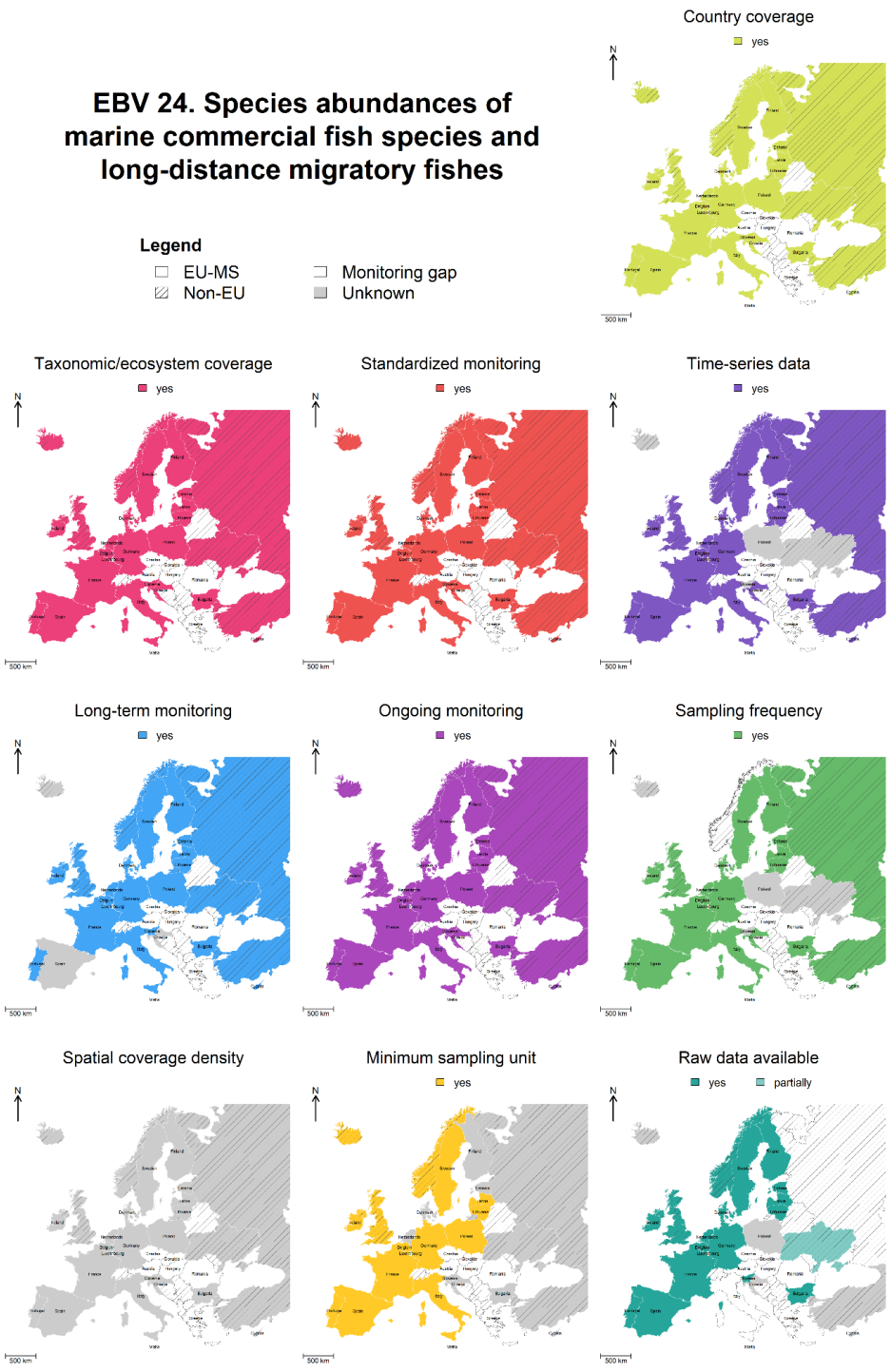
Figure 24.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

Figure 24.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.



REFERENCES

Jessop, A., Chow, C., Dornelas, M., Pereira, P., Sousa-Pinto, I., Hernández Chan, S., Junker, J., Soares, J., Ratnarajah, L., Fernández, M., Mendo, T. (2022). MarBioME. Overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters. European Commission. Directorate General for Research and Innovation.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

EUROPABON

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of marine birds**
Summary	Monitoring data on species distributions of marine birds across Europe is integrated by a Pan-European monitoring initiative (**EBBA2**) and at least four regional monitoring schemes **(ESAS, HELCOM-OSPAR, Baltic seabirds transects survey, OBIS)** covering the North Sea, W Mediterranean coast and Baltic Sea and the NE Atlantic, and involving at least 29 European countries. Monitoring is mostly based on standardized monitoring protocols collecting data since late 70's-onwards. Most countries have data with more that 10 years [late 70's-onwards]. All countries covered by SEA, OSPAR-HELCOM and ICES have ongoing monitoring. The sampling frequency is likely to be adequate to provide the EBV at the desired temporal resolution for most countries. While the minimum sampling unit is likely to be adequate to provide the EBV at the desired spatial resolution, it is unknown whether the spatial coverage density sufficient. Raw data mostly stored in online databases such as ICES and the EMODnet with access to standard data products. Main gaps in the regeneration of the EBV "Species distributions of marine birds" include the lack of a European initiative integrating monitoring data on marine birds and spatial coverage density. There is a huge uncertain on whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution.
EBV characteristics (target)	
ID	25
Realm	Marine
Class	Species populations
Name	Species distributions of marine birds
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of European marine bird species at their breeding sites over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Marine bird species indicated in the Review and analysis of Member States' 2018 reports Descriptor 1: Species biological diversity
Current monitoring	
Integration initiative **[EBBA2, ESAS and others]**	There is no single European initiative integrating monitoring data on marine fishes able to produce the EBV "Species distributions of marine birds" in their European breeding sites. However, data of marine bird species have been collected by a Pan-European monitoring initiative (**EBBA2**) and at least four regional monitoring schemes **(ESAS, HELCOM-OSPAR, Baltic seabirds transects survey, OBIS).** **EBBA2 (Pan-European not ongoing snapshot).** The second European Breeding Bird Atlas (EBBA2, Keller (2020), https://ebba2.info/) is the most recent and comprehensive European integration initiative mapping the species distributions of all European birds. EBBA2 was carried out by the EBCC network of partner organisations located in 48 countries. The main fieldwork period lasted five years, from 2013 to 2017, covering all bird species reported to breed in the study period 2013–2017.

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	EBBA2 outputs include 50x50 km maps (usually showing abundance data) for 556 bird species, including **63** marine and coastal species in their land nesting places. **ESAS (North Sea, NE Atlantic ongoing time series).** European Seabirds At Sea (ESAS, (https://www.ices.dk/data/data-portals/Pages/European-Seabirds-at-sea.aspx) assembles offshore monitoring data on seabirds and marine mammals. This international database mostly includes data from the North Sea, yet large parts of the NE Atlantic Ocean are covered as well. It finds its origin in the 'Seabirds At Sea' project, which was initiated in 1979. This led to the execution of large-scale ship-based surveys across the North Sea using a standardized data collection method and a first European-wide data assembly in 1991. ESAS data are collected by various partners during aerial or ship-based surveys at sea and according to a methodology that allows to calculate georeferenced seabird densities. Standard practice further implies collecting as much information as possible on animal age, plumage and behaviour as well as observation conditions and distance to the observed individuals. As part of the WOZEP research project, ESAS data were migrated in 2022 from its former host JNCC (UK) to ICES. The ICES infrastructure allows partners to submit new data and users to download or request data. There is currently a joint working group on Marine Birds between OSPAR-HELCOM and ICES (https://www.ices.dk/about-ICES/Documents/Resolutions/Science%20EG%20ToRs/EPDSG/2021/JWGBIRD%20ToRs%202021%E2%80%932023.pdf), to enable long-term planning and delivery of significant products across NE Atlantic (**ICES, OSPAR Marine Bird Program** (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-birds/bird-abundance/) and Baltic Sea (**HELCOM**, time series Nest counts of 6 breeding bird species). **Other regional initiatives include:** **Baltic seabirds transect surveys (Baltic Sea not ongoing time series).** Seabirds transect surveys were annually conducted in Baltic Sea over seven years (1992-1999) in the Baltic Sea (https://seamap.env.duke.edu/dataset/358/html). Flying birds along 1000 m wide transect over 300 m transects were recorded to estimate seabird densities during snapshots (unit of abundance = IndCountInt). **OBIS (Western Mediterranean coast not ongoing time series).** Replicate springtime (May - June) vessel-based surveys in the western Mediterranean during standardized trawl surveys of the Spanish continental shelf and slope over three years (1999, 2000, 2002). The initiative provides broad-scale information on seabird distributions in the Mediterranean coast from the **Strait of Gibraltar to Cape Creus.** A 300 m strip-width transect band was used, counting at both sides of the vessel (i.e., surveying a 600 m band) when the conditions (light and wind) were appropriate. Snapshot counts for flying birds were used. All birds observed during the surveys were recorded and aggregated into 10-minute bins.
Country coverage **Very-High [91% EU-MS]**	There are 29 European countries with distribution data on marine and coastal birds: Albania, Belgium, Bosnia and Herzegovina, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Russia, Slovenia, Spain, Sweden, Turkey, United Kingdom, covering the North Sea, W Mediterranean coast and Baltic Sea and the NE Atlantic

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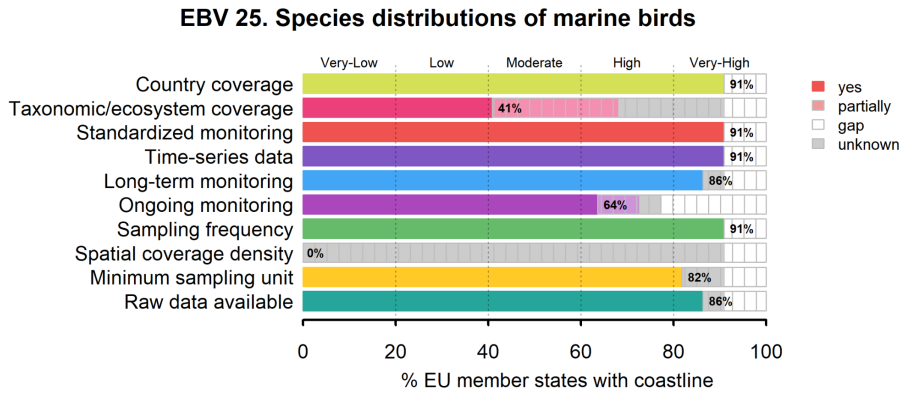
Taxonomic/ Ecosystem coverage **Moderate [41% EU-MS]**	All bird species are expected to be recorded in each monitoring site, except HELCOM monitoring programm that only collects data for 6 species.
Standardized monitoring **Very-High [91% EU-MS]**	Monitoring is mostly based on standardized monitoring protocols.
Time-series **Very-High [91% EU-MS]**	All countries have time series data [late 70's-onwards].
Long term monitoring **Very-High [86% EU-MS]**	Most countries have data with more that 10 years [late 70's-onwards] Unknown monitoring starting date for Iceland, Norway, and Sweden.
Ongoing monitoring **High [64% EU-MS]**	All countries covered by the European Seabirds At Sea and OSPAR-HELCOM and ICES working group have ongoing monitoring.
Sampling frequency **Very-High [91% EU-MS]**	The sampling frequency is likely to be adequate to provide the EBV at the desired temporal resolution for most countries. Unknown sampling frequency for Albania, Belgium, Iceland, Ireland, Netherlands and Norway.
Spatial Coverage Density **Low [0% EU-MS]**	It is unknown whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution.
Minimum sampling unit **Very-High [82% EU-MS]**	Exact location. The minimum sampling unit is likely to be adequate to provide the EBV at the desired spatial resolution.
Raw data access **Very-High [86% EU-MS]**	Raw data is made available for most of the countries. For example, ESA has datasets from: Belgium, Germany, Denmark, United Kingdom, Irland, Netherlands, Portugal available online (https://www.ices.dk/data/data-portals/Pages/European-Seabirds-at-sea.aspx)
Monitoring gaps	
Figure 25.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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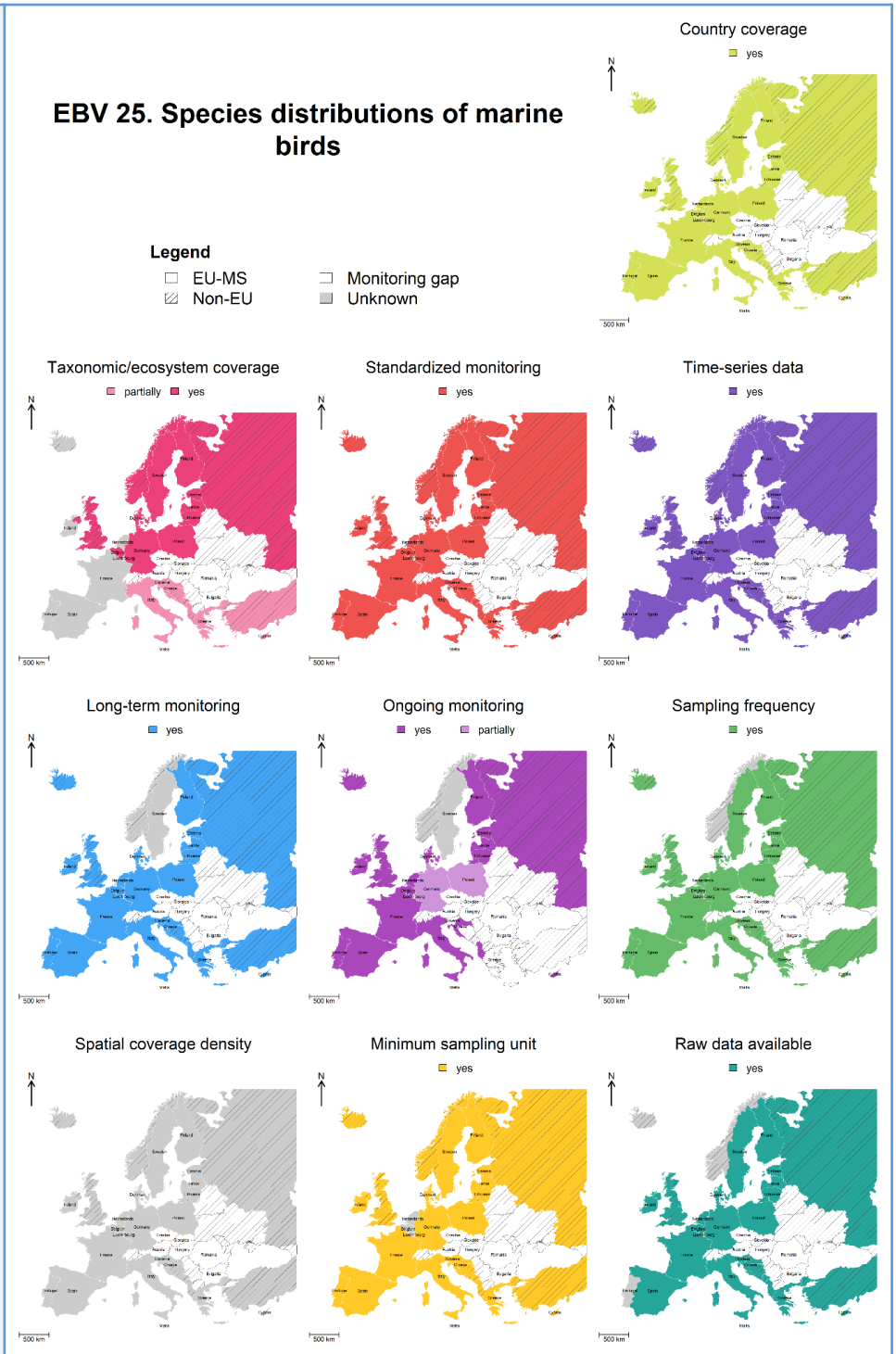

Figure 25.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

REFERENCES

Zydelis, R. 2006. Baltic Seabirds Transect Surveys.

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography. 22(2):104-115.

Jessop, A., Chow, C., Dornelas, M., Pereira, P., Sousa-Pinto, I., Hernández Chan, S., Junker, J., Soares, J., Ratnarajah, L., Fernández, M., Mendo, T. (2022). MarBioME. Overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters. European Commission. Directorate General for Research and Innovation.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of marine mammals**
Summary	Monitoring data on species distributions of marine mammals in EU's marine waters is integrated by at least three regional monitoring schemes: the Harbour porpoise, HELCOM - Seal abundance, and NASS altogether covering all mammal species and all marine regions. In addition there are other regional monitoring snapshots (>10 years frequency) that can provide valuable long-term data when combined with ongoing schemes to provide timely species distribution of European mammal species. These are SCANS and CODA - Ship and aircraft surveys. Raw data mostly stored in online databases such as ICES, HELCOM and the EMODnet with access to standard data products. Main gaps in the regeneration of the EBV "Species distributions of marine birds" include the lack of a European initiative integrating monitoring data on marine birds and spatial coverage density. There is a huge uncertain on whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution.
EBV characteristics (target)	
ID	26
Realm	Marine
Class	Species populations
Name	Species distributions of marine mammals
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence (or probability of occurrence) of European marine mammal species within contiguous spatial units (grid cells) in EU's marine waters over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Marine mammal species indicated in the Review and analysis of Member States' 2018 reports Descriptor 1: Species biological diversity
Current monitoring	
Integration initiative **[HELCOM and others]**	There is not a single integration initiative able to produce the EBV at the European level. Instead, the integration of marine monitoring schemes is currently done at regional level by three initiatives: the **Harbour porpoise**, **HELCOM - Seal abundance**, and **NASS** altogether covering all mammal species and all marine regions. Harbour porpoise in an iniciative targueting Harbour porpoise monitoring in the Baltic Proper, Baltic Sea and Belt Sea. HELCOM - Seal abundance: an iniciative targueting Harbour porpoise monitoring in the Baltic Proper, Baltic Sea and Belt Sea. NASS in an ongoing long-term monitoring scheme based in standartized monitoring with repteated measures every **3-6 years** covering all mammal species in North Atlantic Ocean. In addition there are other regional monitoring **snapshots (>10 years frequency)** that can provide valuable long-term data when combined with ongoing schemes to provide timely species distribution of European mammals species. These are **SCANS** and **CODA** - Ship and aircraft surveys developed by the University of University of St. Andrews (https://scans3.wp.st-andrews.ac.uk/background/). A series of large scale surveys for cetaceans in European Atlantic waters was initiated in 1994 (SCANS; Hammond et al.

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	2002) and continued in 2005 (SCANS-II; Hammond et al. 2013) and 2007 (CODA 2009). The third such survey, SCANS-III, took place in 2016. **SCANS - Ship and aircraft surveys.** Small Cetaceans in European **Atlantic** waters and the North Sea (SCANS) **(https://scans3.wp.st-andrews.ac.uk/survey-blocks/).** The survey area was divided into blocks and increased in every survey, starting in the area of the **North Atlantic delimited by the Celtic Sea and the Shetland Islands** (SCANS 1994) and ending covering the whole European Atlantic continental shelf, from **Portugal to Scandinavia** (SCANS-III 2016). The methodology consisted in ships and aircraft transect surveys carried out in summer. Each ship/aircraft included two surveyor teams, one at each side of the ship/aircraft. For the ships surveys, distance and angle was recorded for every sighting to allow corrections for detectability. **CODA - Ship and aircraft surveys.** The methodology consisted in ships transect surveys carried out in summer with two surveyors teams, one at each side of the ship/aircraft. The shipboard surveys for data collection were planned for July 2007 to coincide seasonally with SCANS-II. Visual and acoustic methods were used onboard four 1 ships. The survey area was divided into four survey blocks and transects designed to ensure equal coverage probability using program DISTANCE. State-of-the-art methods for conducting visual surveys of cetaceans from ships had been developed and employed during the SCANS-II project (SCANS-II, 2008). These methods were used and further enhanced for the CODA surveys. The approach adopted was a double platform survey with two teams of observers on each ship to allow generation of abundance estimates that are corrected for animals missed on the transect line and also for the effects of movement of animals in response to the approaching ship.
Country coverage **High [64% EU-MS]**	**Harbour porpoise:** Baltic Proper, Baltic Sea & Belt Sea **HELCOM - Seal abundance:** Belt Sea **NASS:** North Atlantic Ocean. **SCANS and CODA Ship and aircraft surveys**: North Atlantic delimited by the Celtic Sea and the Shetland Islands; European Atlantic continental shelf, from Portugal to Scandinavia. Geographic Gap in Mediterranean Sea.
Taxonomic/ Ecosystem coverage **Moderate [45% EU-MS]**	All mammal species are monitored by the **NASS, SCANS** and **CODA** - Ship and aircraft surveys. Harbour porpoise and HELCOM - Seal abundance are target monitoring scheems.
Standardized monitoring **High [64% EU-MS]**	All monitoring scheems but HELCOM - Grey Seal are based on standartized protocols.
Time-series **Low [27% EU-MS]**	**SCANS** and **CODA** - Ship and aircraft surveys are one-off monitoring scheme.
Long term monitoring **Moderate [59% EU-MS]**	Long-term monitoring data is available for most of the covered countries.
Ongoing monitoring **Low [0% EU-MS]**	Monitoring is expected to be ongoing in most countries.
Sampling frequency **Low [23% EU-MS]**	Anually - >10years **SCANS** and **CODA** Ship and aircraft surveys: >10 years NASS: every **3-6 years**
Spatial Coverage Density **High [64% EU-MS]**	Unknown

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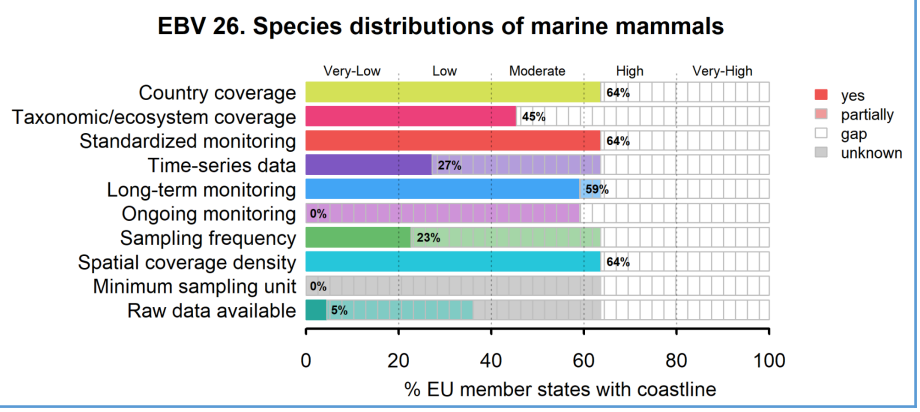
Minimum sampling unit **Low [0% EU-MS]**	Unknown
Raw data access **Low [5% EU-MS]**	Data is integrated and stored in several databases such as EMODnet, ICES, HELCOM, OSPAR and National repositories.
Monitoring gaps	
Figure 26.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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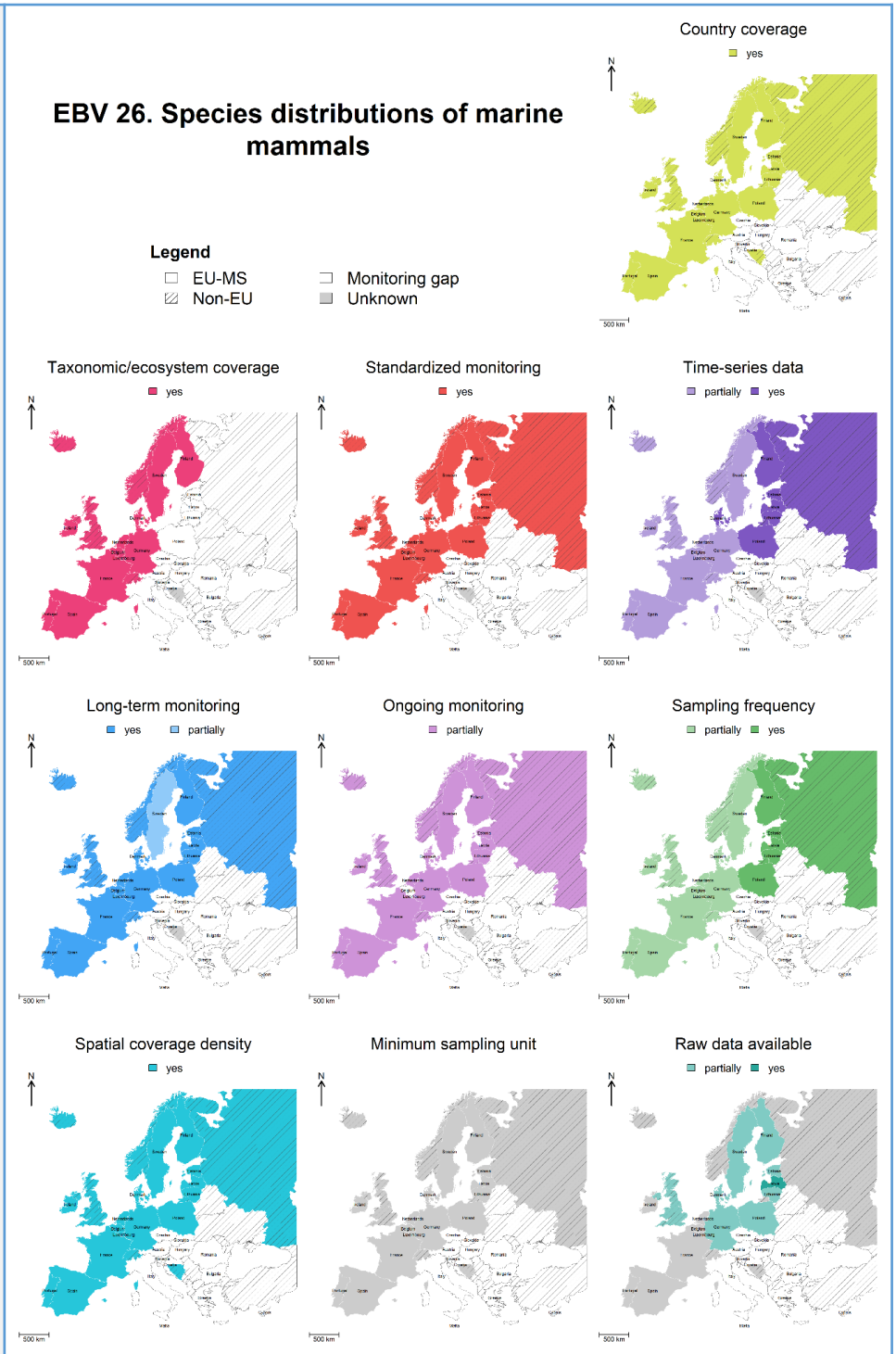

Figure 26.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Distributions of marine turtle species nesting grounds**
Summary	There is not a European initiative integrating monitoring data on marine turtles able to produce the EBV "Distributions of marine turtle species nesting grounds" in EU's coastline. However, there is one regional monitoring scheme (The Fixed Line Transect Mediterranean monitoring Network (FLT Med Net) using standardized protocols to monitor one of the target species (*Caretta caretta*) in the Mediterranean Sea, involving four European countries. In addition, there are a number of national and sub-national level ongoing monitoring programs running by eleven European countries, collecting long term data on marine turtles across the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subarea7, parts of the Mediterranean Sea, Channel Islands, Cyprus, United Kingdom and Ireland coasts. Main gaps in the regeneration of the EBV "Distributions of marine turtle species nesting grounds" include the lack of a European initiative integrating monitoring data on marine turtles and reduced country coverage. From the existing monitoring schemes, most are not targeted on turtles and there is a huge uncertain arround the covered species, whether the spatial coverage density and minimum sampling unit are adequate to provide the EBV at the desired spatial resolution across the EU countries, and in regard to the sampling frequency. Raw data is available in some cases but not all.
EBV characteristics (target)	
ID	27
Realm	Marine
Class	Species populations
Name	Distributions of marine turtle species nesting grounds
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of marine turtle species nesting grounds in EU's coastline over time
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Turtle species indicated in the Habitats Directive and the Review and analysis of Member States' 2018 reports Descriptor 1: Species biological diversity: *Caretta caretta* (Loggerhead turtle), *Chelonia mydas* (Green turtle), *Dermochelys coriacea* (Leatherback turtle), *Eretmochelys imbricata* (Hawksbill turtle), *Lepidochelys kempii* (Kemp's Ridley turtle)
Current monitoring	
Integration initiative **[FLT Med Net]**	There is not a European initiative integrating monitoring data on marine turtles able to produce the EBV "Distributions of marine turtle species nesting grounds" in EU's coastline. However, there is one regional monitoring scheme (The Fixed Line Transect Mediterranean monitoring Network (**FLT Med Net,** https://www.isprambiente.gov.it/en/activities/biodiversity/flt-mediterranean-monitoring-network-marine-species-and-threat) using standardized protocols to monitor one of the target species (*Careta careta*) in the Mediterranean Sea, involving four European countries (France, Greece, Italy and Spain). In addition, there are a number of national and sub-national level monitoring programs running by at least eleven

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	European countries, collecting turtle's distribution data across the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subarea7, parts of the Mediterranean Sea, Channel Islands, Cyprus coast, United Kingdom and Ireland coasts. See details in MarBioMe marine biodiversity monitoring database for details on monitoring schemes covering marine turtles (Jessop et al. 2022)
Country coverage **Low [36% EU-MS]**	**FLT Med Net:** France, Greece, Italy and Spain covering the Mediterranean Sea **National and Subnational monitoring programes** running by at least eleven European countries: Albania, Croatia, Cyprus, France, Greece, Ireland, Italy, Slovenia, Spain, Turkey, United Kingdom, covering the North East Atlantic (FAO 27), Northern Bay of Biscay, ICES Subarea7, parts of the Mediterranean Sea, Channel Islands, Cyprus coast, United Kingdom and Ireland coasts.
Taxonomic/ Ecosystem coverage **Very-Low [0% EU-MS]**	At least *Caretta caretta* is *monitored by* FLT Med Net but is unknown the taxonomic coverage of the other schemes.
Standardized monitoring **Very-Low [18% EU-MS]**	Monitoring under FLT Med Net is based on a monitoring protocol where the *Caretta caretta* is specifically identified (https://www.isprambiente.gov.it/en/activities/biodiversity/technical-annex-i_monitoring-protocol_dec2020-1.pdf). Standartized monitoring is unknown for the national an subnational level monitoring programs.
Time-series **Low [36% EU-MS]**	All programs have time series data.
Long term monitoring **Low [32% EU-MS]**	All programs have Long term data.
Ongoing monitoring **Low [36% EU-MS]**	All programs are ongoing.
Sampling frequency **Low [0% EU-MS]**	It is unknown whether the spatial coverage density is adequate to provide the EBV at the desired spatial resolution in the coastline EU countries.
Spatial Coverage Density **Low [0% EU-MS]**	It is unknown whether the minimum sampling unit is adequate to provide the EBV at the desired spatial resolution in the coastline EU countries
Minimum sampling unit **Low [0% EU-MS]**	It is unknown whether the sampling frequency is adequate to provide the EBV at the desired temporal resolution.
Raw data access **Very-Low [14% EU-MS]**	Raw data is partially available for Croatia, Cyprus, Italy, and United Kingdom monitoring programs, and partially available for Ireland monitoring programs. Unknown data availability for FLT Med Net; and Albania, Slovenia and Turkey monitoring programs.
Monitoring gaps	

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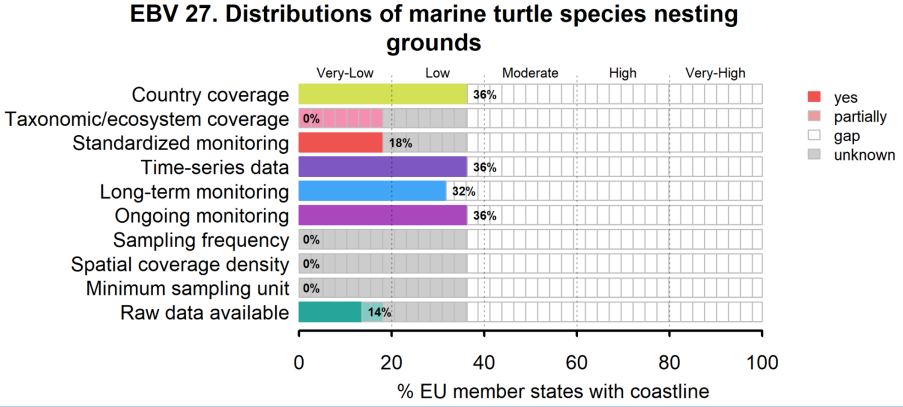
Figure 27.1 - Loading bars expressing the % of coastline member states that meet the criteria to estimate the EBV.



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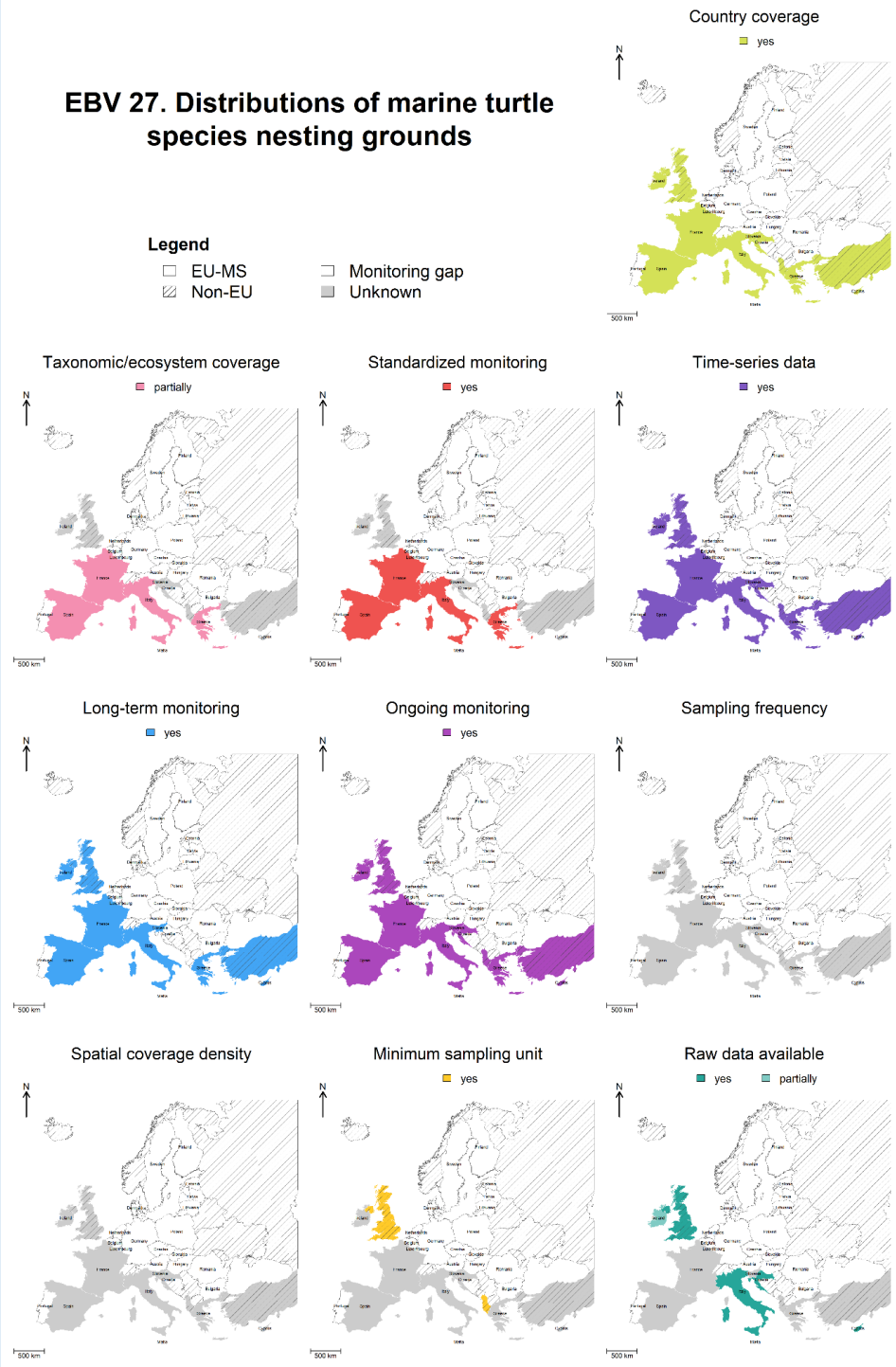

Figure 27.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

REFERENCES

Jessop, A., Chow, C., Dornelas, M., Pereira, P., Sousa-Pinto, I., Hernández Chan, S., Junker, J., Soares, J., Ratnarajah, L., Fernández, M., Mendo, T. (2022). MarBioME. Overview and assessment of the current state of Biodiversity Monitoring in the European Union and adjacent marine waters. European Commission. Directorate General for Research and Innovation.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of invasive alien marine taxa of European concern**
Summary	There is an initiative to collect and harmonise invasive alien species data across Europe, including marine species from Union Concern - **EASIN** (European Alien Species Information Network). EASIN facilitates the exploration of existing Alien Species information from a variety of sources through freely available tools and interoperable web services, compliant with internationally recognized standards. The EASIN GeoDatabase (v9.0- 19.07.22, https://easin.jrc.ec.europa.eu/easin/GeoDatabase) contains occurrence records for more than 14,000 species, across 40 different countries (https://easin.jrc.ec.europa.eu/easin/Catalogue), including 1,417 marine alien species, of which 3 are Invasive Alien Species of Union Concern over a small subset of the costal areas of Spain, France, United Kingdom, and Turkey. EASIN species mapping tool (https://easin.jrc.ec.europa.eu/spexplorer/search/) shows the distribution of species at the country level, or at 10x10 km grid cells. Data in the EASIN GeoDatabase can be easily accessed and downloaded from the website, while ownership of the data remains within its source, which is properly cited and linked. However, EASIN is not a monitoring network and its data come from a variety of sources, including standardized monitoring programs, occasional observations, data portals, and iterature review, making it difficult to collect the country-level information needed to identify monitoring gaps in the generation of the EBV "Species distributions of invasive alien marine taxa of European concern" at the European level. Information on monitoring gaps of invasive alien freshwater taxa of European concern to generate this EBV can be partially inferred from several monitoring initiatives covering different taxa and described in detail for other EBVs: “Species distributions of marine fishes”; “Species distributions of marine birds”; “Species distributions of marine mammals”; and “Distributions of marine turtle species nesting grounds”.
EBV characteristics (target)	
ID	29
Realm	Marine
Class	Species populations
Name	Species distributions of invasive alien marine taxa of European concern
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of invasive freshwater species (as specified in the Consolidated List of Invasive Alien Species of Union Concern) in EU's marine waters within contiguous spatial units (grid cells) over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Coastal marine taxa of invasive concern within 1-5 km from the shore.

This project receives funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003553.

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APPENDIX IV. Factsheets describing monitoring gaps for Terrestrial EBVs

Genetic composition

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Genetic diversity of selected terrestrial taxa**
Summary	There is no European initiative integrating national data on the genetic diversity of terrestrial taxa able to produce the EBV "Genetic diversity of selected terrestrial taxa" at the European scale.
EBV characteristics (target)	
ID	42a
Realm	Terrestrial
Class	Genetic composition
Name	Genetic diversity of selected terrestrial taxa
Step in identification process	Expert workshop
Definition	Genetic richness (number of alleles in a population) and genetic evenness (expected proportion of heterozygotes in a population at equilibrium) of taxa.
Metric	- Allelic richness - Nucleotide diversity (π) - He = expected heterozygosity under Hardy–Weinberg assumptions - HO = observed heterozygosity (probability of randomly drawing two different alleles from the population)
Spatial resolution units	Sample sites (populations) across the geographic range of selected taxa
Temporal resolution units	10 years
Taxonomic/ ecosystem focus group	Selected species of birds, mammals, reptiles, amphibians or other taxonomic groups which are categorized as threatened by the European Red List.
Current monitoring	
Integration initiative **[None]**	There is no European initiative integrating national data on the genetic diversity of terrestrial taxa able to produce the EBV "Genetic diversity of selected terrestrial taxa" at the European scale.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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Species populations

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of terrestrial birds**
Summary	Monitoring data on species distributions of terrestrial birds across Europe is currently flowing to four European monitoring initiatives - EBBA2 (The second European Breeding Bird Atlas) covering all EU-MS. In addition, bird count data are currently flowing to three European monitoring initiatives PECBMS (The Pan-European Common Bird Monitoring Scheme), EURING (The European Union for Bird Ringing), and EBP (Euro Bird Portal). Data is collected during breeding (EBBA2, PECBMS, EURING) and migration (EURING) following standardized protocols at exact locations, or within 10x10 km grid cells. EBP monitoring is based on citizen science data collected all year round based on unstructured but intensive sampling following both standardised and non-standardised protocols aggregated in 10x10 km grid cells. EBBA2 provided snapshots with low temporal resolution (ca. 30 years), while PECBMS and EURING collect ongoing long-term time-series updated on a yearly basis in most EU-MS and EBP collects time-series data since 2003 updated on a daily basis at 10x10 km grid cells resolution. Main monitoring gaps in the generation of the EBV "Species distributions of terrestrial birds" include low sampling frequency and spatial coverage density, and data availability. There is no single ongoing initiative collecting species distribution data for all terrestrial birds over Europe at the desired spatial and temporal resolutions. EBBA2 sampling frequency is inadequate to generate the EBV at 3-6 years temporal resolution. While the minimum sampling unit is in most cases adequate to generate the EBV at the defined spatial resolution (1x1 km - 10x10 km), the density of sampling sites is, in most cases, unlikely to be adequate to generate the EBV at the defined spatial resolution (1x1 km - 10x10 km). The spatial coverage density of baseline data from EBBA2 is adequate to provide the EBV at the spatial resolution of 10x10km only for a subset of breeding 222 bird species and for common birds species sampled under PECBMS, while it is unlikely to be adequate for EURING and EBP. Bird distribution data is available upon request and through payment at the atlas scale for EBBA2. PECBMS, EBP and EURING data are available upon request without payment, but EBP dada access requires authorization from national owners.
EBV characteristics (target)	
ID	44
Realm	Terrestrial
Class	Species populations
Name	Species distributions of terrestrial birds
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of each European terrestrial bird species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence during breeding season - Probability of occurrence during breeding season
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	All terrestrial birds of the EU (taxonomy based on the HBW and BirdLife Taxonomic Checklist, with focus on those bird species that are officially recognized in the List of birds of the European Union.
Current monitoring	

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Integration initiative **[EBBA2, PECBMS, EURING, EBP]**	**EBBA2.** The second European Breeding Bird Atlas (EBBA2, Keller (2020), https://ebba2.info/) is the most recent and comprehensive European integration initiative mapping the species distributions of all European terrestrial birds. The EBBA2 project was carried out by the EBCC network of partner organisations located in 48 countries. In total, around 120,000 fieldworkers contributed data to the atlas (mainly voluntaries). The main fieldwork period lasted five years, from 2013 to 2017, covering all bird species reported to breed in the study period 2013–2017. EBBA2 outputs include 50x50 km maps (usually showing abundance data) for 556 bird species; 10x10 km modelled distribution maps for 222 species; and trend maps comparing current distribution with that obtained 30 years ago for the first EBCC atlas (EMMA1, Hagemeijer and Blair 1997) covering a sampling period from 1985 to 1988. In addition, there are three European initiatives collecting species abundance and occurrence data yearly (PECBMS), seasonally (EURING), and daily (EBP). These initiatives can be used to complement the work developed by EBBA2 to provide timely estimations of species distributions of all terrestrial bird species. **PECBMS**. The Pan-European Common Bird Monitoring Scheme (PECBMS, https://pecbms.info/) project started in 2002 as a joint initiative of the European Bird Census Council (EBCC) and BirdLife International, among others. The project was first supported by the Royal Society for the Protection of Birds (RSPB, the BirdLife International Partner in the UK), and since 2006 it is also funded by the European Commission. **EURING**. The European Union for Bird Ringing (EURING, https://euring.org/) is the coordinating organisation for European bird ringing schemes. The organization collects data in the EURING Data Bank (EDB, https://euring.org/node/4), which holds a high proportion of the ringing recovery data that have been gathered by bird ringing schemes throughout Europe. The databank is hosted by the British Trust for Ornithology. The data are computerised according to standard protocols that are used by all EURING schemes. **EBP.** The Euro Bird Portal (EBP, https://eurobirdportal.org/) is a European integration initiative gathering data from online portals to map large-scale spatio-temporal patterns of bird distributions within 30x30 km grid cells on a weekly basis. EBP obtains year-round data from unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases even no protocol (casual observations). The EBBA Live Farmland initiative (showcased in EuropaBON Deliverable 5.1), aims at combining the PECBMS and EBP datasets to produce updated maps of breeding distribution.
Country coverage **Very-High [100% EU-MS]**	46 European countries report species abundance data to **EBBA2**: Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom 31 European countries report species abundance data to **PECBMS**: Andorra, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and United Kingdom.

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	41 European countries report species abundance data to **EURING:** Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and United Kingdom All European countries report species abundance data to **EBP.**
Taxonomic/ Ecosystem coverage **Low [0% EU-MS]**	**EBBA2** covers 596 breeding species (539 native species and 57 non-native species). **PECBMS** covers 168 common breeding bird species. All birds detected are reported. **EURING** covers 300 bird species. All birds captured are reported. **EBP** has the potential to collect data on all bird species occurring in Europe but, by 2023, data was only available for 137 species. It is possible that not all species detected in a given square are reported (e.g. incomplete lists) **(partial gap).** Overall, species are only partially covered because not all wintering species are being monitored (**partial gap**).
Standardized monitoring **Very-High [100% EU-MS]**	**EBBA2** monitoring was based on targeted surveys following standardized field protocol involving time surveys 60 – 120 min, carried out between 2013 – 2017 during the breeding season within 10x10 km grid cells. There were 19 European countries covered by EBBA2 targeted/timed birds surveys: Albania, Andorra, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Estonia, Georgia, Greece, Iceland, Kosovo, Moldova, Montenegro, North Macedonia, Poland, Russia, Ukraine. Monitoring data from different national monitoring programs (e.g. national atlases, national breeding birds surveys) were aggregated at 50x50 km grid cells. **PECBMS** monitoring is based on standardised fieldwork protocols to collect count data for all common bird species across Europe during the breeding season at a fine spatial resolution (sampling transects or point stations). **EURING** monitoring is based on standardised fieldwork protocols to collect count data on a seasonal basis (breeding, wintering and migration). **EBP** monitoring is based on unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases, even no protocol (casual observations) obtained year-round. Only a small part of the data is collected following standardized monitoring protocols (**partial gap**). Overall, all bird species are likely to be covered at least at a (**partial gap**).
Time-series **Very-High [100% EU-MS]**	Two snapshots: [1985-1988]. **EBBA1** and [2013–2017]. **EBBA2** Times-series [1975-ongoing]. **PECBMS** Times-series [1889-ongoing]. **EURING** Times-series [2003-ongoing]. **EBP**
Long-term monitoring **Very-High [93% EU-MS]**	Long-term monitoring (30 years) for all EU-MS covered by EBBA1. The longest time-series are from 1975 (Denmark, Finland and Sweden). The first modern bird ringing took place in Denmark in 1889. The first national ringing schemes developed over the following 20 years and there are now some 49 European Ringing Schemes that are members of EURING. EBP longest time-series is from 2003.
Ongoing monitoring	EBBA2 monitoring has stopped.

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Very-High [100% EU-MS]	PECMBS, EURING and EBP monitoring schemes are all ongoing.
Sampling frequency **Very-High [100% EU-MS]**	>30 years. **EBBA2.** Sampling frequency for EBBA2 is inadequate to generate the EBV at the defined temporal resolution (3-6 years). Annually. **PECBMS:** higher than the EBV temporal resolution (3 or 6 years) Seasonally/Annually. **EURING:** higher than the EBV temporal resolution (3 or 6 years) Daily. **EBP.** The local online portals collect most of their data through mobile apps in near-real time or shortly after it has been recorded in the field and the data is transferred to the EBP on a daily basis. PECBMS, EURING and EBP data can be used to complement EBBA2 to provide timely estimations of species distributions of terrestrial bird species over Europe but not.
Spatial Coverage Density **Low [0% EU-MS]**	**EBBA2:** Distribution and abundance data were collected for 5,110 50x50 km grid cells for 596 breeding birds across Europe (96% of the study area). Species distribution maps at 10 x 10 km resolution were developed for 222 species using statistical modelling. The spatial coverage density is likely to be adequate to generate the EBV at 10x10km spatial resolution for 222 species through modelling. **PECBMS:** Bird abundance data of common birds are collected in a variable number of sampling points, transects, 1x1km grid cells unevenly distributed in each country in each country (the degree of coverage is particularly low in South and East European countries). The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) but is too low to permit the production of the EBV at the higher spatial resolution (1x1km). **EURING:** Bird abundance data are collected in sampling points unevenly distributed in each country. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (1x1km-10x10km) (**gap**). **EBP:** Bird count data of ca. 137 are collected in transects or sampling points. Although the maps featured in the EBP viewer (www.eurobordportal.org) are aggregated by week and 30x30 km, data is stored in the EBP central data repository aggregated at 10x10 km resolution. The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) but is too low to permit the production of the EBV at the higher spatial resolution (1x1km) **(partial gap).** Altogether, the network of sites is likely to be sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) for a subset of species, and is too low to permit the production of the EBV at the higher spatial resolution (1x1km) in any case (**partial gap**).
Minimum sampling unit **Very-High [89% EU-MS]**	**EBBA2:** Exact location - 10x10 km grid cells for most countries except for Andorra (50x50km), Czech Republic (12x12km), and Serbia (50x50km). The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km) for most countries. **PECBMS:** Exact location/1x1km. The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km) for all countries except Greece and Hungary **(partial gap**). **EURING:** Exact location. The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km).

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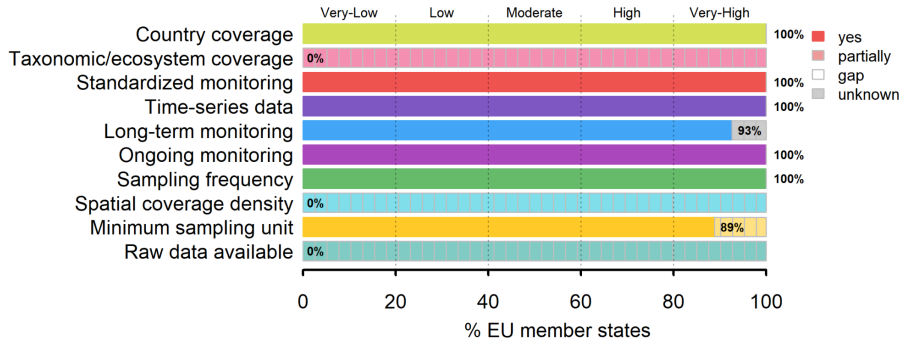
	EBP: 10x10km. Data is aggregated at 10x10 km grid cells. The minimum sampling unit is likely to be adequate to generate the EBV at a lower spatial resolution (10x10km). (**partial gap**) All countries have monitoring data with a minimum sampling unit < 1x1km. Altogether, monitoring data collected from the different schemes are likely to be adequate to generate the EBV at the desired spatial resolution (1x1km-10x10km).
Raw data access **Very-Low [0% EU-MS]**	**EBBA2** bird distribution data is available upon request and through payment at the atlas scale for both 10 x 10 km and 50 x 50 km spatial resolutions but raw data is not available in any case (**partial gap**). **PECBMS** and **EURING** data are available upon request. **EBP** is available upon request and subject to agreement by National coordinators who hold the ownership of data, but just one centralized data request should be done as data is already centralized in the EBP databank (authorizations by national owners are coordinated by EBP) (**partial gap**). Overall, data is only partially available.
Monitoring gaps	
Figure 44.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	
REFERENCES	Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., ... & Foppen, R. P. B. (2020). European breeding bird atlas 2: Distribution, abundance and change. European Bird Census Council and Lynx Editions, 967 pp.

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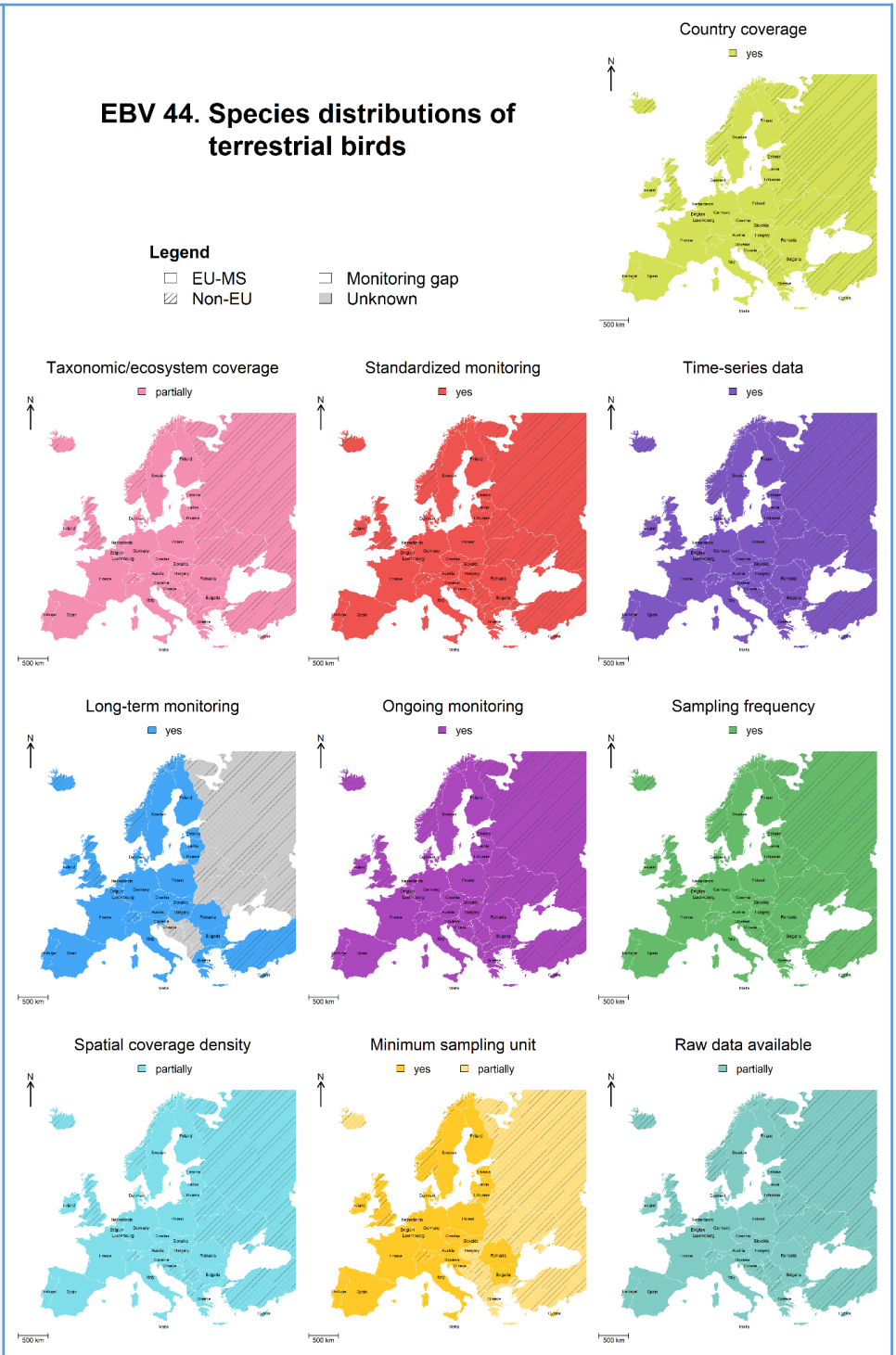

Figure 44.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

REFERENCES

Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., ... & Foppen, R. P. B. (2020). European breeding bird atlas 2: Distribution, abundance and change.

Hagemeijer, E.J.M., and M.J. Blair (editors). 1997. The EBCC Atlas of European Breeding Birds: their distribution and abundance. T & A.D. Poyser, London.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of terrestrial birds**
Summary	Monitoring data on species abundances of terrestrial birds across Europe is currently flowing to three European monitoring initiatives: The PanEuropean Common Bird Monitoring Scheme (PECBMS, common birds); The European Union for Bird Ringing (EURING, common birds and target species), and The Euro Bird Portal (EBP, all bird species) - altogether covering all EU-MS. PECBMS, EURING data are collected annualy following standardized protocols at exact locations, or within 10x10 km grid cells, providing ongoing long-term time-series updated on a yearly basis in most EU-MS. EBP monitoring is based on citizen science data collected all year round based on unstructured but intensive sampling following both standardized and non-standardized protocols, providing time-series data since 2003 updated on a daily basis aggregate at 10x10 km grid cells resolution. Main monitoring gaps in the generation of the EBV "Species abundances of terrestrial birds" include low spatial coverage density and data availability. While the minimum sampling unit is in most cases adequate to generate the EBV at the defined spatial resolution (1x1km - 10x10km), the density of sampling sites is only likely to be adequate to generate the EBV at 10x10 km resolution for common birds but not for rare and priority species. PECBMS, EURING and EBP data are available upon request, but EBP dada access requires authorization from national owners.
EBV characteristics (target)	
ID	45a
Realm	Terrestrial
Class	Species populations
Name	Species abundances of terrestrial birds
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of European rare, priority, and common bird species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals in spring and winter - Modeled relative abundance in spring and winter
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	1-year
Taxonomic/ ecosystem focus group	- Taxonomy based on the HBW and BirdLife Taxonomic Checklist - Rare bird species as included in the Annex 1 of the Birds Directive (i.e. species with small populations or restricted local distribution) - Priority bird species as included in Annex 1 of the Birds Directive (i.e. in danger of extinction, vulnerable to specific changes in their habitat or requiring particular attention for reasons of the specific nature of the habitat) - Common bird species as included in the Pan-European Common Bird Monitoring Scheme (PECBMS)
Current monitoring	
Integration initiative **[PECBMS, EURING, EBP]**	There are currently three European initiatives collecting Species abundances of terrestrial birds yearly (PECBMS), seasonally (EURING), and daily (EBP). Monitoring data flowing for these initiatives can be used to provide a timely estimation of Species abundances of common, rare and priority terrestrial bird species in spring and winter.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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	PECBMS. The PanEuropean Common Bird Monitoring Scheme (PECBMS, https://pecbms.info/) project started in 2002 as a joint initiative of the European Bird Census Council (EBCC) and BirdLife International, among others. The project was first supported by the Royal Society for the Protection of Birds (RSPB, the BirdLife International Partner in the UK), and since 2006 it is also funded by the European Commission. **EURING**. The European Union for Bird Ringing (EURING, https://euring.org/) is the coordinating organisation for European bird ringing schemes. The organization collects data in the EURING Data Bank (EDB, https://euring.org/node/4), which holds a high proportion of the ringing recovery data that have been gathered by bird ringing schemes throughout Europe. The databank is hosted by the British Trust for Ornithology. The data are computerised according to standard protocols that are used by all EURING schemes. **EBP.** The Euro Bird Portal (EBP, https://eurobirdportal.org/) is a European integration initiative gathering data from online portals to map large-scale spatio-temporal patterns of bird distributions within 30x30 km grid cells on a weekly basis. EBP obtains year-round data from unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases even no protocol (casual observations). The EBBA Live Farmland initiative (showcased in EuropaBON Deliverable 5.1), aims at combining the PECBMS and EBP datasets to produce updated maps of breeding distribution.
Country coverage **Very-High [100% EU-MS]**	31 European countries report species abundance data to **PECBMS**: Andorra, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom. 41 European countries report species abundance data to **EURING**: Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom All European countries report species abundance data to **EBP**.
Taxonomic/ Ecosystem coverage **Very-High [100% EU-MS]**	**PECBMS** covers 168 common breeding bird species. All birds detected are reported. **EURING** covers 300 bird species. All birds captured are reported. **EBP** has the potential to collect data on all bird species occurring in Europe but, by 2023, data was only available for 137 species. It is possible that not all species detected in a given square are reported (e.g. incomplete lists) **(partial gap).** Overall, species are only partially covered because not all wintering species are being monitored (**partial gap**).
Standardized monitoring	**PECBMS** monitoring is based on standardised fieldwork protocols to collect count data for all common bird species across Europe during the breeding season at a fine spatial resolution (sampling transects or point stations).

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Very-High [100% EU-MS]	**EURING** monitoring is based on standardised fieldwork protocols to collect count data on a seasonal basis (breeding, wintering and migration). **EBP** monitoring is based on unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases, even no protocol (casual observations) obtained year-round. Only a small part of the data is collected following standardized monitoring protocols (**partial gap**). Overall, all bird species are covered.
Time-series **Very-High [100% EU-MS]**	Times-series [1975-ongoing]. **PECBMS** Times-series [1889-ongoing]. **EURING** Times-series [2003-ongoing]. **EBP**
Long-term monitoring **Very-High [93% EU-MS]**	The longest time series are from 1975 (Denmark, Finland and Sweden). The first modern bird ringing took place in Denmark in 1889. The first national ringing schemes developed over the following 20 years and there are now some 49 European Ringing Schemes that are members of EURING. EBP longest-time series is from 2003.
Ongoing monitoring **Very-High [100% EU-MS]**	PECMBS, EURING and EBP monitoring schemes are all ongoing.
Sampling frequency **Very-High [100% EU-MS]**	Annually during the breeding season for all covered countries. **PECBMS:** higher than the EBV temporal resolution (3 or 6 years). However, it is not adequate to provide species abundance during winter (**partial gap)**. Seasonally/Annually. **EURING:** higher than the EBV temporal resolution (3 or 6 years) Daily. **EBP.** The local online portals collect most of their data through mobile apps in near-real time or shortly after it has been recorded in the field and the data is transferred to the EBP on a daily basis. Altogether, PECBMS, EURING and EBP data can be used to provide a timely estimation of species abundances of all terrestrial bird species in the covered countries.
Spatial Coverage Density **Low [0% EU-MS]**	**PECBMS:** Bird abundance data are collected in a variable number of sampling points, transects or 1x1km grid cells in each country. The spatial coverage density is likely to be representative of the available sites. **EURING:** Bird abundance data are collected in sampling points unevenly distributed in each country. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (1x1km-10x10km) (**gap**). **EBP:** Bird count data of ca. 137 are collected in transects or sampling points. Although the maps featured in the EBP viewer (www.eurobordportal.org) are aggregated by week and 30x30 km, data is stored in the EBP central data repository aggregated at 10x10 km resolution. The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) but is too low to permit the production of the EBV at the higher spatial resolution (1x1km) **(partial gap).** Altogether, the network of sites is likely to be sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) for a subset of species, and is too low to permit

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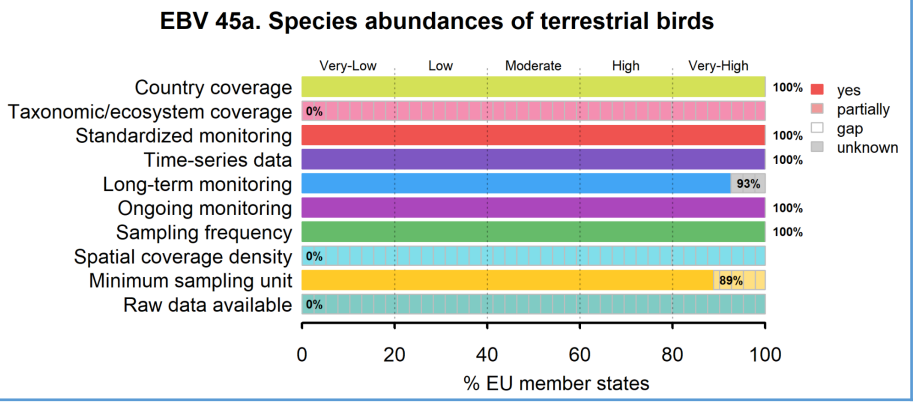
	the production of the EBV at the higher spatial resolution (1x1km) in any case (**partial gap**).
Minimum sampling unit **Very-High [89% EU-MS]**	**PECBMS:** Exact location/1x1km. Greece and Hungary. The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km) for all countries except Greece and Hungary **(partial gap**). **EURING:** Exact location. The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km). **EBP:** 10x10km. Data is aggregated at 10x10 km grid cells. The minimum sampling unit is likely to be adequate to generate the EBV at a lower spatial resolution (10x10km). (**partial gap**) Altogether, monitoring data collected from the different schemes are likely to be adequate to generate the EBV at the lowest spatial resolution 10x10km (**partial gap**
Raw data access **Very-Low [0% EU-MS]**	**PECBMS** and **EURING** data are available upon request. **EBP** is available upon request and subject to agreement by National coordinators who hold the ownership of data, but just one centralized data request to should be done as data is already centralized in the EBP databank (authorizations by national owners are coordinated by EBP) (**partial gap**). Overall, data is only partially available.
Monitoring gaps	
Figure 45a.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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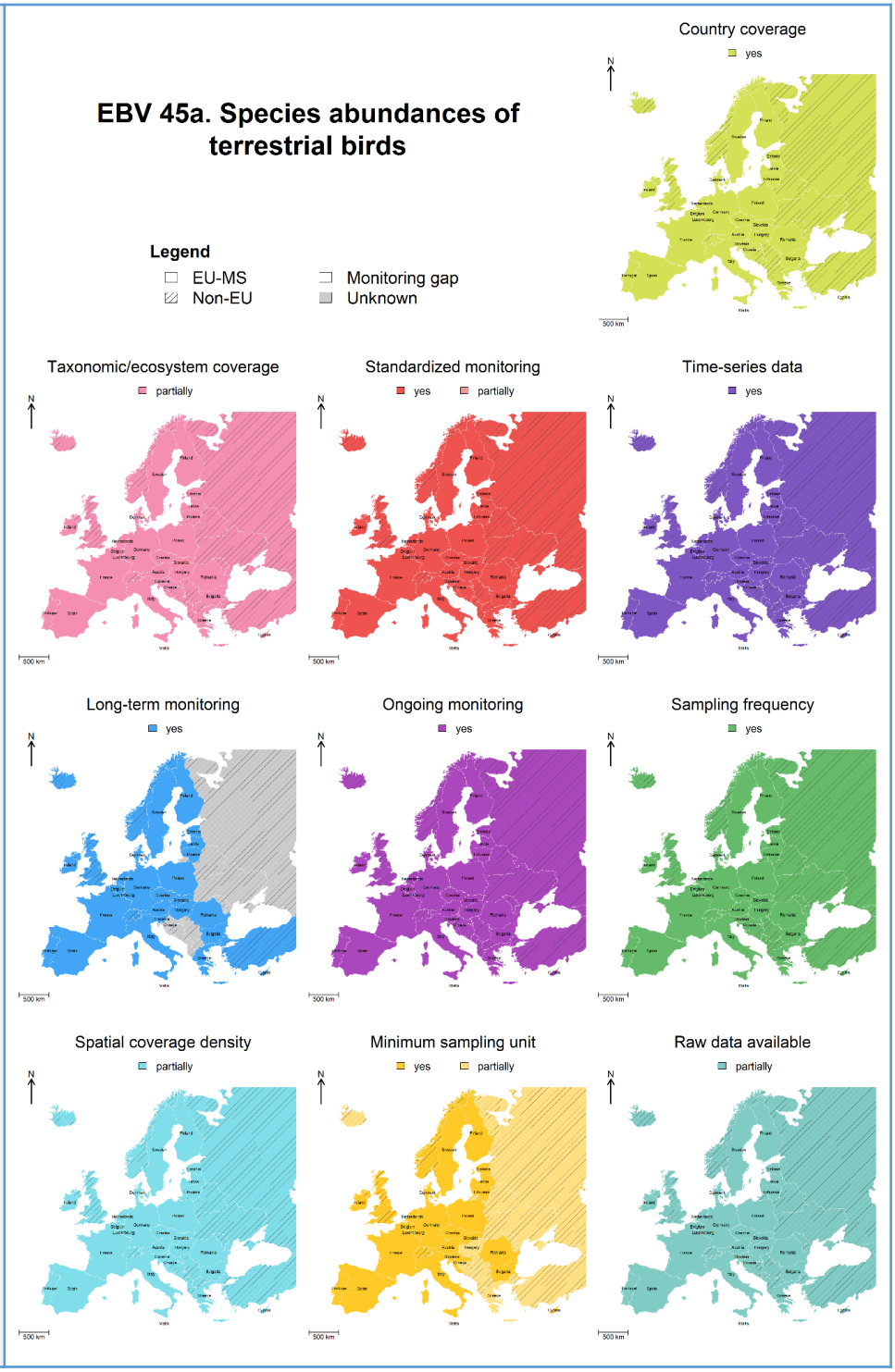

Figure 45a.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of terrestrial migratory birds**
Summary	Monitoring data on species abundances of terrestrial migratory birds is currently flowing to the European Union for Bird Ringing **(EURING)** and the **EuroBirdPortal (EBP)** - altogether covering all EU-MS. EURING data is collected during breeding following standardized protocols at exact locations, or within 10x10 km grid cells, providing ongoing long-term time-series updated on a yearly basis in most EU-MS. EBP monitoring is based on citizen science data collected all year round based on unstructured but intensive sampling following both standardised and non-standardized protocols, providing time series data since 2003 updated on a daily basis aggregate at 10x10 km grid cells resolution. Main monitoring gaps in the generation of the EBV "Species abundances of terrestrial migratory birds" include inadequate spatial coverage density and data availability. While the minimum sampling unit of the ringing data is in most cases adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km), the density of sampling sites is unlikely to be adequate. In contrast, the spatial resolution of bird count data gathered by the EBP is lower than desired. Data collected by EURING and EBP data are available upon request, but EBP dada access requires authorization from national owners.
EBV characteristics (target)	
ID	45b
Realm	Terrestrial
Class	Species populations
Name	Species abundances of terrestrial migratory birds
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of migratory bird species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals - Modeled relative abundance
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	- Real-time
Taxonomic/ ecosystem focus group	- Taxonomy based on the HBW and BirdLife Taxonomic Checklist - Migratory bird species defined as full migrants in the European Red List
Current monitoring	
Integration initiative **[EURING, EBP]**	Real-time monitoring data on species abundances of terrestrial migratory birds is currently flowing to **EURING** and **EuroBirdPortal**. The European Union for Bird Ringing (**EURING**, https://euring.org/) is the coordinating organisation for European bird ringing schemes. The organization collects data in the EURING Data Bank (EDB, https://euring.org/node/4), which holds a high proportion of the ringing recovery data that have been gathered by bird ringing schemes throughout Europe and along the Eurasian African flyway. The databank is hosted by the British Trust for Ornithology. The data are computerised according to standard protocols that are used by all EURING schemes.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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	The **Euro Bird Portal** (**EBP**, https://www.eurobirdportal.org) is a European integration initiative gathering data from online portals to map large-scale spatio-temporal patterns of bird distributions (seasonal distributional changes, migratory patterns, phenology) within 30x30 km grid cells at a weekly basis. EBP obtains year-round data from unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases even no protocol (casual observations).
Country coverage **Very-High [100% EU-MS]**	41 European countries report species abundance data to **EURING:** Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and United Kingdom All European countries report species abundance data to **EBP.**
Taxonomic/ Ecosystem coverage **Very-High [96% EU-MS]**	**EURING** covers 300 bird species. All birds captured are reported. **EBP** has the potential to collect data on all bird species occurring in Europe but, by 2023, data was only available for 137 species. It is possible that not all species detected in a given square are reported (e.g. incomplete lists) **(partial gap).** Overall, species are only partially covered because not all species are being monitored (**partial gap**).
Standardized monitoring **Very-High [96% EU-MS]**	**EURING** monitoring is based on standardised fieldwork protocols to collect count data on a seasonal basis (breeding, wintering and migration). **EBP** monitoring is based on unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases, even no protocol (casual observations) obtained year-round. Only a small part of the data is collected following standardized monitoring protocols (**partial gap**).
Time-series **Very-High [100% EU-MS]**	Times-series [1889-ongoing]. **EURING** Times-series [2003-ongoing]. **EBP**
Long-term monitoring **Very-High [93% EU-MS]**	The longest time series are from 1975 (Denmark, Finland and Sweden). The first modern bird ringing took place in Denmark in 1889. The first national ringing schemes developed over the following 20 years and there are now some 49 European Ringing Schemes that are members of EURING. EBP longest-time series is from 2003.
Ongoing monitoring **Very-High [100% EU-MS]**	**EURING** and **EBP** are both ongoing.
Sampling frequency **Very-High [100% EU-MS]**	Seasonally/Annually. **EURING:** higher than the EBV temporal resolution (3 or 6 years) Daily. **EBP.** The local online portals collect most of their data through mobile apps in near-real time or shortly after it has been recorded in the field and the data is transferred to the EBP on a daily basis. Altogether, EURING and EBP data can be used to provide a timely estimation of species abundances of all terrestrial bird species in the covered countries.

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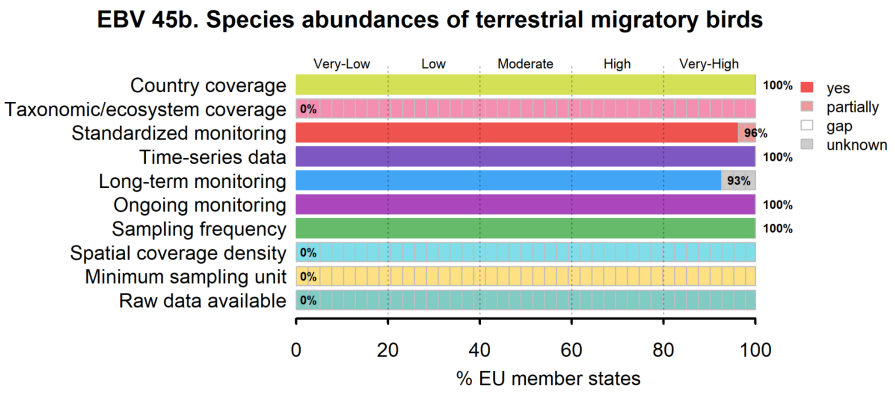
Spatial Coverage Density **Very-Low [0% EU-MS]**	**EURING:** Bird abundance data are collected in sampling points unevenly distributed in each country. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (1x1km-10x10km) (**gap**). **EBP:** Bird count data of ca. 137 are collected in transects or sampling points. Although the maps featured in the EBP viewer (www.eurobordportal.org) are aggregated by week and 30x30 km, data is stored in the EBP central data repository aggregated at 10x10 km resolution. The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) but is too low to permit the production of the EBV at the higher spatial resolution (1x1km) **(partial gap).** Altogether, the network of sites is likely to be sufficiently dense to produce the EBV at the lower spatial resolution (10x10km) for a subset of species, and is too low to permit the production of the EBV at the higher spatial resolution (1x1km) in any case (**partial gap**).
Minimum sampling unit **Very-Low [0% EU-MS]**	**EURING:** Exact location. The minimum sampling unit is likely to be adequate to generate the EBV at the desired spatial resolution (1x1km - 10x10km). **EBP:** 10x10km. Data is aggregated at 10x10 km grid cells. The minimum sampling unit is likely to be adequate to generate the EBV at a lower spatial resolution (10x10km) (**partial gap**) Altogether, monitoring data collected from the different schemes are likely to be adequate to generate the EBV at the lowest spatial resolution 10x10km (**partial gap**).
Raw data access **Very-Low [0% EU-MS]**	**EURING** data are available upon request. **EBP** is available upon request and subject to agreement by National coordinators who hold the ownership of data, but just one centralized data request should be done as data is already centralized in the EBP databank (authorizations by national owners are coordinated by EBP) (**partial gap**). Overall, data is only partially available.
Monitoring gaps	
Figure 45b.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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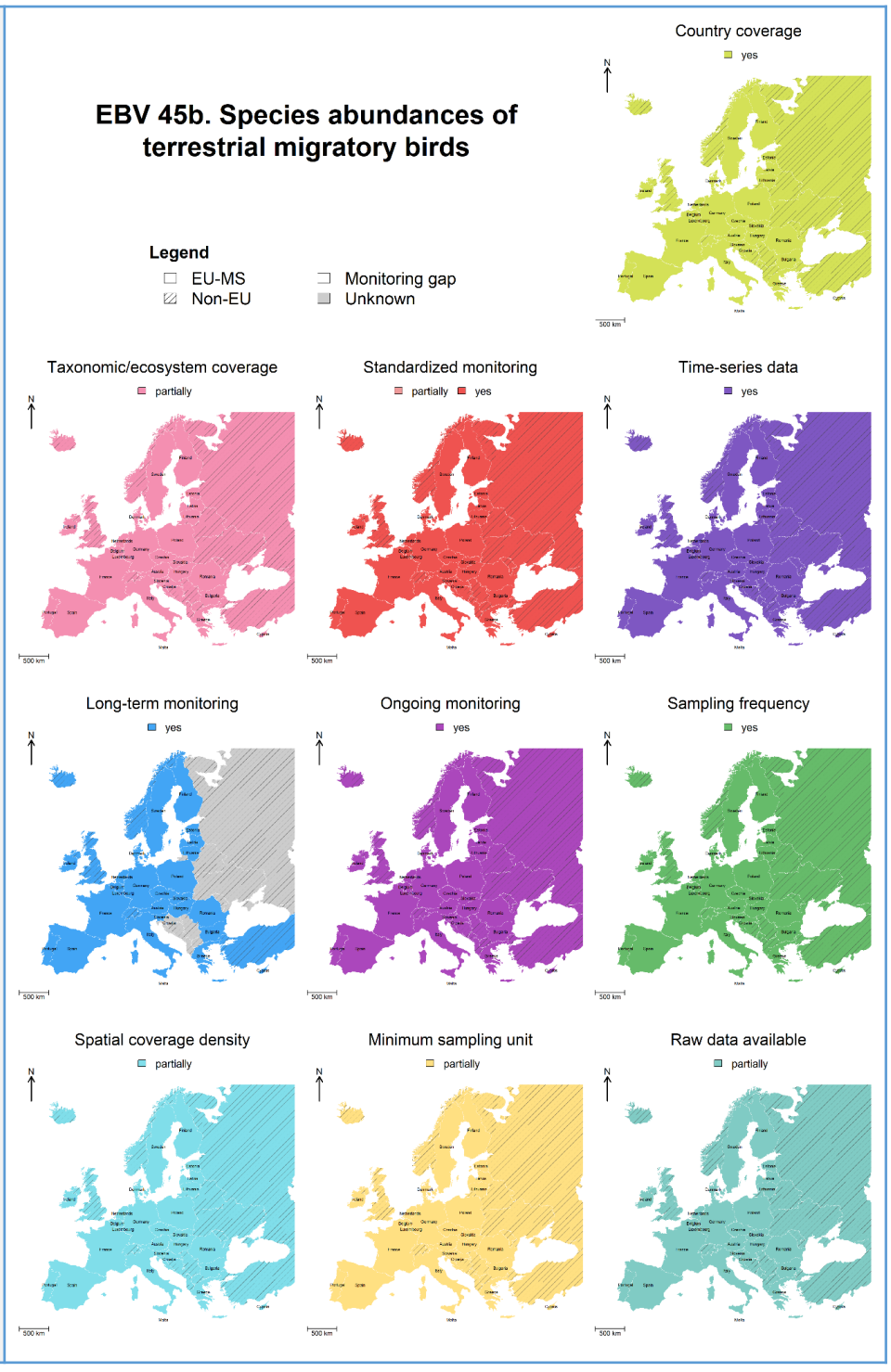

Figure 45b.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of selected terrestrial mammals**
Summary	The most recent European initiative potentially collecting data on the abundance of Carnivora, Artiodactyla and Chiroptera species is the Second European Mammal Atlas (EMMA2). By 2023, EMMA2 will provide the second snapshot on the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (since 1999). However, EMMA2 compiles information available from several sources, based on both opportunistic observations and standardized sampling and citizen science data, and thus abundance data is only available for a subset of countries and particular taxa. Specifically, Chiroptera abundance time series data are available for cave-dwelling bats at a fine temporal resolution (yearly/seasonally) following guidelines produced by EUROBATS working groups. Standardized monitoring data were gathered to develop the Prototype European Hibernating Bat Indicator, and, more recently, the Bat Monitoring Programme. Main monitoring gaps in the generation of the EBV "Species abundances of selected terrestrial mammals" include lack of country coverage, inadequate sample frequency, unknown sampling unit, lack of time series data, and unavailable raw data. Specifically, although EMMA2 covers all European countries, information based on species abundance is not available for all countries. The information on the data available is insufficient with huge uncertainty on the sampling frequency, and on the spatial resolution of the baseline data. Specifically, only a few countries have data collected on a regular basis able to provide the EBV at the desirable temporal resolution (1-year). The spatial coverage density of baseline data is likely to be inadequate to provide the EBV at the desirable spatial resolution (1x1km - 10x10km). Data will be only available at the atlas scale (50x50-km) for Carnivora, Artiodactyla and Chiroptera, while data from the Bat Monitoring Program will be available at exact locations under request.
EBV characteristics (target)	
ID	46
Realm	Terrestrial
Class	Species populations
Name	Species abundances of selected terrestrial mammals
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of European terrestrial Carnivora, Artiodactyla and Chiroptera species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals - Modeled relative abundance - Estimated counts of individuals in key underground sites (hibernation, breeding and transitional roost-sites) as defined by EUROBATS - Estimated counts of individuals in key overground sites (hibernation, breeding and transitional roost-sites) as defined by EUROBATS
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	1 year
Taxonomic/ ecosystem focus group	Terrestrial Carnivora, Artiodactyla and Chiroptera species included in the European Red List.
Current monitoring	
Integration initiative **[EMMA2, Prototype**	The EMMA2 (Second European Mammal Atlas, https://discovermammals.org/projects/the-2nd-european-mammal-atlas/) realised by

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European Hibernating Bat Indicator; Bat Monitoring Programme]	the European Mammal Foundation (the successor of the Societas Europaea Mammalogy that published the first Atlas). EMMA2 is the second edition of the Atlas of European Mammals published in 1999, updating information for the area already covered and extending the area to the whole of Europe. EMMA2 will provide by 2023 the second snapshot of the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (1999). EMMA2 is based on verified data from national databases including both standardized and opportunistic observations and citizen science data. In addition, there are two European initiatives collecting bat data - the Prototype European Hibernating Bat Indicator) and The Bat Monitoring Programme) that can be used to complement the work developed by the EMMA2 to provide a timely estimation of Species abundances of bat species. **Prototype European Hibernating Bat Indicator.** The Prototype European Hibernating Bat Indicator (https://link.springer.com/article/10.1016/j.mambio.2014.09.004) was the first tentative for aggregating monitoring data on hibernating bats across a number of European countries to analyse supranational bat trends at their hibernation sites in Europe between 1993 and 2011. The initiative was developed by the EUROBATS (https://www.eurobats.org/) by gathering data collected by national programs via standardised protocols defined by the EUROBATS Monitoring and Surveillance Intersessional Working Group. **Bat Monitoring Programme** The Bat Monitoring Programme, www.batmonitoring.org) is a new monitoring programme running since 2019 which was initially implemented in Catalonia and is currently implemented in Spain and aims to be extended to all EU countries. The programme is based on standard protocols designed for monitoring different bat species and habitats (ChiroRivers, ChiroHAbitats, ChiroBoxes and ChiroRoosts) throughout the year (summer, winter, spring and autumn), thus being expected to provide reliable abundance data for all bat species. The programme will include national bat monitoring programmes that report to the EUROBATS (https://www.eurobats.org/) Monitoring and Surveillance Intersessional Working Group on a voluntary basis alongside the reporting to the Habitats Directive. National protocols are largely comparable in the case of under- and overground roosts monitoring (ChiroRoosts and ChiroBoxes) but not for acoustic data (ChiroRivers and ChiroHAbitats).
Country coverage **High [81% EU-MS]**	21 European countries providing abundance data on mammals for **EMMA2:** Austria, Belgium, Bulgaria, Croatia, Estonia, Finland, France, Iceland, Ireland, Italy, Lithuania, North Macedonia, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, United Kingdom. 9 European countries providing data on hibernating bat abundance for **Prototype European Hibernating Bat Indicator:** Germany, Hungary, Latvia, Netherlands, Portugal, Slovak Republic, Slovenia, and the United Kingdom. 9 European countries providing data on bat abundance for **Bat Monitoring Programme:** Bulgaria, Czech Republic, Germany, Ireland, Norway, Romania, Slovakia, Spain (Catalonia, Basque Country), and the United Kingdom.
Taxonomic/ Ecosystem coverage **High [26% EU-MS]**	All terrestrial selected mammal species are covered by the EMMA2**.** While not all hibernating bat species were monitored under **Prototype European Hibernating Bat Indicator,** all bats will be monitored under **Bat Monitoring Programme.**

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Standardized monitoring **High [74% EU-MS]**	Bat monitoring follows standardized field protocols since 2019
Time-series **Very-low [48% EU-MS]**	**- Two snapshots: [1999 - 2023].** EMMA - EMMA2**.** **- Time-series [2006-ongoing].** There are 4 countries with ongoing monitoring schemes with time-series data (Albania, Netherlands, North Macedonia, and Kosovo). - Times-series [1986-2012]. **Prototype European Hibernating Bat Indicator** - Times-series [earlier 1969-ongoing]. **Bat Monitoring Programme**
Long-term monitoring **Low [56% EU-MS]**	- The longest time series are from 1969. - Long-term data is available at least for the countries covered by the first atlas.
Ongoing monitoring **Very-low [44% EU-MS]**	Monitoring is ongoing for most countries covered by EBBA2.
Sampling frequency **Very-low [7% EU-MS]**	**EMMA2.** 24 years interval between the two atlases [1999 - 2023]. **>10 years:** Albania, North Macedonia, Kosovo. **Seasonal:** Netherlands.
Spatial Coverage Density **Very-Low [0% EU-MS]**	It remains unknown if the density of sampling sites is adequate to generate the EBV at the defined spatial resolution (1x1km - 10x10km).
Minimum sampling unit **Low [52% EU-MS]**	**EMMA2.** **Exact location (abundance data):** Albania, Bulgaria, Netherlands, North Macedonia, Norway, Sweden, and Kosovo. **10x10km grid cells (abundance and presence-absence data):** Denmark, Ireland, Italy, North Macedonia, Poland, Portugal, Serbia, Spain, and the United Kingdom. **50x50km grid cells (**presence-absence data)**:** Romania and Ukraine. **Unknown sampling unit** for the remaining countries.
Raw data access **Moderate [30% EU-MS]**	**Open:** Czech Republic, Denmark, Ireland, Luxembourg, Netherlands, Portugal, Romania, Sweden **On-demand:** Albania, Austria, Belgium, Bulgaria, Croatia, Estonia, Italy, Lithuania, Netherlands, Russia, Spain, United Kingdom **Not available:** Serbia, Slovenia **Unknown data access** for the remaining countries. Data will be made open at least at the atlas resolution (50x50km). Yet, national coordinators are been encouraged to make the majority of records freely accessible at a higher resolution than in the Atlas, with the appropriate safeguards for sensitive records (https://www.european-mammals.org/public-documents?task=download.send&id=81&catid=2&m=0).
Monitoring gaps	

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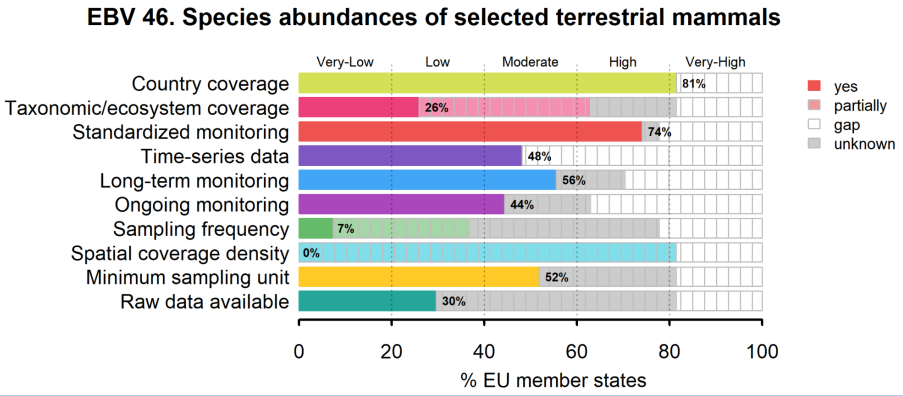
Figure 46.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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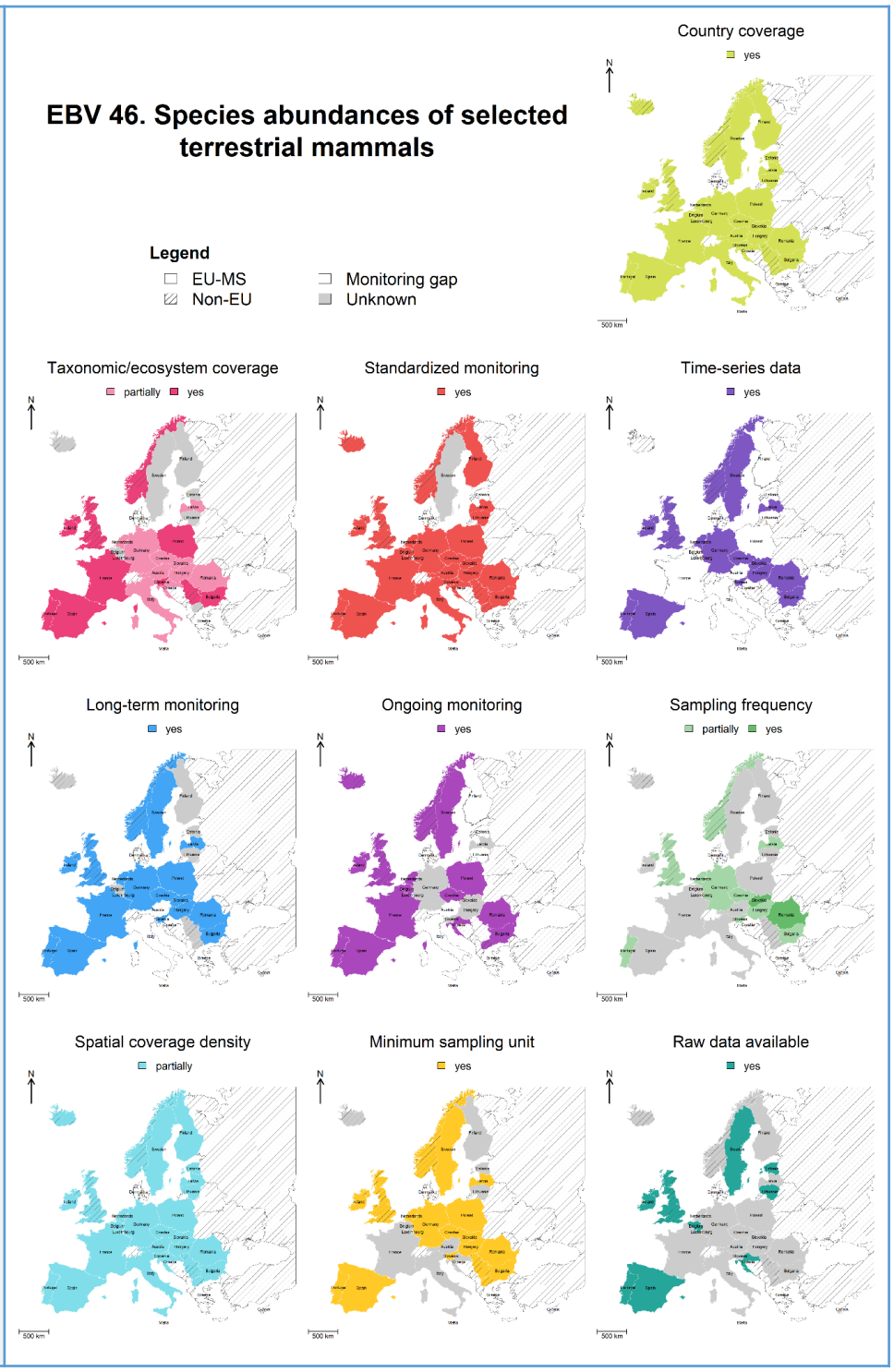

Figure 46.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of terrestrial mammals**
Summary	The most recent European initiative on species distributions of terrestrial mammals is the EMMA2. By 2023, EMMA2 will provide the second snapshot of the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (1999). EMMA2 is based on verified data from national databases including both standardized and opportunistic observations, and citizen science data. Although EMMA2 covers all European countries, information based on monitoring data is only available for 78% of the EU-MS. Yet, only a few countries have time-series data collected at a regular basis. The spatial coverage density of baseline data is likely to be adequate to provide the EBV at the spatial resolution of 50x50 km as this is the spatial resolution of the atlas. Data will be open and freely available at least at the atlas scale (50x50 km) to all countries. Main gaps in the generation of the EBV "Species distributions of freshwater mammals" include the lack of timely updated time-series data able to produce the EBV at the desired temporal resolution and the lack of long-term data, although it is expected to be available for the countries covered by the first atlas. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km).
EBV characteristics (target)	
ID	47
Realm	Terrestrial
Class	Species populations
Name	Species distributions of all terrestrial mammals
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of all European terrestrial mammal species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	European terrestrial mammal species included in the European Red List.
Current monitoring	
Integration initiative **[EMMA2]**	The EMMA2 (Second European Mammal Atlas, https://discovermammals.org/projects/the-2nd-european-mammal-atlas/) realised by the European Mammal Foundation (the successor of the Societas Europaea Mammalogy that published the first Atlas). EMMA2 is the second edition of the Atlas of European Mammals published in 1999, updating information for the area already covered and extending the area to the whole of Europe. EMMA2 will provide by 2023 the second snapshot of the distribution of European Mammals at the 50x50 km spatial resolution in 24 years (1999). EMMA2 is based on verified data from national databases including both standardized and opportunistic observations and citizen science data.
Country coverage **High [96% EU-MS]**	The new atlas involve the participation of all European countries but Cyprus, Georgia and Vatican City.

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Taxonomic/ Ecosystem coverage **Very-Low [0% EU-MS]**	All mammal species are covered by EMMA2. However, because many data came from opportunistic surveys a partial gap was assumed to all countries.
Standardized monitoring **Very-Low [0% EU-MS]**	EMMA2 sets up the national databases by collating dedicated monitoring data and historical data available in museums, scientific literature, notebooks, and project databases (**partial gap**). Additional fieldwork is being done to gather new data and citizens are encouraged to pass on observations of mammals in European and country level Data portals (https://discovermammals.org/mammal-portals/). There are 23 countries with web portals dedicated for uploading mammal observations: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Netherlands, Norway, Romania, Russia, Spain, Sweden, Switzerland, United Kingdom, Ukraine. Standardised monitoring programs are reported in the EuropaBON database for 27 coountries: Albania, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Lithuania, Luxemburg, Netherlands, North Macedonia, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Turkey, United Kingdom.
Time-series **Very-low [11% EU-MS]**	Two snapshots: [1999 - 2023]. EMMA - EMMA2. Time-series [2006-ongoing]. There are 4 countries with ongoing monitoring schemes with time-series data (Albania, Netherlands, North Macedonia, and Kosovo).
Long-term monitoring **Low [33% EU-MS]**	Two snapshots: [1999 - 2023]. EMMA - EMMA2.
Ongoing monitoring **Very-low [48% EU-MS]**	There are 4 countries with ongoing monitoring schemes with time-series data (Albania, Netherlands, North Macedonia, and Kosovo).
Sampling frequency **Very-low [0% EU-MS]**	**24 years interval between the two atlases [1999 - 2023].** **>10 years:** Albania, North Macedonia, Kosovo. **Seasonal:** Netherlands.
Spatial Coverage Density **Very-Low [0% EU-MS]**	The spatial coverage density of baseline data is likely to be adequate to provide the EBV at the spatial resolution of 50x50 km as this is the spatial resolution of the atlas. However, the density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km) (**partial gap**).
Minimum sampling unit **Low [33% EU-MS]**	**Exact location (abundance data):** Albania, Bulgaria, Netherlands, North Macedonia, Norway, Sweden, and Kosovo. **10x10km grid cells (abundance and presence-absence data):** Denmark, Ireland, Italy, North Macedonia, Poland, Portugal, Serbia, Spain, and the United Kingdom. **50x50km grid cells (**presence-absence data)**:** Romania and Ukraine. **Unknown sampling unit** for the remaining countries. The minimum sampling unit is ≤10x10 km at least for 17 countries (Bulgaria, Czech Republic, Denmark, France, Iceland, Ireland, Italy, Netherlands, North Macedonia, Norway, Poland, Portugal, Serbia, Spain, Sweden, and the United Kingdom), and likely to be adequate to provide the EBV at the higher spatial resolution (10x10 km). For the remaining countries, the minimum sampling 50x50km grid cells or unknown is likely to provide the EBV at the lower spatial resolution (50x50 km) which is the spatial resolution of the EMMA2 atlas (**partial gap**).
Raw data access	Data will be made open at least at the atlas resolution to all countries (50x50 km) (**partial gap**). Yet, national coordinators are been encouraged to make the majority of

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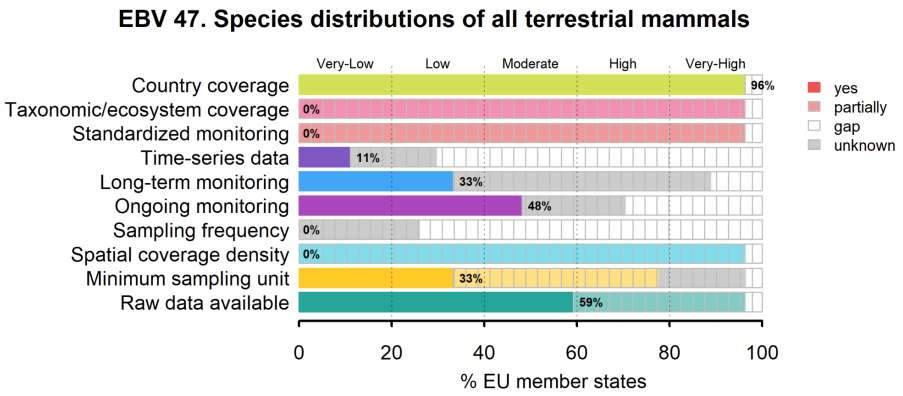
Moderate [59% EU-MS]	records freely accessible at a higher resolution than in the Atlas, with the appropriate safeguards for sensitive records (https://www.european-mammals.org/public-documents?task=download.send&id=81&catid=2&m=0). **Raw data open:** Czech Republic, Denmark, Ireland, Luxembourg, Netherlands, Portugal, Romania (partially), Sweden **Raw data available on-demand:** Albania (partially), Austria, Belgium, Bulgaria, Croatia, Estonia, Italy (partially), Lithuania, Netherlands, Russia, Spain, United Kingdom **Raw data not available for** Serbia, Slovenia and **unknown raw data access** for the remaining countries (**partial gap**).
Monitoring gaps	
Figure 47.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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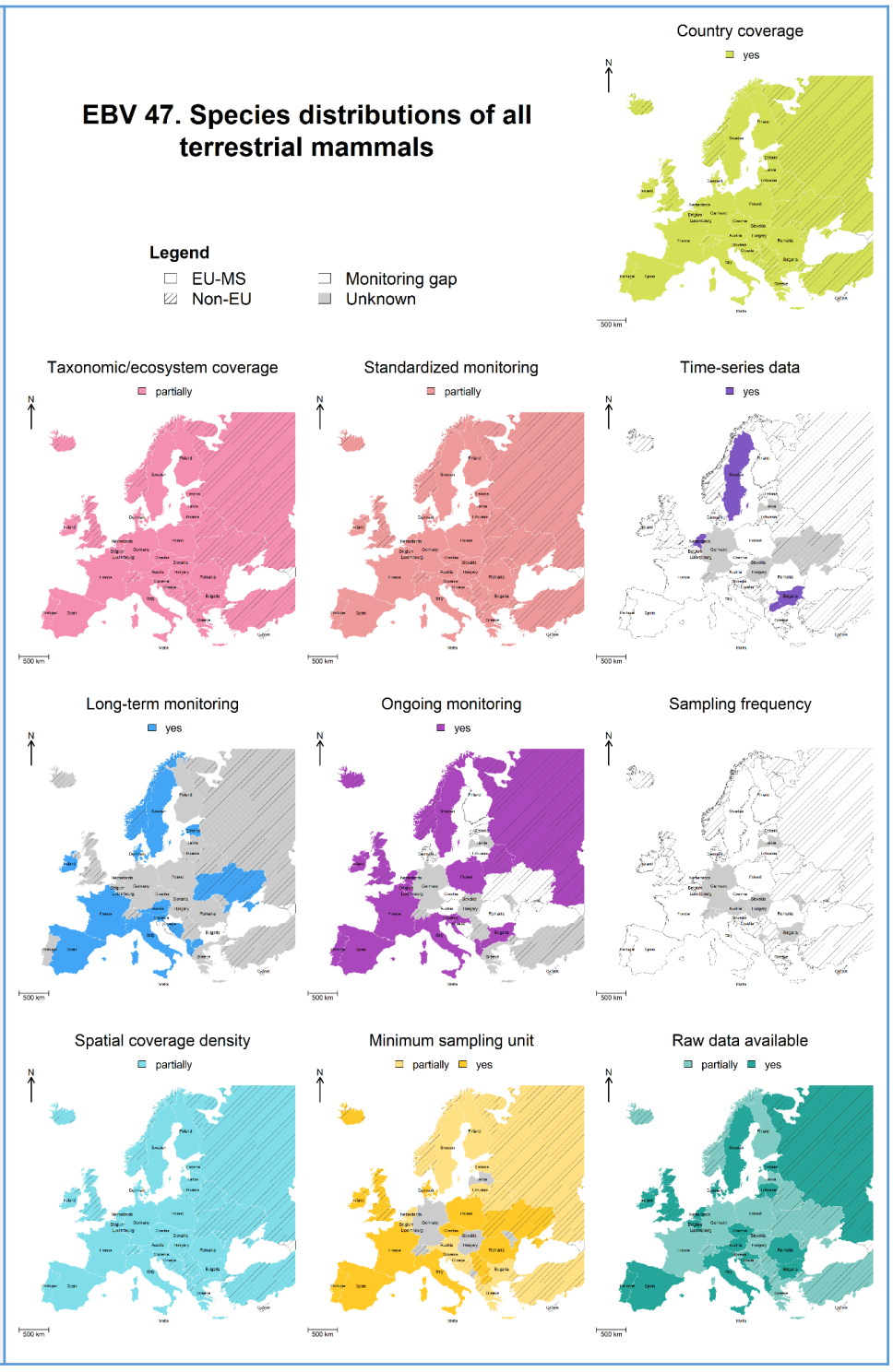

Figure 47.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of terrestrial reptiles**
Summary	The most recent European initiative on Species distributions of terrestrial reptiles is the New Atlas of European Amphibians and Reptiles (NA2RE). The initiative is a snapshot from 2014 compiling information available for several sources and national and subnational efforts to access species distributions, covering 70% of the EU-MS. Data is colected based on opportunistic observations complemented in a come cases by standardized sampling following different field protocols. Data from the first Atlas of European Amphibians and Reptiles in 1997 and the Global Information Facility (GBIF: www.gbif.org) were used when country-level databases were not available. NA2RE builds on the first Atlas of European Amphibians and Reptiles in 1997 and thus some long-term data is available for some EU-MS. Main monitoring gaps in the generation of the EBV "Species distributions of terrestrial reptiles" include the lack of ongoing timely updated standardized monitoring programs with adequate spatial coverage across Europe, and of an ongoing European integration initiative able to produce the EBV. The information on the data available is insufficient with large uncertainty on the sampling frequency, and on the spatial resolution of the baseline data. Only a few countries have standardised monitoring data collected on a regular basis. The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution (1x1km - 50-50 km). Data is open and freely available at least at the atlas scale (50x50 km) for all countries but some countries have raw data publicly available.
EBV characteristics (target)	
ID	48
Realm	Terrestrial
Class	Species populations
Name	Species distributions of terrestrial reptiles
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of all European terrestrial reptile species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	European terrestrial reptile species included in the European Red List.
Current monitoring	
Integration initiative **[NA2RE]**	The NA2RE (New Atlas of European Amphibians and Reptiles, https://www.seh-herpetology.org/distribution-atlas) is the most recent European initiative able to produce an EBV on freshwater Amphibian and Reptiles species distribution across Europe. NA2RE is a snapshot compiling information of over 384,000 grid and exact location records distributed across Europe available from several sources including national and subnational atlases, personal datasets, the first European Atlas, and GBIF. NA2RE was the base to an interactive atlas compiles information from the atlas.

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Country coverage **High [70% of MS]**	There are 23 countries with national-level distribution data for the NA2RE: Austria; Belgium; Bosnia and Herzegovina; Bulgaria; Estonia; France; Germany; Greece; Hungary; Ireland; Italy; Luxembourg; Malta; Netherlands; Poland; Portugal; Romania; Slovenia; Spain; Sweden; Switzerland; Ukraine; United Kingdom. In addition, there are 20 countries to which national-level databases were not available and the only available data is from the first Atlas of European Amphibians and Reptiles in 1997 (Gasc et al. 1997) and the Global Information Facility (GBIF: www.gbif.org). This includes: Albania; Andorra; Belarus; Croatia; Czech Republic; Denmark; Finland; Latvia; Liechtenstein; Lithuania; Moldova; Monaco; Montenegro; North Macedonia; Norway; Russia; San Marino; Serbia; Slovakia; Turkey.
Taxonomic/ Ecosystem coverage **High [70% EU-MS]**	NA2RE covers 145 species of reptiles. It includes 18 reptile species that were not represented in the 1997 European Atlas (Gasc et al. 1997).
Standardized monitoring **Very-Low [0% EU-MS]**	NA2RE compiles data from several sources. Distribution data of amphibians and reptiles relies mainly on non-standardised opportunistic data, including historical records. Although some data may came from monitoring programmes, these have usualy limited spatial coverage, focusing on grid cells with less data (**partial gap**). At least partial standardised monitoring data is reported in the EuropaBON T3.1 database for 8 countries: Austria, Belgium, France, Netherlands, Portugal, Spain, Switzerland and the United Kingdom. Standardised monitoring is unknown for the remaining countries.
Time series **Very-low [4% EU-MS]**	Two snapshots: [1997]: 1st atlas; and [2014]: NA2RE Time-series [1960-ongoing]. There are at least 3 countries with time-series data: the Netherlands, Switzerland and the United Kingdom.
Long-term monitoring **Very-low [26% EU-MS]**	There are at least 9 countries with long-term data (≥10 years): Austria, Belgium, France, Italy, Netherlands, Portugal, Spain, Switzerland and the United Kingdom. Long-term data (>17 years) is likely to exist for the countries covered by the first Atlas of European Amphibians and Reptiles.
Ongoing monitoring **Very-low [7% EU-MS]**	There are at least 3 countries with ongoing monitoring schemes: Austria, Netherlands, and Switzerland.
Sampling frequency **Very-low [4% EU-MS]**	NA2RE is a **snapshot**. The previous/first Atlas of European Amphibians and Reptiles was in 1997 (17 years interval). **Annually** data is produced in two countries: the Netherlands and the United Kingdom. The sampling frequency is unlikely to be adequate to generate the EBV at the desirable temporal resolution (3-6 years) for most countries (**gap**) except the Netherlands and the United Kingdom. However, the information on the data available is insufficient with large uncertainty on the sampling frequency of the baseline data.
Spatial Coverage Density **Very-Low [0% of MS]**	The NA2RE involves the compilation of 143,446 records for Reptiles. The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution (1x1km - 10x10km) **(gap)**.
Minimum sampling unit **Moderate [70% EU-MS]**	**NA2RE and first Atlas:** Presence/Absence data at 50x50-km resolution. **Raw data with different spatial resolutions:** Exact locations, 1x1 km - 50×50 km grid cells. There are at least 20 countries with a minimum sampling unit ≤ 10x10km which is likely to be adequate to provide the EBV at the lower desired spatial resolution

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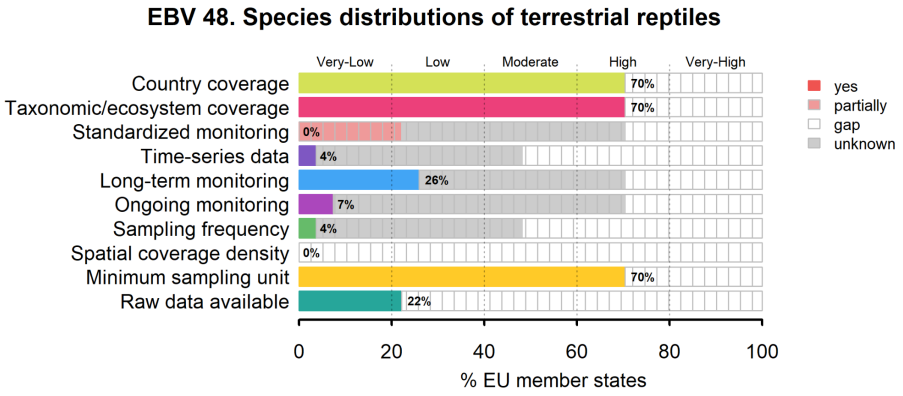
	(10x10km): Austria; Belgium; Bosnia and Herzegovina; Bulgaria; Estonia; Germany; Hungary; Ireland; Italy; Luxembourg; Netherlands; Poland; Portugal; Romania; Slovenia; Spain; Sweden; Switzerland; Ukraine; United Kingdom (**partial gap**). For the remaining countries, the minimum sampling unit is >10x10km and thus unlikely to be adequate to provide the EBV at the desired spatial resolution of (1x1km - 10x10km) (**gap**).
Raw data access **Moderate [22% EU-MS]**	Species distribution data is open and freely available for the countries covered by NA2RE at the atlas scale (50x50 km) which is lower than the EBV spatial resolution (**gap**). Raw data is open available or available under request at least for Austria, Italy, Netherlands, Portugal, Slovenia, Spain, Switzerland, and the United Kingdom. Unknown raw data access for the remaining countries.
Monitoring gaps	
Figure 48.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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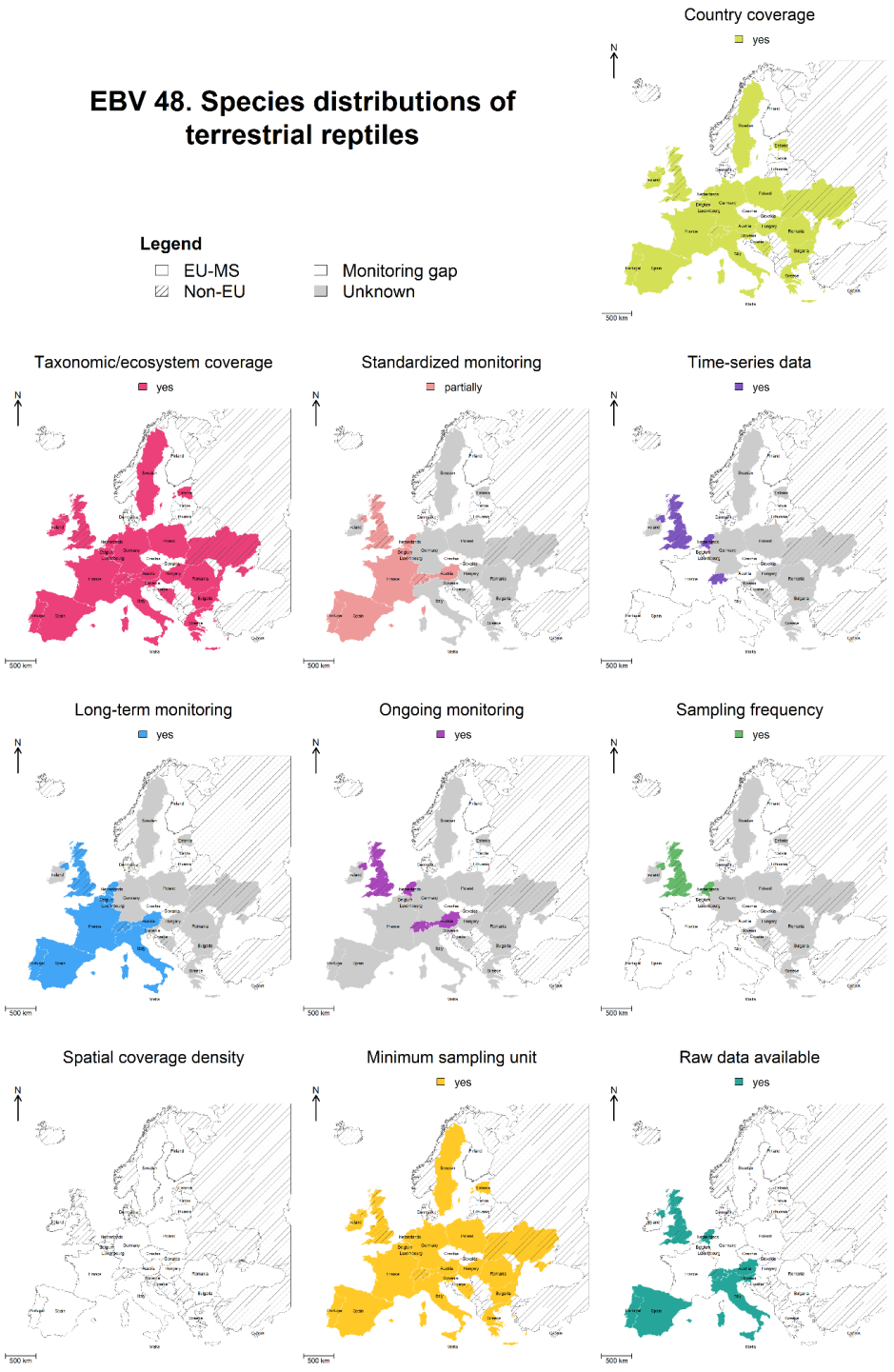
Figure 48.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.



REFERENCES

Gasc, J.-P., Cabela, A., Crnobrnja-Isailovi´c, J., Dolmen, D., Grossenbacher, K., Haffner, P., Lescure, J., Martens, H., Martínez-Rica, J.P., Maurin, H., Oliveira, M.E., Sofi anidou, T.S., Veith, M., Zuiderwijk, A. (1997): Atlas of Amphibians and Reptiles in Europe. Societas Europaea Herpetologica and Muséum national d'Histoire.

Sillero, N., J. Campos, A. Bonardi, C. Corti, R. Creemers, P.-A. Crochet, J. Crnobrnja Isailovic, M. Denoël, G. F. Ficetola, J. Gonçalves, S. Kuzmin, P. Lymberakis, P. de Pous, A. Rodríguez, R. Sindaco, J. Speybroeck, B. Toxopeus, D.R. Vieites, M. Vences (2014): Updated distribution and biogeography of amphibians and reptiles of Europe. Amphibia-Reptilia 35: 1-31. (download PDF with all supplements - 40 MB)

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of butterflies**
Summary	Species abundances of butterflies are currently monitored by the European Butterfly Monitoring Scheme (eBMS) - covering 81% of the EU-MS. Data is collected following standardized protocols on a yearly basis and annually reported at exact locations or 1x1km - 5x5 km grid cells. The minimum sampling unit is in most cases adequate to generate the EBV at the defined spatial resolution (10x10km - 50x50km). Main monitoring gaps in the generation of the EBV "Species abundances of butterflies" include lack of Long-term data, low spatial coverage density, and lack of data availability. Specifically, long-term time series (≥10 years) are available for only 37% of the EU-MS. The density of sampling sites is likely to be adequate to generate the EBV at least at the lower desired spatial resolution (50x50km) for only 15% EU-MS. Finally, the raw data is freely available upon request under the signature of a license agreement but only for the countries officially covered by the eBMS.
EBV characteristics (target)	
ID	49
Realm	Terrestrial
Class	Species populations
Name	Species abundances of butterflies
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of butterfly species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals of grassland butterfly species - Modeled relative abundance of grassland butterfly species
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	1 year
Taxonomic/ ecosystem focus group	Current list of butterfly species underlying the European grassland butterfly indicator, with extension to butterfly species from other habitats.
Current monitoring	
Integration initiative **[eBMS]**	There is currently one European monitoring scheme involving a large network of volunteers and scientists (>100,000) to produce the European Butterfly Monitoring Scheme (eBMS, https://butterfly-monitoring.net). The **eBMS** is an ongoing monitoring scheme to collects abundance data for > 312 butterfly and moth species.
Country coverage **Very-High [81% EU-MS]**	There are 29 Butterfly Monitoring Schemes (BMS): - 19 BMS operating across **16 EU-MS:** Austria - AUBMS; Austria (AUBMS; Viel-Falter – VFBMS); Belgium (Flanders – BEBMS); Croatia (HRBMS); Czech Republic (CZBMS); Estonia (EEBMS); Finland (FIBMS); France (FRBMS); Germany (DEBMS); Hungary (HUBMS); Ireland (IRBMS); Italy (ITBMS); Luxembourg (LUBMS); Portugal (PTBMS); Slovenia (SIBMS); Spain (Catalonia - ES-CTBMS, Zerynthia - ES-CBBMS, Spain excluding Catalonia and Zerynthia – ESBMS); Sweden (SEBMS); Netherlands (NLBMS). - 4 BMS operating in **4 non EU-MS**: Andorra (BMSAnd), Norway (NOBMS); Switzerland (CHBMS); United Kingdom (UKBMS).

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	- **1 EU-MS** with subnational coverage only (Belgium). - **5 EU-MS** with a BMS but not officially covered by the eBMS: Bulgaria (BUBMS); Latvia (LVBMS); Lithuania (LTBMS); Malta (MABMS); Romania (ROBMS) and for Estonia (EEBMS). - **5 EU-MS** without BMS: Cyprus, Denmark, Greece, Poland, Slovakia.
Taxonomic/ Ecosystem coverage **Very-High [81% EU-MS]**	All butterfly species are monitored in each sampling site.
Standardized monitoring **Very-High [81% EU-MS]**	eBMS uses a standardized protocol. The basic and more important methodology of eBMS is the transect counts where we get the most robust information on the butterfly population. Butterfly monitoring is done during the butterfly season. Ideally, transects should be walked every week, but if this is not possible, they should be walked as often as possible. All BMS are made by many different transects in their country. However, due to the difficulty of applying transects in some countries and remote areas, a new methodology 15-min Counts was created to reinforce the monitored data and give more flexibility in its collection. With 15-min Counts is expected to increase the butterfly monitored data in Europe, but a BMS should always have as a basis an important number of transects (details in https://butterfly-monitoring.net/sites/default/files/Pdf/Butterfly%20Transect%20Counts-Manual%20v1.pdf).
Time-series data **Very-High [81% EU-MS]**	Time-series [1976-onwards]. The first BMS began in the UK in 1976 (UKBMS), and since then, this methodology has been adopted in many other European countries to monitor butterflies.
Long-term monitoring **Low [37% EU-MS]**	Long time-series (≥10 years) not available for 5 MS: Austria, Croatia, Hungary, Italy, Portugal and Spain. Unknown temporal extent for the 10 MS with a BMS but not officially covered by the eBMS and Estonia.
Ongoing monitoring **Very-High [81% EU-MS]**	All the BMS are expected to be ongoing.
Sampling frequency **Low [56% EU-MS]**	- Annually. All the EU-MS with a BMS has the target temporal resolution (1-year): Andorra, Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Ireland, Luxemburgo, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, and United Kingdom. - 5 years: Switzerland (**gap**) - Unknown sampling frequency for the countries with a BMS but not officially covered by the eBMS.
Spatial Coverage Density **Very-Low [0% EU-MS]**	The network involves more than 10,816 transects unevenly distributed across countries. as from the map of the density of Butterfly Monitoring transects visited per 50x50 km grid cells across all schemes that have contributed to the eBMS database in 2020 (https://butterfly-monitoring.net/bms-schemes). The density of sampling sites is likely to be adequate to generate the EBV at least at the lower desired spatial resolution (50x50km) for 6 countries: Germany, Ireland, Luxemburg, Netherlands, Switzerland, and the United Kingdom (**partial gap**).

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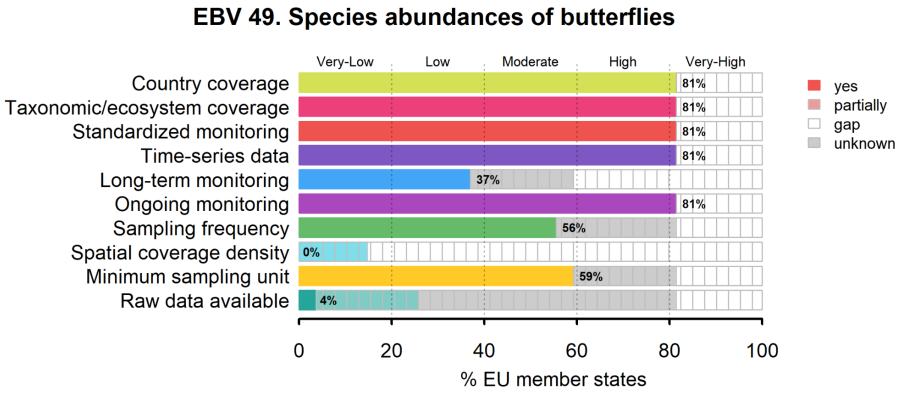
	The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution for the remaining countries (**gap**).
Minimum sampling unit **Moderate [59% EU-MS]**	Exact location of the transect (1-3 km transects). All the MS with a BMS has the higher desired spatial resolution (10x10km). Unknown minimum sampling unit for the 5 MS with a BMS but not officially covered by the eBMS (Bulgaria – BUBMS, Latvia – LVBMS, Lithuania – LTBMS, Malta – MABMS, Romania – ROBMS).
Raw data access **Low [4% EU-MS]**	The availability of raw data varies across countries. eBMS database has data from 21 BMS in 19 different countries. Raw data is freely available upon request through the signature of a license agreement (https://butterfly-monitoring.net/sites/default/files/eBMS%20DATA%20REQUEST%20POLICY%20%3D%20Annex%20B%20v2019%2004%2001.pdf). All Depositors (National BMS) are informed of requests for use of their data and will be given an option for involvement in any resulting publications (**partial gap**). Raw data is open and freely available for Finland. Unknown raw data available for the BMS is not officially covered by the eBMS.
Monitoring gaps	
Figure 49.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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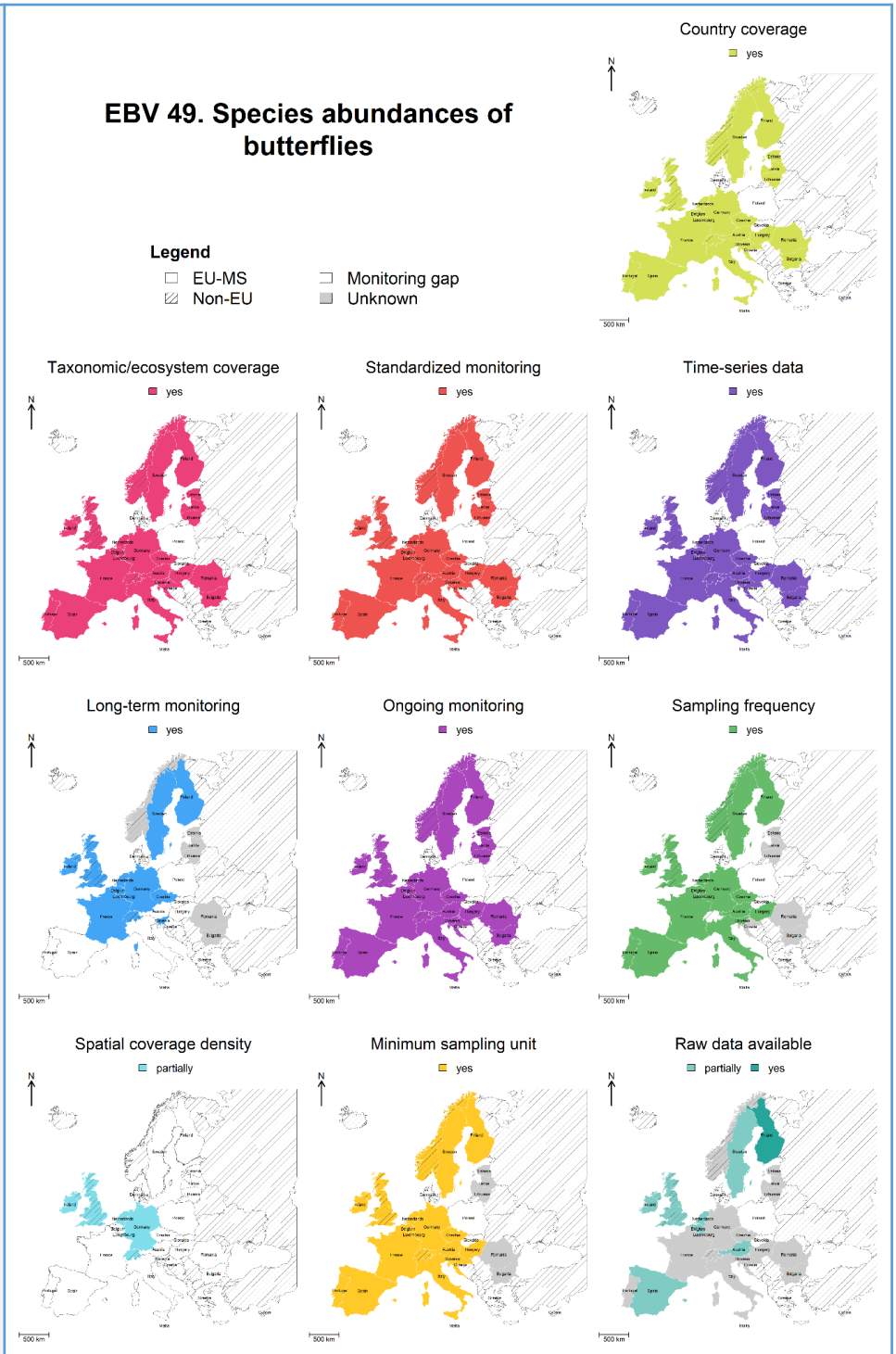

Figure 49.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of terrestrial priority invertebrates and key pollinators**
Summary	There is not a single initiative integrating monitoring data on terrestrial priority invertebrates and key pollinators able to produce the EBV "Species distributions of terrestrial priority invertebrates and key pollinators" at the European scale. However, species abundances of butterflies are currently monitored by the European Butterfly Monitoring Scheme (eBMS) - covering 81% of the EU-MS. Data is collected following standardized protocols on a yearly basis and annually reported at exact locations or 1x1km - 5x5 km grid cells. The minimum sampling unit is in most cases adequate to generate the EBV at the defined spatial resolution (10x10km - 50x50km). In addition, a new European monitoring scheme is beeing implemented at the European Pollinator Monitoring scheme (EUPoMS) aiming to monitor at the European scale key pollinator species covered by the EBV and some priority invertebrates. Main monitoring gaps in the generation of the EBV "Species abundances of butterflies" include the lack of an ongoing European integration initiative able to produce the EBV, lack of taxonomic coverage and of long-term data, low spatial coverage density, and lack of data availability. Specifically, long-term time series (≥10 years) are available for only 37% of the EU-MS. EUPoMS was only implemented in the United Kingdom and thus the taxonomic coverage in incomplete for all EU-MS. The density of sampling sites is likely to be adequate to generate the EBV at least at the lower desired spatial resolution (50x50km) for only 15% EU-MS. Finally, the raw data is freely available upon request under the signature of a license agreement but only for the countries officially covered by the eBMS. EUPoMS data is not available yet but will be open.
EBV characteristics (target)	
ID	50
Realm	Terrestrial
Class	Species populations
Name	Species distributions of terrestrial priority invertebrates and key pollinators
Step in identification process	Internal review process
Definition	The presence/absence or probability of occurrence of priority invertebrates and key pollinator species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	- Priority invertebrates as listed in the Annex II and Annex IV of the Habitats Directive - Key pollinator species as specified by the EU Pollinator Monitoring Scheme (EUPoMS)
Current monitoring	
Integration initiative **[eBMS and EUPoMS]**	There are two European monitoring initiatives collecting data that could provide data to the generation of this EBV: The European Butterfly Monitoring Scheme (eBMS, https://butterfly-monitoring.net/) and the European Pollinator Monitoring scheme (EUPoMS, https://wikis.ec.europa.eu/pages/viewpage.action?pageId=23462107). The **eBMS** is an ongoing monitoring scheme involving a large network of volunteers and scientists (>100,000) to collect abundance data for > 312 butterfly and moth species. It also collects data of other pollinator species (e.g. bumblebees) but only in a small proportion of the transects and the quality of the data is highly variable.

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	The **EUPoMs** is a new monitoring scheme that as being prepared to collect abundance data of systematic surveys of key pollinators, independently from eBMS, at the European level. **EUPoMs** will not integrate existing data. Although the EUPoMs proposal has identified more than 76 pollinator monitoring schemes already collecting pollinators' data across Europe, the variety of sampling methods used makes it difficult to combine the already existing data in these programs to generate pollinator indicators or to estimate abundance trends at the European level.
Country coverage **Very-High [81% EU-MS]**	**eBMS.** There are 29 Butterfly Monitoring Schemes (BMS): - 19 BMS operating across **16 EU-MS:** Austria - AUBMS; Austria (AUBMS; Viel-Falter – VFBMS); Belgium (Flanders – BEBMS); Croatia (HRBMS); Czech Republic (CZBMS); Estonia (EEBMS); Finland (FIBMS); France (FRBMS); Germany (DEBMS); Hungary (HUBMS); Ireland (IRBMS); Italy (ITBMS); Luxembourg (LUBMS); Portugal (PTBMS); Slovenia (SIBMS); Spain (Catalonia - ES-CTBMS, Zerynthia - ES-CBBMS, Spain excluding Catalonia and Zerynthia – ESBMS); Sweden (SEBMS); Netherlands (NLBMS). - 4 BMS operating in **4 non EU-MS**: Andorra (BMSAnd), Norway (NOBMS); Switzerland (CHBMS); United Kingdom (UKBMS). - **1 EU-MS** with subnational coverage only (Belgium). - **5 EU-MS** with a BMS but not officially covered by the eBMS: Bulgaria (BUBMS); Latvia (LVBMS); Lithuania (LTBMS); Malta (MABMS); Romania (ROBMS) and for Estonia (EEBMS). - **5 EU-MS** without BMS: Cyprus, Denmark, Greece, Poland, Slovakia. **EUPoMS.** The Pilot EUPMS monitoring was developed by the SPRING project (https://wikis.ec.europa.eu/display/EUPKH/SPRING+project) in the United Kingdom.
Taxonomic/ Ecosystem coverage **Very-High [0% EU-MS]**	**eBMS.** All butterflies and moths species. It also collects data of other pollinator species (e.g. bumblebees) but only in a small proportion of the transects and the quality of the data is highly variable. **EUPoMS.** All key pollinator species, including bees, butterflies and hoverflies. Not all terrestrial priority invertebrates are covered (**partial gap**).
Standardized monitoring **Very-High [81% EU-MS]**	**eBMS.** BMS uses a standardized protocol. The basic and more important methodology of eBMS is the transect counts where we get the most robust information on the butterfly population. Butterfly Monitoring is done during the butterfly season. Ideally, transects should be walked every week, but if this is not possible, they should be walked as often as possible. All the Butterfly Monitoring Schemes (BMS) are made by many different transects in their country. However, due to the difficulty of applying transects in some countries and remote areas, a new methodology 15-min Counts was created to reinforce the monitored data and give more flexibility in its collection. With 15-min counts are expected to increase the butterfly monitored data in Europe, but a BMS should always have as a basis an important number of transects (details in https://butterfly-monitoring.net/sites/default/files/Pdf/Butterfly%20Transect%20Counts-Manual%20v1.pdf). **EUPoMS.** Pilot EUPMS monitoring developed by the SPRING project (https://wikis.ec.europa.eu/display/EUPKH/SPRING+project).

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Time-series data **Very-High [81% EU-MS]**	**eBMS.** Time-series [1976-onwards]. The first BMS began in the UK in 1976 (UKBMS), and since then, this methodology has been adopted in many other European countries to monitor butterflies. **EUPoMS.** Start year: 2022-2023 (pilot UK), 2023 full scheme (some countries) and 2024 onwards (all countries).
Long-term monitoring **Low [37% EU-MS]**	**eBMS.** Long time-series (>10 years) not available for 5 MS: Austria, Croatia, Hungary, Italy, Portugal and Spain. Unknown temporal extent for the 10 MS with a BMS but not officially covered by the eBMS and Estonia. **EUPoMS.** Temporal scale: several sampling rounds per year, scheme expected to continue on an annual basis.
Ongoing monitoring **Very-High [81% EU-MS]**	**eBMS.** All the BMS are expected to be ongoing. **EUPoMS.** Monitoring scheme is only ongoing in the United Kingdom.
Sampling frequency **Low [56% EU-MS]**	**eBMS.** Annually (every week-month during the butterfly season) for all EU-MS with a BMS: Andorra, Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Ireland, Luxemburgo, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, and United Kingdom. - 5 years: Switzerland (**partial gap**) - Unknown sampling frequency for the countries with a BMS but not officially covered by the eBMS. **EUPoMS.** Annually (several sampling rounds per year) and assessments every three years.
Spatial Coverage Density **Very-Low [0% EU-MS]**	**eBMS.** The network involves more than 10,816 transects unevenly distributed across countries as from the map of the density of Butterfly Monitoring transects visited per 50x50 km grid cells across all schemes that have contributed to the eBMS database in 2020 (https://butterfly-monitoring.net/bms-schemes). The density of sampling sites is likely to be adequate to generate the EBV at least at the lower desired spatial resolution (50x50km) for 6 countries: Germany, Ireland, Luxemburg, Netherlands, Switzerland, and the United Kingdom (**partial gap**). The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution for the remaining countries (**gap**). **EUPoMS.** Number of sites to be defined but expected to be >2,000 across the EU+UK.
Minimum sampling unit **Moderate [59% EU-MS]**	**eBMS.** Exact location of the transect (1-3 km transects). All the MS with a BMS has the minimum target spatial resolution (10x10km). Unknown minimum sampling unit for the 5 MS with a BMS but not officially covered by the eBMS (Bulgaria – BUBMS, Latvia – LVBMS, Lithuania – LTBMS, Malta – MABMS, Romania – ROBMS). **EUPoMS.** Exact location of the transect.
Raw data access **Very-Low [0% EU-MS]**	**eBMS.** The availability of raw data varies across countries. eBMS database has data from 21 BMS in 19 different countries. Raw data is freely available upon request through the signature of a license agreement (https://butterfly-monitoring.net/sites/default/files/eBMS%20DATA%20REQUEST%20POLICY%20%3D%20Annex%20B%20v2019%2004%2001.pdf). All Depositors (National BMS) are informed of requests for use of their data and will be given an option for involvement in any resulting publications (**partial gap**). Raw data is open and freely

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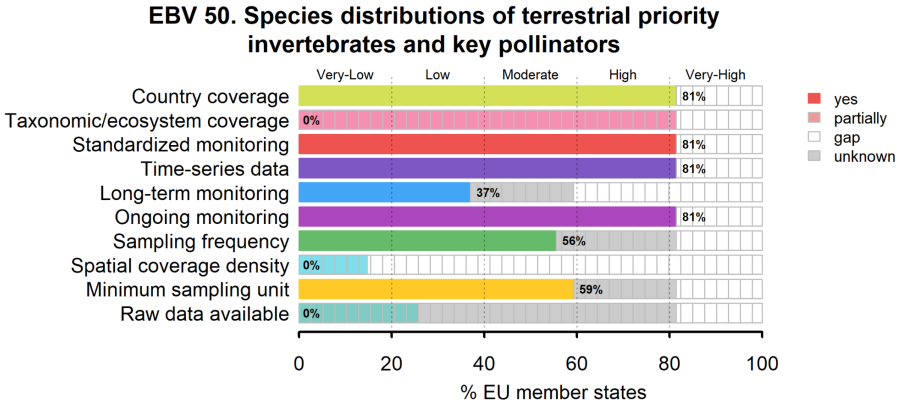
	available for Finland. Unknown raw data available for the BMS is not officially covered by the eBMS. **EUPoMS.** Data is not available yet but will be open.
Monitoring gaps	
Figure 50.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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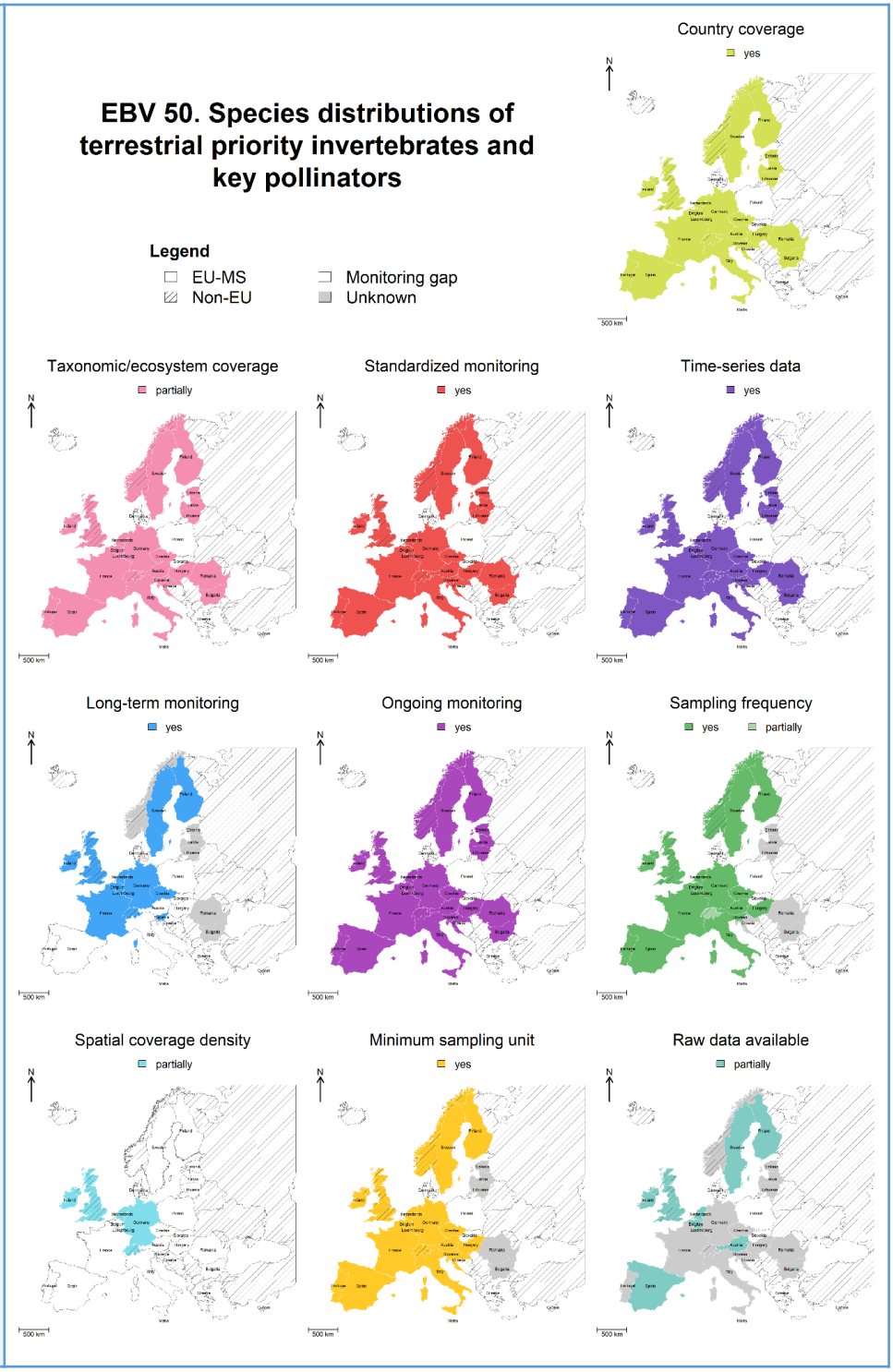

Figure 50.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of terrestrial plants**
Summary	Monitoring databases on species distributions of terrestrial plants across Europe and adjacent areas is gathered by the European Vegetation Archive (EVA). In addition, tree species distribution data in Europe is compiled the European National Forest Inventory Network (ENFIN), which is a pan-European initiative set up in 2003 to harmonise data from National Forest Inventories (NFI). Overall, plant species distribution data flowing for both initiatives are collected following standardised protocols over the covered countries, and long-term (>10 years) data is available for most EU-MS. Sampling frequency is variable among countries and in most cases > than 5 years. The density of sampling sites is likely to be adequate to generate the EBV at least at the lower desired spatial resolution (50x50km) for most of the EU-MS. Monitoring data needed to estimate the EBV is open available are made available upon request for many EU-MS. Main monitoring gaps in the generation of the EBV "Species distributions of terrestrial plants" include a lack of information on the raw data in relation to time-series, ongoing monitoring, sampling frequency and spatial resolution. EVA database is a snapshot of the abundance of vascular plants in vegetation plots mostly sampled over the last decades. It remains unknown if there are time-series data for most of the countries, or if monitoring is ongoing. In addition, information on sampling frequency and sampling unit is scarce and, the density of sampling sites is likely to be too low to permit the production of the EBV at the higher temporal and spatial resolutions desired for priority species. Most of these gaps would be solved with the implementation of a new database - the EVA Database - eSurveyEurope that aims at mobilizing vegetation-plot resurvey data with repeated measurements over time and establishing a collaborative initiative as a basis for nuanced and robust assessment of biodiversity trends on small spatial grains over longer periods in Europe.
EBV characteristics (target)	
ID	51
Realm	Terrestrial
Class	Species populations
Name	Species distributions of terrestrial plants
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of terrestrial vascular plant species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	- Priority species: 1 × 1 km – 10 × 10 km - All vascular plant species: 10 × 10 km – 50 × 50 km
Temporal resolution units	- Priority species: 1 year - All vascular plant species: 3 or 6 years
Taxonomic/ ecosystem focus group	- All European terrestrial vascular plants species included in the European Red List - Priority terrestrial vascular plants as listed in Annex II and Annex IV of the Habitats Directive
Current monitoring	
Integration initiative **[EVA]**	**EVA.** The European Vegetation Archive (EVA, http://euroveg.org/eva-database) is an European initiative of the Working Group European Vegetation Survey (EVS) of the International Association for Vegetation Science (IAVS) to integrative databases of vegetation plots across Europe and adjacent areas. By April 2021, EVA comprised 99 national and supranational vegetation plots databases and contains 1,804,985 vegetation plots from 53 countries. At the end of 2021, the EVA launched the EVA Database - eSurveyEurope (http://euroveg.org/eva-database-re-survey-europe), an

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	initiative that seeks to mobilize vegetation-plot resurvey data with repeated measurements over time and establishing a collaborative initiative as a basis for nuanced and robust assessment of biodiversity trends on small spatial grains over longer periods in Europe. **ENFIN**. The European National Forest Inventory Network (ENFIN, http://enfin.info/) is a pan-European initiative set up in 2003 to harmonise data from National Forest Inventories (NFI) entailing the most comprehensive data set on *in situ* tree species occurrences in Europe. ENFIN provides support and data to other European integration initiatives such as the European Forest Data Centre (EFDCA, https://climate-adapt.eea.europa.eu/en/metadata/portals/efdac-european-forest-data-centre) and more recently to the Forest Information System For Europe (FISE, https://forest.eea.europa.eu/). Products of the data harmonized by ENFIN includes the map of the distribution of 250 tree species across Europe (https://op.europa.eu/en/publication-detail/-/publication/f0e8dc29-7ebe-11ea-aea8-01aa75ed71a1/language-en), some of them collected in the European Atlas of Forest Tree species (https://forest.jrc.ec.europa.eu/en/european-atlas/#:~:text=The%20European%20Atlas%20of%20Forest%20Tree%20Species%20is%20both%20a,richness%20of%20our%20forests%20to).
Country coverage **Very-High [100% EU-MS]**	All European countries have monitoring data on plant species distribution gathered by EVA. From this, there are at least 24 European countries with in situ monitoring distribution data of tree species: Austria, Belgium (Wallonia), Belarus, Bosnia and Herzegovina, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.
Taxonomic/ Ecosystem coverage **Very-High [0% EU-MS]**	Not all the vascular plant species included in the European Red List and the priority terrestrial vascular plants are sampled in each monitoring program (**partial gap**).
Standardized monitoring **Very-High [100% EU-MS]**	Vegetation surveys follow standardised monitoring methods in each covered country.
Time-series **Moderate [56% EU-MS]**	EVA database is a snapshot of the abundance of vascular plants in vegetation plots mostly sampled over the last decades. Time-series data is only reported to Latvia, Poland, Switzerland and United Kingdom. It remains unclear if countries have time-series data. However, all countries covered by ENFIN but Greece have time series data [1919-onwards].
Long-term monitoring **Very-High [96% EU-MS]**	Long-term data. All covered countries add monitoring data for more than 10 years (11-102 years).
Ongoing monitoring **Very-High [93% EU-MS]**	Ongoing monitoring is lacking for most countries covered by EVA. EVA database is a snapshot of the abundance of vascular plants in vegetation plots mostly sampled over the last decades. Ongoing monitoring is reported to Switzerland but it remains unclear if other countries have ongoing monitoring schemes. However, NFI monitoring is ongoing in all covered countries but Romania. Current monitoring status is unknown for Greece, Iceland and North Macedonia.

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Sampling frequency **Very-Low [7% EU-MS]**	**Seasonally/Annually (EVA)**: Latvia; Russia; Slovenia; and United Kingdom. The sampling frequency is likely to be adequate to generate the EBV at the desired temporal resolution for all vascular species (3-6 years) and priority species (1-year). **5 years (EVA and NFI):** Belarus, Denmark, Hungary, Iceland, Ireland, Lithuania, Poland, Sweden. The sampling frequency is likely to be adequate to generate the EBV at the desired temporal resolution for all vascular species (3-6 years) but not for priority species (1-year) (**partial gap**). **6-10 years: EVA** and **NFI**: Switzerland. **NFI:** Austria, Czech Republic, Estonia, Finland, France, Latvia, Netherlands, Norway, Portugal, Slovak Republic, Slovenia, Spain, Switzerland, Croatia, Czech Republic. It is unclear if the sampling frequency is adequate to provide the EBV at the desired temporal resolution for all vascular species (3-6 years), but it is not adequate for priority species (1-year) (**partial gap**). **>10-years (NFI):** Belgium, Germany, Italy, Latvia, Luxembourg, United Kingdom. This is not adequate to reach the EBV at the desired temporal resolution of 3 or 6 years (**gap**). Unknown sampling frequency in for the remaining countries.
Spatial Coverage Density **Very-High [93%% EU-MS]**	Monitoring data in EVA databases involves the sample of at least 1,383,619 sampling sites unequally distributed across Europe, with the highest concentration in Central and Northwest Europe, where the density of sampling sites is likely to be adequate to generate the EBV at least at the 50x50 km resolution (**partial gap**). Major gaps in spatial coverage (<1plots/100 km², Chytrý M. et al. 2016, http://euroveg.org/eva-database) are in Belarus, Bosnia and Herzegovina, Sweden, Iceland, Malta, Moldova, Russia, Sweden and Tukey, where the density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution (**gap**). NFI monitoring involves the sample of at least 768,228 sampling sites across Europe. The density of sampling sites is likely to be adequate to generate the EBV but only at the 50x50 km resolution (**partial gap**) as this is the resolution of the map the distribution of 250 tress species across Europe.
Minimum sampling unit **Very-High [100% EU-MS]**	Raw data with different spatial resolutions: Exact locations, and grid cells: 1x1km, 10x10 km. Unknown spatial resolution for some databases. **Exact location/1x1km: (EVA) -** Albania, Austria, Belarus, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Italy, Latvia, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Spain, Slovenia, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom. **(NFI) -** Croatia, Italy, Luxembourg, Netherlands, Spain, and Switzerland. **2x2km - 4x4 km (NFI)** - Czech Republic, Denmark, Germany, Ireland, Poland, Romania, Serbia, Slovak Republic, Slovenia. **10x10km (EVA):** Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Iceland, Ireland, Italy, Lithuania, Latvia, Malta, Montenegro, Netherlands, Norway, North Macedonia, Poland, Portugal, Romania, Russia, Serbia, Slovenia, Slovak Republic, Spain, Sweden, Turkey, Ukraine, United Kingdom. All countries (but Liechtenstein, Monaco, San Marino) have data to which the minimum sampling unit is likely to be adequate to provide the EBV at the desired

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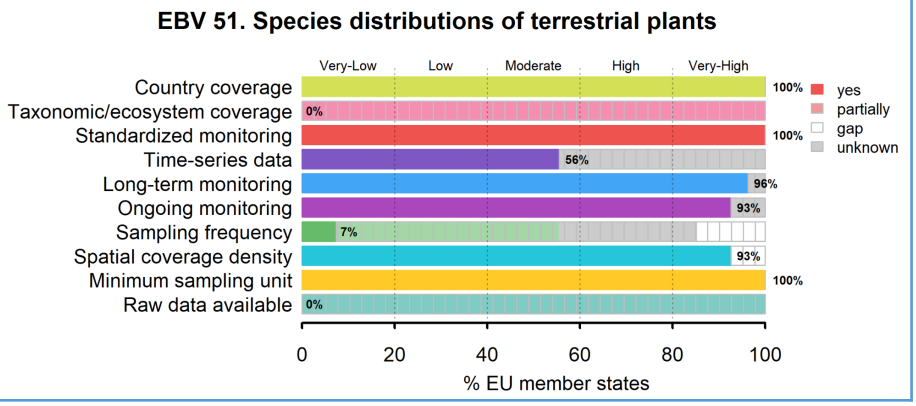
	spatial resolution for both all vascular plant species (10x10km - 50x50km) and priority species at the resolution (1x1km-10x10km).
Raw data access **Very-High [0% EU-MS]**	EVA raw data are openly available or available upon request for all covered countries but it relies on data owners decisions (**partial gap**). NFI raw data are openly available or available upon request for 19 countries: Austria, Belgium, Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Raw data is not available: North Macedonia. Unknown raw data availability for 13 countries: Belarus, Denmark, Greece, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Romania, Serbia, Slovak Republic, Slovenia, Ukraine.
Monitoring gaps	
Figure 51.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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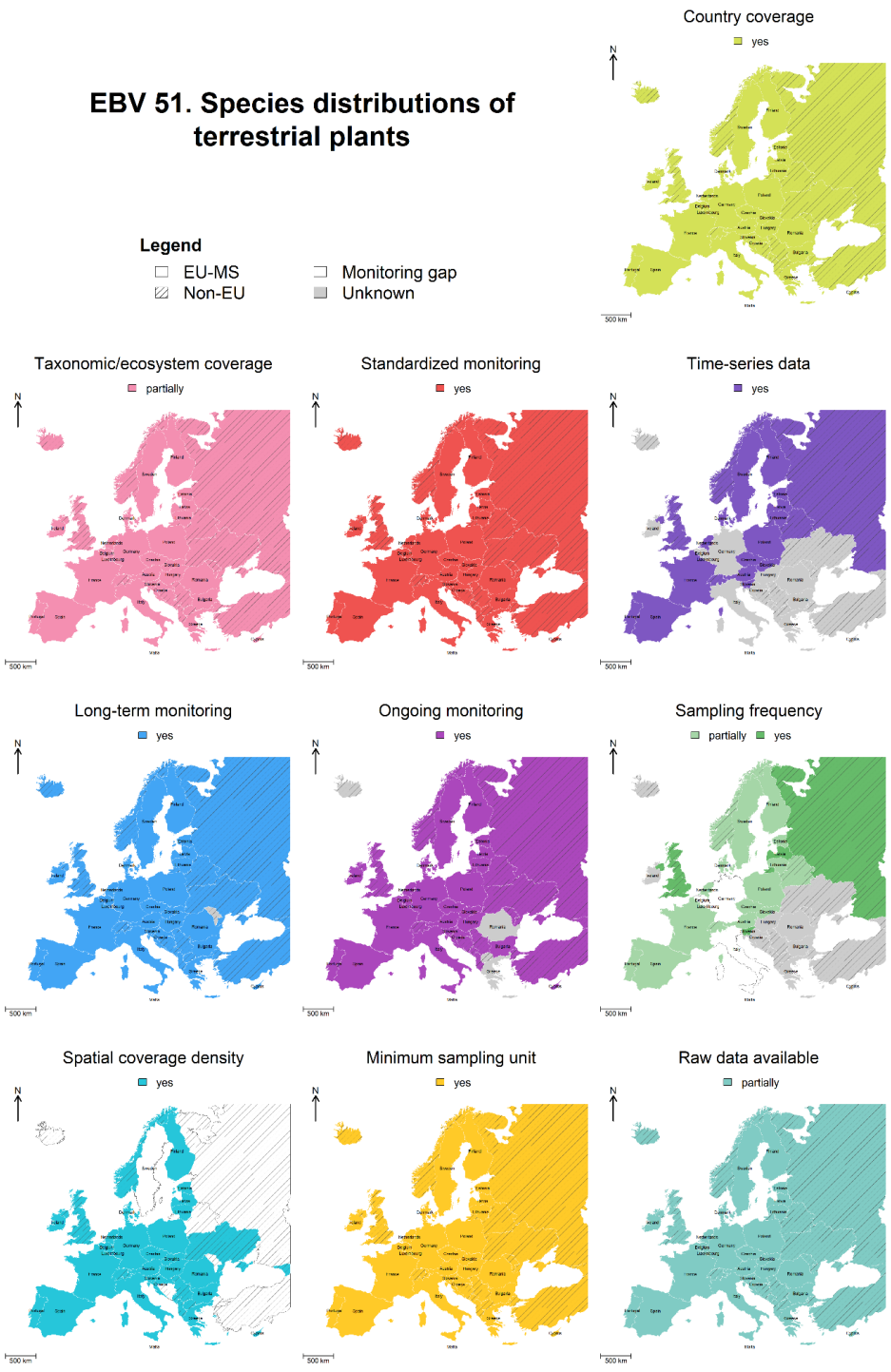
Figure 51.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.



REFERENCES

Chytrý M. et al. 2016. European Vegetation Archive (EVA): an integrated database of European vegetation plots. Applied Vegetation Science 19: 173–180. - https://onlinelibrary.wiley.com/doi/full/10.1111/avsc.12191

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of main trees**
Summary	Monitoring data on Species distributions of main trees is currently flowing to a European initiative - ENFIN - set up in 2003 to harmonise data from National Forest Inventories (NFI). Species distribution data of the main trees are collected following standardised protocols across many EU-MS (89%). Long-term (>10 years) time-series data are available for most EU-MS, while sampling frequency is variable among countries and in most cases > than 5 years. The density of sampling sites and the minimum sampling unit are likely to be adequate to generate the EBV at the desired spatial resolution. Monitoring data needed to estimate the EBV is open available are made available upon request for many EU-MS. Main monitoring gaps in the generation of the EBV "Species distributions of main trees" include low sampling frequency as most countries' sampling frequency <6-years and thus are unlikely to provide the EBV at the desired temporal resolution (3 or 6 years).
EBV characteristics (target)	
ID	52
Realm	Terrestrial
Class	Species populations
Name	Species distributions of main trees
Step in identification process	Expert workshop
Definition	The presence/absence or probability of occurrence of European tree species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Tree species included in the EU-Trees4F dataset (67 species)
Current monitoring	
Integration initiative **[ENFIN]**	The European National Forest Inventory Network (ENFIN, http://enfin.info/) is a pan-European initiative set up in 2003 to harmonise data from National Forest Inventories (NFI) entailing the most comprehensive data set on *in situ* tree species occurrences in Europe. ENFIN provides support and data to other European integration initiatives such as the European Forest Data Centre (EFDCA, https://climate-adapt.eea.europa.eu/en/metadata/portals/efdac-european-forest-data-centre) and more recently to the Forest Information System For Europe (FISE, https://forest.eea.europa.eu/). Products of the data harmonized by ENFIN includes the map of the distribution of 250 tree species across Europe (https://op.europa.eu/en/publication-detail/-/publication/f0e8dc29-7ebe-11ea-aea8-01aa75ed71a1/language-en), some of them collected in the European Atlas of Forest Tree species (https://forest.jrc.ec.europa.eu/en/european-atlas/#:~:text=The%20European%20Atlas%20of%20Forest%20Tree%20Species%20is%20both%20a,richness%20of%20our%20forests%20to).

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Country coverage **Very-High [89% EU-MS]**	There are at least 24 European countries with in situ monitoring distribution data of main trees: Austria, Belgium (Wallonia), Belarus, Bosnia and Herzegovina, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.
Taxonomic/ Ecosystem coverage **Very-High [89% EU-MS]**	ENFIN have harmonized data from at least 241 tree species.
Standardized monitoring **Very-High [89% EU-MS]**	Forest inventories follow standardised monitoring methods in all covered countries.
Time-series **Very-High [85% EU-MS]**	Time series [1919-onwards]. All covered countries but Greece have time series data.
Long-term monitoring **Very-High [89% EU-MS]**	Long-term data (11-102 years). All covered countries add monitoring data with more than 10 years.
Ongoing monitoring **Very-High [85% EU-MS]**	Monitoring is ongoing in all covered countries but Romania. Current monitoring status is unknown for Greece, Iceland and North Macedonia.
Sampling frequency **Low [22% EU-MS]**	There are at least 6 countries with sampling frequency **< 6-years**: Belarus, Denmark, Hungary, Iceland, Ireland, Lithuania, Poland, Sweden. 15 countries with a sampling frequency **6-10-years**: Austria, Czech Republic, Estonia, Finland, France, Latvia, Netherlands, Norway, Portugal, Slovak Republic, Slovenia, Spain, Switzerland, Croatia, Czech Republic. For these partial fulfilment of the criteria was considered as it is unlikely to be adequate to reach the EBV at the desired temporal resolution of 3 or 6 years. 15 countries with sampling frequency **>10-years**: Belgium, Germany, Italy, Latvia, Luxembourg, United Kingdom. This is not adequate to reach the EBV at the desired temporal resolution of 3 or 6 years.
Spatial Coverage Density **Very-Low [0% EU-MS]**	NFI monitoring involves the sample of at least 768,228 sampling sites across Europe. The density of sampling sites is likely to be adequate to generate the EBV only at the 50x50 km resolution (**partial gap**) as this is the resolution of the map the distribution of 250 tress species across Europe.
Minimum sampling unit **Moderate [48% EU-MS]**	Raw data with different spatial resolutions: Exact locations, and grid cells < 10 km and this is likely to provide the EBV at the desired spatial resolution (10x10km - 50x50km). Spatial resolution is unknown for 7 countries: Belgium, Germany, Italy, Latvia, Luxembourg, United Kingdom. This is not adequate to reach the EBV at the desired temporal resolution of 3 or 6 years (**gap**)
Raw data access **Moderate [56% EU-MS]**	Raw data is openly available or available upon request for 19 countries: Austria, Belgium, Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Raw data is not available: North Macedonia

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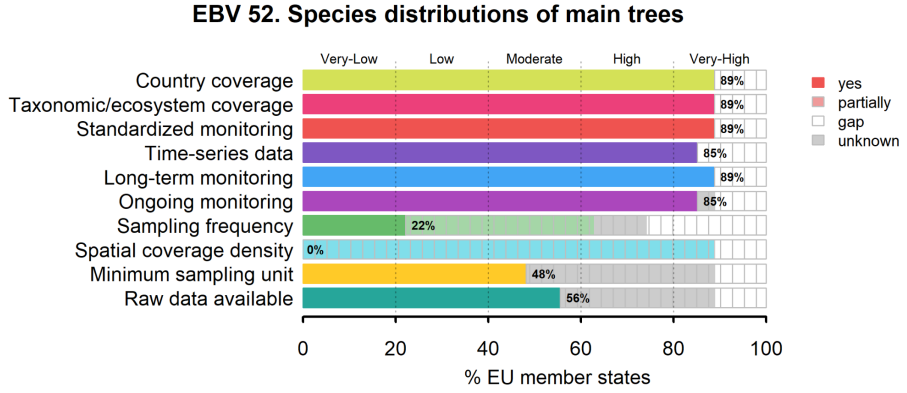
	Unknown raw data availability for 13 countries: Belarus, Denmark, Greece, Hungary, Iceland, Latvia, Lithuania, Luxembourg, Romania, Serbia, Slovak Republic, Slovenia, Ukraine
Monitoring gaps	
Figure 52.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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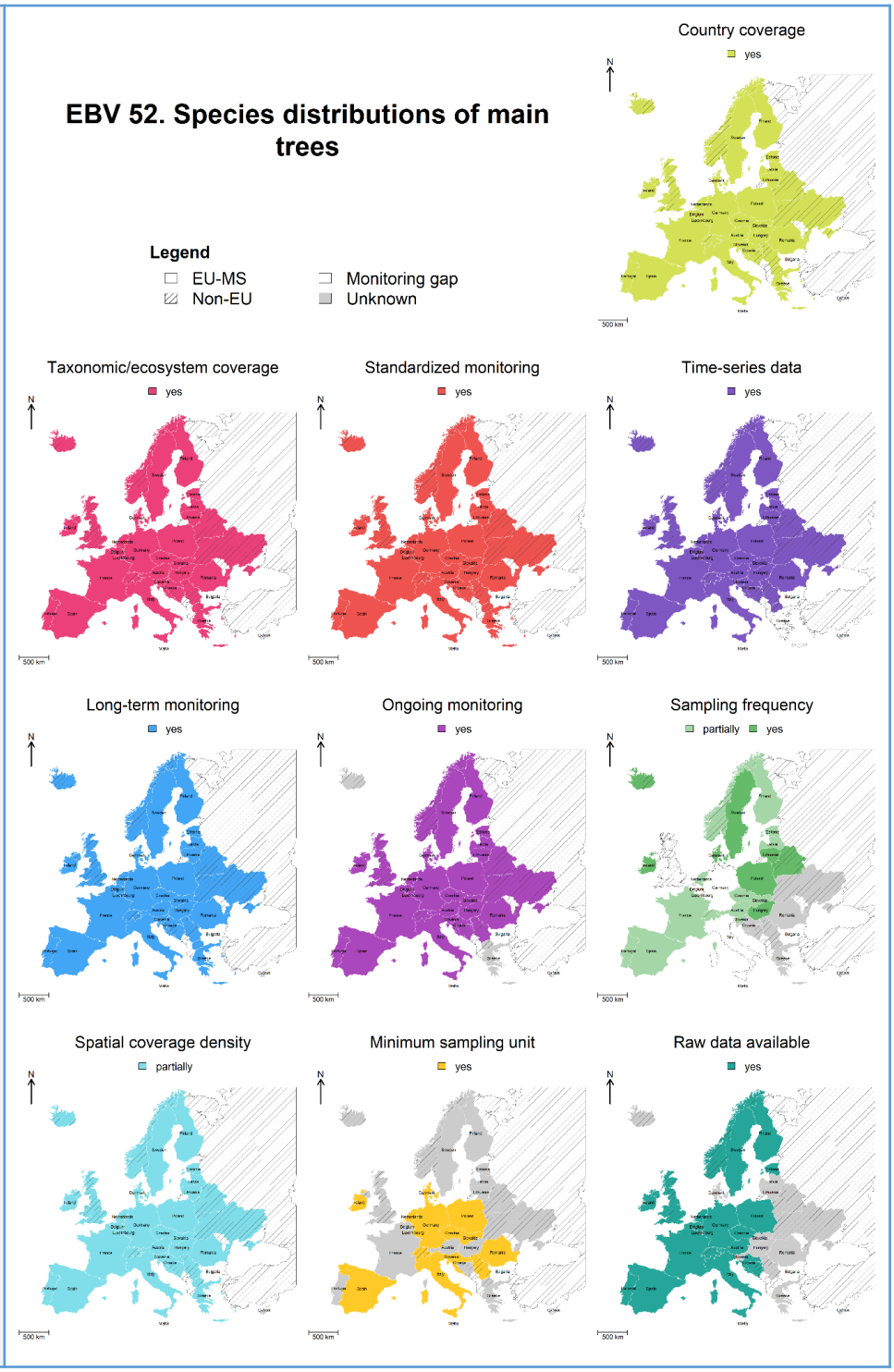

Figure 52.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of lichens (as indicators of pollution)**
Summary	There is no initiative integrating trans-national data able to produce the EBV "Species distributions of lichens (as indicators of pollution)" at the European scale.
EBV characteristics (target)	
ID	53
Realm	Terrestrial
Class	Species populations
Name	Species distributions of lichens (as indicators of pollution)
Step in identification process	Expert workshop
Definition	The presence/absence or probability of occurrence of ecological quality indicator lichen species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Ecological quality indicator lichens as defined in POPLAIR and other sources
Current monitoring	
Integration initiative **[None]**	There is no initiative integrating trans-national data able to produce the EBV "Species distributions of lichens (as indicators of pollution)" at the European scale.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species distributions of invasive alien terrestrial taxa of European concern**
Summary	There is an initiative to collect and harmonise invasive alien species data across Europe, including terrestrial species from Union Concern - **EASIN** (European Alien Species Information Network). EASIN facilitates the exploration of existing Alien Species information from a variety of sources through freely available tools and interoperable web services, compliant with internationally recognized standards. The EASIN GeoDatabase (v9.0- 19.07.22, https://easin.jrc.ec.europa.eu/easin/GeoDatabase) contains occurrence records for more than 14,000 species, across 40 different countries (https://easin.jrc.ec.europa.eu/easin/Catalogue), including 10,169 terrestrial alien species, of which 61 are Invasive Alien Species of Union Concern, over all European countries but Andorra. EASIN species mapping tool (https://easin.jrc.ec.europa.eu/spexplorer/search/) shows the distribution of species at the country level or at 10x10 km grid cells. Data in the EASIN GeoDatabase can be easily accessed and downloaded from the website, while ownership of the data remains within its source, which is properly cited and linked. However, EASIN is not a monitoring network and its data come from a variety of sources, including standardized monitoring programs, occasional observations, data portals, and literature review, making it difficult to collect the country-level information needed to identify monitoring gaps in the generation of the EBV "Species distributions of invasive alien terrestrial taxa of European concern" at the European level. Information on monitoring gaps of invasive alien freshwater taxa of European concern to generate this EBV can be partially inferred from several European initiatives covering different taxa and described in detail for other EBVs: “Species distributions of terrestrial birds”; “Species distributions of all terrestrial mammals”; “Species distributions of terrestrial reptiles”; and “Species distributions of terrestrial plants”.
EBV characteristics (target)	
ID	54
Realm	Terrestrial
Class	Species populations
Name	Species distributions of invasive alien terrestrial taxa of European concern
Step in identification process	User & Policy Needs Assessment
Definition	The presence/absence or probability of occurrence of invasive terrestrial species within contiguous spatial units (grid cells) across the EU over time.
Metric	- Binary presence/absence - Probability of occurrence
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	3 or 6 years
Taxonomic/ ecosystem focus group	Species specified in the List of Invasive Alien Species of Union Concern

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of selected terrestrial disease vectors**
Summary	There is no initiative integrating trans-national data able to produce the EBV "Species abundances of selected terrestrial disease vectors" at the European scale.
EBV characteristics (target)	
ID	55a
Realm	Terrestrial
Class	Species populations
Name	Species abundances of selected terrestrial disease vectors
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of animal vectors within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals - Modeled relative abundance
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	Real-time
Taxonomic/ ecosystem focus group	The taxonomic scope for disease vectors is defined in ECDPC
Current monitoring	
Integration initiative **[None]**	There is no initiative integrating trans-national data able to produce the EBV "Species abundances of selected terrestrial disease vectors" at the European scale.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Species abundances of selected terrestrial crop pests**
Summary	There is no initiative integrating trans-national data able to produce the EBV "Species abundances of selected terrestrial crop pests" at the European scale.
EBV characteristics (target)	
ID	55b
Realm	Terrestrial
Class	Species populations
Name	Species abundances of selected terrestrial crop pests
Step in identification process	User & Policy Needs Assessment
Definition	The estimated count of individuals of crop pests within contiguous spatial units (grid cells) across the EU over time.
Metric	- Estimated count of individuals - Modeled relative abundance
Spatial resolution units	100x100m - 1x1km
Temporal resolution units	Strongly species-dependent
Taxonomic/ ecosystem focus group	The taxonomic scope for crop pests is defined in EU list of priority pests
Current monitoring	
Integration initiative **[NONE]**	There is no initiative integrating trans-national data able to produce the EBV "Species abundances of selected terrestrial crop pests" at the European scale.

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Species traits

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Phenology of fructification of mushrooms and wild fruits**
Summary	There is no initiative integrating trans-national data able to produce the EBV "Phenology of fructification of mushrooms and wild fruits" at the European scale.
EBV characteristics (target)	
ID	56
Realm	Terrestrial
Class	Species traits
Name	Phenology of fructification of mushrooms and wild fruits
Step in identification process	User & Policy Needs Assessment
Definition	The annual timing of the fructification of wild mushroom species and wild fruits within contiguous spatial units (grid cells) across the EU over time.
Metric	Probability of the start/end date, presence/absence, abundance, seasonal amplitude and duration of fructification.
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	1 week
Taxonomic/ ecosystem focus group	- Wild mushroom species of commercial and recreational significance - Wild fruits of trees and shrubs
Current monitoring	
Integration initiative **[NONE]**	There is no initiative integrating trans-national data able to produce the EBV "Phenology of fructification of mushrooms and wild fruits" at the European scale.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Phenology of flowering and leaf senescence**
Summary	There is no initiative integrating trans-national data able to produce the EBV "Phenology of flowering and leaf senescence" at the European scale.
EBV characteristics (target)	
ID	57
Realm	Terrestrial
Class	Species traits
Name	Phenology of flowering and leaf senescence
Step in identification process	User & Policy Needs Assessment
Definition	The annual timing of flowering and leaf senescence of European flowering plants and deciduous trees within contiguous spatial units (grid cells) across the EU over time.
Metric	Species-specific phenology metrics such as: - Day of first flowering/senescence - Day of maximum flowering/senescence - Seasonal amplitude - Length of season
Spatial resolution units	10x10km - 50x50km
Temporal resolution units	1 week-1 month
Taxonomic/ ecosystem focus group	Flowering plants and deciduous trees
Current monitoring	
Integration initiative **[None]**	There is no initiative integrating trans-national data able to produce the EBV "Phenology of flowering and leaf senescence" at the European scale.

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Phenology of migration of terrestrial birds**
Summary	Monitoring data on phenology of migration of terrestrial birds able to produce the EBV "Phenology of migration of terrestrial birds" at the European scale is currently flowing to **EURING** and **EuroBirdPortal** to produce **The Eurasian African Migration Atlas** and the **Migration Mapping Tool 2022**. The Eurasian African Migration Atlas provides interactive migration maps for 300 species using ringing data collected all year round by EURING following standardized protocols at exact locations and involves ongoing long-term time-series updated on a yearly basis in most EU-MS. The Migration Mapping Tool is a joint initiative by EURING, EBP, EFSA to provide information of the migratory connectivity of 50 bird species in Europe, primarily to inform management of Avian Influenza outbreaks and the risks of another disease transmission by birds. EBP data is stored in the EBP central data repository aggregated at 10x10 km resolution. Main monitoring gaps in the generation of the EBV "Phenology of migration of terrestrial birds" include lack of: taxonomic coverage, standardised monitoring, spatial coverage density, and data availability. While the EURING data is based on well stablished standirtised field protocols, only a small part of the EBP data is collected following standardized monitoring protocols. Monitoring does not cover all migratory species. The network of sites is likely to be sufficiently dense to produce the EBV at the desired spatial resolution (10x10km) but only for a subset of species. EURING and EBP data are available upon request, but EBP dada access requires authorization from national owners.
EBV characteristics (target)	
ID	58a
Realm	Terrestrial
Class	Species traits
Name	Phenology of migration of terrestrial birds
Step in identification process	User & Policy Needs Assessment
Definition	The annual timing of arrival and departure of European terrestrial migratory bird species at breeding, staging and wintering sites over time.
Metric	Migration phenology metrics such as: - Day of arrival - Day of departure - Length of stay
Spatial resolution units	10x10km
Temporal resolution units	1 week (traits derived from weekly distribution data)
Taxonomic/ ecosystem focus group	Migratory bird species defined as full migrants in the European Red List
Current monitoring	

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

Integration initiative **[EURING, EuroBirdPortal]**	Monitoring data on phenology of migration of terrestrial birds is currently flowing to **EURING** and **EuroBirdPortal** to produce **The Eurasian African Migration Atlas** and the **Migration Mapping Tool 2022**. The **EURING** (https://euring.org/) is the coordinating organisation for European bird ringing schemes. The organization collects data in the EURING Data Bank (**EDB**, https://euring.org/node/4), which holds a high proportion of the ringing recovery data that have been gathered by bird ringing schemes throughout Europe and along the Eurasian African flyway. The databank is hosted by the British Trust for Ornithology. The data are computerised according to standard protocols that are used by all EURING schemes. EURING data was used to produce the Eurasian African Migration Atlas (https://migrationatlas.org/about), encompassing the flyways between Eurasia and Africa. Movements in time and space of **300 bird species** are mapped and analysed drawing on data gathered by European Ringing Schemes over more than a century and collated by the EURING databank. The **EuroBirdPortal** (**EBP**, https://eurobirdportal.org/) is a European integration initiative gathering data from online portals to map large-scale spatio-temporal patterns of bird distributions within 30x30 km grid cells on a weekly basis. EBP obtains year-round data from unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases even no protocol (casual observations). However, data is stored in the EBP central data repository aggregated at 10x10 km resolution. Data from **EURING** Ringing Schemes and bird recording portals contributing to EuroBirdPortal are used to build The Migration Mapping Tool 2022 (https://euring.org/research/migration-mapping) is a joint initiative by EURING, EBP, EFSA to provide information of the migratory connectivity of 50 bird species in Europe, primarily to inform management of Avian Influenza outbreaks and the risks of another disease transmission by birds.
Country coverage **Very-High [100% EU-MS]**	41 European countries report species abundance data to **EURING:** Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and United Kingdom. All European countries report species abundance data to **EBP.**
Taxonomic/ Ecosystem coverage **Very-Low [0% EU-MS]**	Movements in time and space of 300 bird species are mapped and analysed by the **Eurasian African Migration Atlas**. Migratory connectivity of 50 bird species in Europe are available through the **Migration Mapping Tool 2022.** **EBP** has the potential to collect data on all bird species occurring in Europe but, by 2023, data was only available for 137 species. It is possible that not all species detected in a given square are reported (e.g. incomplete lists) **(partial gap).**
Standardized monitoring **Very-High [96% EU-MS]**	**EURING** monitoring is based on standardised fieldwork protocols to collect count data on a seasonal basis (breeding, wintering and migration). **EBP** monitoring is based on unstructured but intensive and widespread activities of birdwatchers following simple standardised protocols (e.g. complete lists), or in some cases, even no protocol (casual observations) obtained year-round. Only a small part of the data is collected following standardized monitoring protocols (**partial gap**).
Time-series	**EURING:** Times-series [1889-ongoing]. **EBP:** Times-series [2003-ongoing].

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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Very-High [100% EU-MS]	
Long-term monitoring **Very-High [93% EU-MS]**	The first modern bird ringing took place in Denmark in 1889. The first national ringing schemes developed over the following 20 years and there are now some 49 European Ringing Schemes that are members of EURING. EBP longest-time series is from 2003.
Ongoing monitoring **Very-High [100% EU-MS]**	**EURING** and **EBP** are both ongoing.
Sampling frequency **Very-High [100% EU-MS]**	Seasonally/Annually. **EURING:** higher than the EBV temporal resolution (3 or 6 years) Daily. **EBP.** The local online portals collect most of their data through mobile apps in near-real time or shortly after it has been recorded in the field and the data is transferred to the EBP on a daily basis. Altogether, EURING and EBP data can be used to provide a timely estimation the phenology of migratory terrestrial bird species across Europe.
Spatial Coverage Density **Very-Low [0% EU-MS**	**EURING:** Bird abundance data are collected in sampling points unevenly distributed in each country. The density of sampling sites is likely to be too low to permit the production of the EBV at the higher spatial resolution (10x10km). **EBP:** Bird count data of ca. 137 are collected in transects or sampling points. Although the maps featured in the EBP viewer (www.eurobordportal.org) are aggregated by week and 30x30 km, data is stored in the EBP central data repository aggregated at 10x10 km resolution. The network of sites is sufficiently dense to produce the EBV at the lower spatial resolution (10x10km). Altogether, the network of sites is likely to be sufficiently dense to produce the EBV at the desired spatial resolution (10x10km) but only for a subset of species (**partial gap**).
Minimum sampling unit **Very-High [100% EU-MS]**	**EURING:** Exact location. **EBP:** 10x10km. Data is aggregated at 10x10 km grid cells. Altogether, monitoring data collected from the different schemes are likely to be adequate to generate the EBV at the desired spatial resolution 10x10km.
Raw data access **Very-Low [0% EU-MS]**	**EURING** data are available upon request. **EBP** is available upon request and subject to agreement by National coordinators who hold the ownership of data, but just one centralized data request to should be done as data is already centralized in the EBP databank (authorizations by national owners are coordinated by EBP) (**partial gap**). Overall, data is only partially available.
Monitoring gaps	

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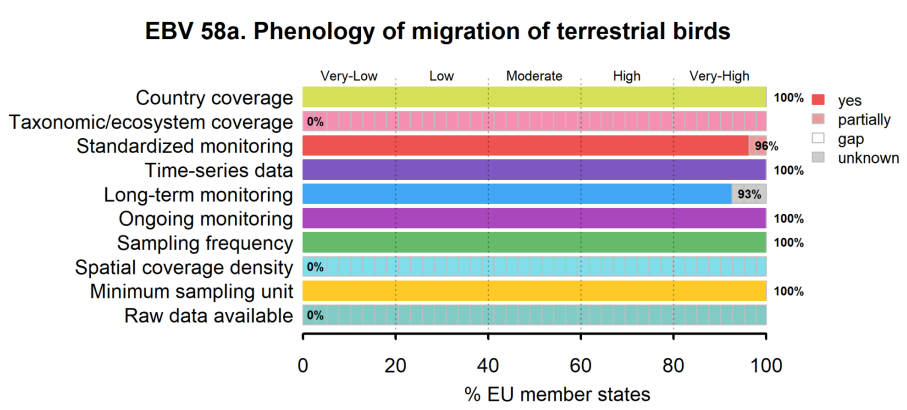
Figure 58a.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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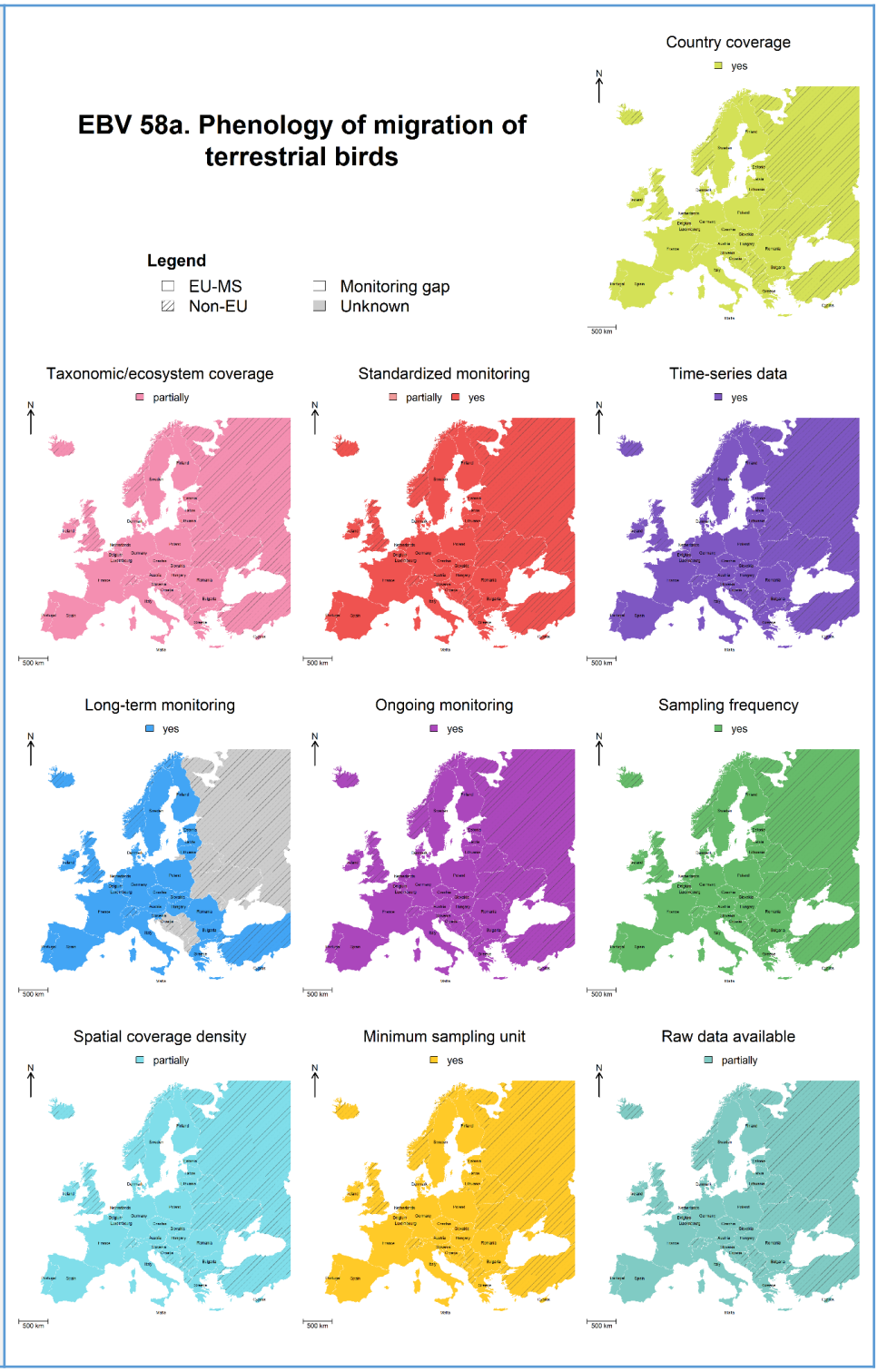

Figure 58a.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Phenology of the emergence of butterflies**
Summary	Phenology of the emergence of butterflies is currently monitored by the European Butterfly Monitoring Scheme (eBMS) - covering 81% of the EU-MS. Data is collected following standardised protocols annually (every week-month during the butterfly season) and reported at exact locations or 1x1km - 5x5 km grid cells. The minimum sampling unit is in most cases adequate to generate the EBV at the 10x10km resolution. Main monitoring gaps in the generation of the EBV "Phenology of the emergence of butterflies" include lack of long-term data, low sampling frequency, low spatial coverage density, and lack of data availability. Specifically, long-term time series (≥10 years) are available for only 37% of the EU-MS. The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution (10x10 km). While transects should ideally be walked every week during the butterfly season, all countries collect data at a lower frequency (fortnightly-monthly during the butterfly season). Finally, the raw data is freely available upon request under the signature of a license agreement but only for the countries officially covered by the eBMS.
EBV characteristics (target)	
ID	58b
Realm	Terrestrial
Class	Species traits
Name	Phenology of the emergence of butterflies
Step in identification process	Expert workshop
Definition	The annual timing of seasonal emergence of butterflies within contiguous spatial units (grid cells) across the EU over time.
Metric	The day after which 5% of individuals have emerged
Spatial resolution units	10x10km
Temporal resolution units	1 week (traits derived from weekly distribution data)
Taxonomic/ ecosystem focus group	Priority butterfly species listed in the Annex II and Annex IV of the Habitats Directive
Current monitoring	
Integration initiative **[eBMS]**	There is currently one European monitoring scheme involving a large network of volunteers and scientists (>100,000) to produce the European Butterfly Monitoring Scheme (eBMS, https://butterfly-monitoring.net). The **eBMS** is an ongoing monitoring scheme to collect abundance data for > 312 butterfly and moth species.
Country coverage **Very-High [81% EU-MS]**	There are 29 Butterfly Monitoring Schemes (BMS): - 19 BMS operating across **16 EU-MS:** Austria - AUBMS; Austria (AUBMS; Viel-Falter – VFBMS); Belgium (Flanders – BEBMS); Croatia (HRBMS); Czech Republic (CZBMS); Estonia (EEBMS); Finland (FIBMS); France (FRBMS); Germany (DEBMS); Hungary (HUBMS); Ireland (IRBMS); Italy (ITBMS); Luxembourg (LUBMS); Portugal (PTBMS); Slovenia (SIBMS); Spain (Catalonia - ES-CTBMS, Zerynthia - ES-CBBMS, Spain excluding Catalonia and Zerynthia – ESBMS); Sweden (SEBMS); Netherlands (NLBMS).

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	- 4 BMS operating in **4 non EU-MS**: Andorra (BMSAnd), Norway (NOBMS); Switzerland (CHBMS); United Kingdom (UKBMS). - **1 EU-MS** with subnational coverage only (Belgium). - **5 EU-MS** with a BMS but not officially covered by the eBMS: Bulgaria (BUBMS); Latvia (LVBMS); Lithuania (LTBMS); Malta (MABMS); Romania (ROBMS) and for Estonia (EEBMS). - **5 EU-MS** without BMS: Cyprus, Denmark, Greece, Poland, Slovakia.
Taxonomic/ Ecosystem coverage **Very-High [81% EU-MS]**	All butterflies species are monitored.
Standardized monitoring **Very-High [81% EU-MS]**	eBMS uses a standardized protocol. The basic and more important methodology of eBMS is the transect counts where we get the most robust information on the butterfly population. Butterfly monitoring is done during the butterfly season. Ideally, transects should be walked every week, but if this is not possible, they should be walked as often as possible. All BMS are made by many different transects in their country. However, due to the difficulty of applying transects in some countries and remote areas, a new methodology 15-min Counts was created to reinforce the monitored data and give more flexibility in its collection. With 15-min Counts is expected to increase the butterfly monitored data in Europe, but a BMS should always have as a basis an important number of transects (details in https://butterfly-monitoring.net/sites/default/files/Pdf/Butterfly%20Transect%20Counts-Manual%20v1.pdf).
Time-series data **Very-High [81% EU-MS]**	Time-series [1976-onwards]. The first BMS began in the UK in 1976 (UKBMS), and since then, this methodology has been adopted in many other European countries to monitor butterflies.
Long-term monitoring **Low [37% EU-MS]**	Long time-series (≥10 years) not available for 5 MS: Austria, Croatia, Hungary, Italy, Portugal and Spain. Unknown temporal extent for the 10 MS with a BMS but not officially covered by the eBMS and Estonia.
Ongoing monitoring **Very-High [81% EU-MS]**	All the BMS are expected to be ongoing.
Sampling frequency **Very-Low [0% EU-MS]**	**- Annually:** Andorra, Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Ireland, Italy, Luxemburgo, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, United Kingdom. While transects should ideally be walked every week during the butterfly season, the highest sampling frequency (weekly) is not always achieved and thus it is unlikely to be possible to generate the EBV at the higher spatial resolution (weekly) (**partial gap**). **- 5 years:** Switzerland (**gap**) - Unknown sampling frequency for the countries with a BMS but not officially covered by the eBMS.
Spatial Coverage Density	The network involves more than 10,816 transects unevenly distributed across countries. as from the map of the density of Butterfly Monitoring transects visited per

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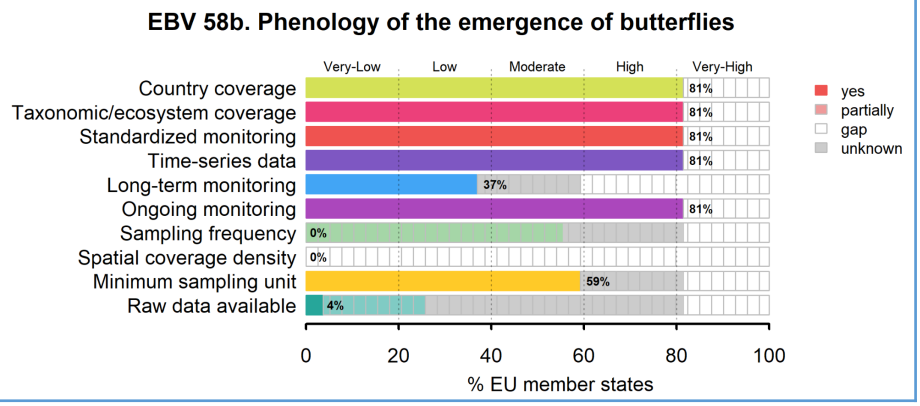
Very-Low [0% EU-MS]	50km grid across all schemes that have contributed to the eBMS database in 2020 (https://butterfly-monitoring.net/bms-schemes). The density of sampling sites is likely to be too low to permit the production of the EBV at the desired spatial resolution (10x10km) (**gap**).
Minimum sampling unit **Moderate [59% EU-MS]**	Exact location of the transect (1-3 km transects). All the MS with a BMS has the higher desired spatial resolution (10x10km). Unknown minimum sampling unit for the 5 MS with a BMS but not officially covered by the eBMS (Bulgaria – BUBMS, Latvia – LVBMS, Lithuania – LTBMS, Malta – MABMS, Romania – ROBMS).
Raw data access **Very-Low [4% EU-MS]**	The availability of raw data varies across countries. eBMS database has data from 21 BMS in 19 different countries. Raw data is freely available upon request through the signature of a license agreement (https://butterfly-monitoring.net/sites/default/files/eBMS%20DATA%20REQUEST%20POLICY%20%3D%20Annex%20B%20v2019%2004%2001.pdf). All Depositors (National BMS) are informed of requests for use of their data and will be given an option for involvement in any resulting publications (**partial gap**). Raw data is open and freely available for Finland. Unknown raw data available for the BMS not officially covered by the eBMS.
Monitoring gaps	
Figure 58b.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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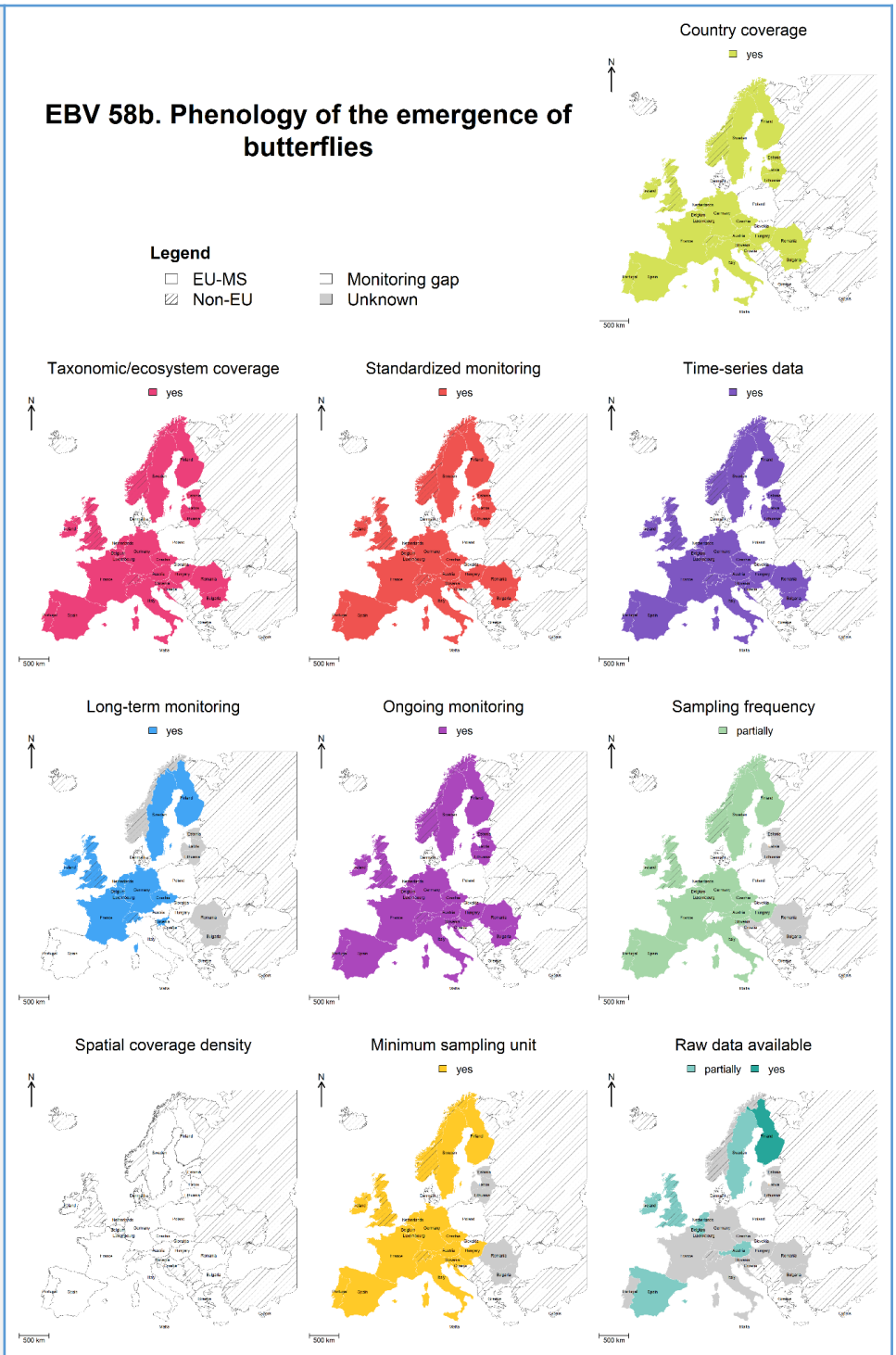

Figure 58b.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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Community composition

REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Community biomass of soil microbes**
Summary	Biomass of the living component of soil organic matter is being monitored by LUCAS (The Land Use/Cover Area frame statistical Survey) since 2018 across all EU-MS. Monitoring is based on a standardised sampling procedure to collect around 0.5 kg of topsoil (0-20 cm) that is dispatched to a central laboratory for physical and chemical analyses of bulk density; soil biodiversity; and the thickness of the organic horizon in organic-rich soil. The the minimum sampling unit is likely to be adequate to generate the EBV at the defined spatial resolution (1x1km). In addition, the sampling frequency (every three years) is likely to be adequate to generate the EBV at the desired temporal resolution (3-years). Monitoring data needed to estimate the EBV is openly available. The main gap in EBV generation is the lack of long-term data thus reducing the ability of the EBV to establish reliable distribution trends in the short term. In addition, the density of sampling sites is unlikely to be representative of the heterogeneity of soil texture and organic carbon content, land use and land cover, topography and soil type to produce the EBV at the desired spatial resolution (1x1 km).
EBV characteristics (target)	
ID	61
Realm	Terrestrial
Class	Community composition
Name	Community biomass of soil microbes
Step in identification process	Internal review process
Definition	Estimated biomass of the living component of soil organic matter (bacteria, fungi and protozoa) within contiguous spatial units (grid cells) across the EU over time.
Metric	- Mass of microbial carbon/mass of dry soil - Mass of microbial carbon/area
Spatial resolution units	1x1km
Temporal resolution units	3 years
Taxonomic/ ecosystem focus group	Soil microbial species
Current monitoring	
Integration initiative **[LUCAS]**	Biomass of the living component of soil organic matter is being monitored by LUCAS (Land Use/Cover Area frame statistical Survey, https://esdac.jrc.ec.europa.eu/projects/lucas). LUCAS is an initiative of the European Statistical Office (EUROSTAT) to organise regular, harmonised surveys across all Member States to gather information on land cover and land use. Monitoring is based on estimates of the area occupied by different land use or land cover types computed on the basis of observations taken at more than 250,000 sample points throughout the EU. In 2009, LUCAS started to sample and analyse the main properties of topsoil in 20,000 points across 23 EU-MS. Since 2018, LUCAS 2018 Soil survey also included: bulk density (i.e. the weight of dry soil in a given soil volume); soil biodiversity; and measurement of the thickness of the organic horizon in organic-rich soil across all EU-MS.

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Country coverage **Very-High [100% EU-MS]**	All European Union Member States are covered by LUCAS soil surveys.
Taxonomic/ Ecosystem coverage **Very-High [100% EU-MS]**	Analysis target Bacteria and Archaea (16S rDNA), Fungi (ITS), Eukaryotes (18S rDNA), Microfauna (nematodes), Mesofauna (arthropods), Macrofauna (earthworms), Metagenomics.
Standardized monitoring **Very-High [100% EU-MS]**	A standardised sampling procedure was used to collect around 0.5 kg of topsoil (0-20 cm). The samples were dispatched to a central laboratory for physical and chemical analyses. The LUCAS 2018 Soil survey includes the most extensive EU assessment of **soil biodiversity**, based on DNA metabarcoding in 1000 points. **Bulk density** is measured at 9000 points selected from the total set based on the heterogeneity of soil texture and organic carbon content, land use and land cover, topography and soil type. A CLHS approach was used to select candidate points, as for the biodiversity. Bulk density data points are coincident with soil biodiversity points to explore the possible correlation between these properties. **Measurement of thickness of the organic horizon in organic-rich soil** is measured at 1470 locations.
Time-series **Very-High [100% EU-MS]**	Time series [2018-onwards].
Long-term monitoring **Very-Low [0% EU-MS]**	Although LUCAS to sample and analyse the main properties of topsoil since 2009, but soil biodiversity surveys only started in 2018 (<10 years).
Ongoing monitoring **Very-High [100% EU-MS]**	LUCAS soil surveys are ongoing in all European Union Member States.
Sampling frequency **Very-High [100% EU-MS]**	The surveys are repeated every three years and thus is likely to provide the EBV at the desired temporal resolution (3-years).
Spatial Coverage Density **Very-Low [0% EU-MS]**	**Soil biodiversity** is measured in 1000 points; **Bulk density** is measured at 9000 points coincident with soil biodiversity points. **Measurement of thickness of organic horizon in organic-rich soil** is measured at 1470 locations. The density of sampling sites is unlikely to be representative of the heterogeneity of soil texture and organic carbon content, land use and land cover, topography and soil type and likely to be adequate to produce the EBV at the desired spatial resolution (1x1 km).
Minimum sampling unit **Very-High [100% EU-MS]**	Surveys are made at exact locations. The minimum sampling unit is likely to be adequate to provide the EBV at the 1x1km spatial resolution.
Raw data access **Very-High [100% EU-MS]**	Raw data is freely available and can be downloaded after prior registration through a Request Form (https://esdac.jrc.ec.europa.eu/content/lucas-2018-topsoil-data).
Monitoring gaps	

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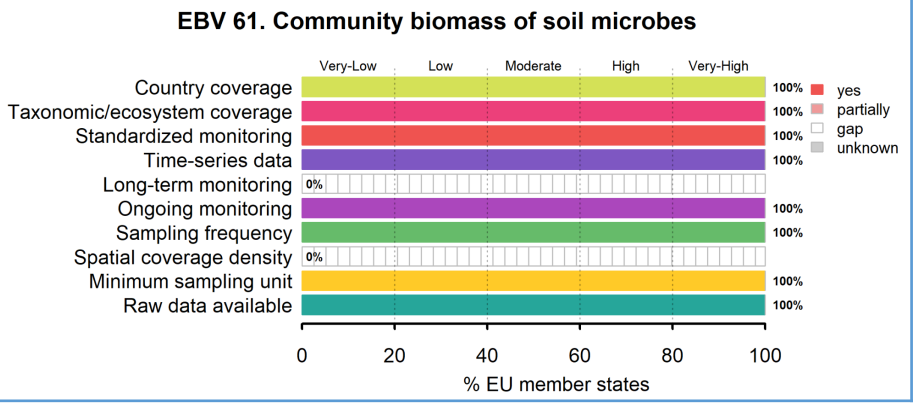
Figure 61.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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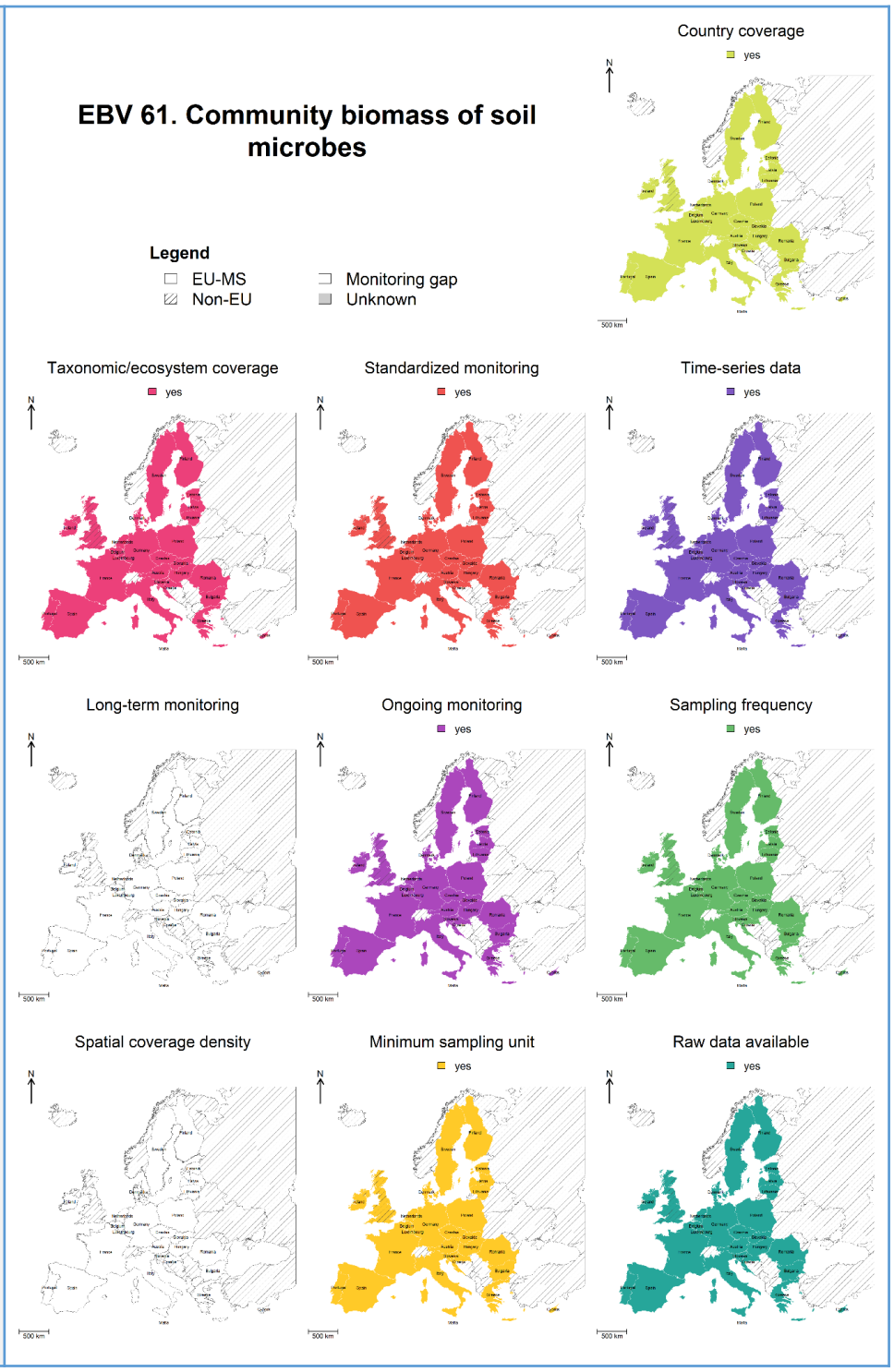

Figure 61.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Community abundance and taxonomic diversity of pollinator insects**
Summary	There is no initiative integrating monitoring data on pollinator insects able to produce the EBV "Community abundance and taxonomic diversity of pollinator insects" at the European scale. However, species abundances of butterflies are currently monitored by the European Butterfly Monitoring Scheme (eBMS) - covering 81% of the EU-MS. Data is collected following standardized protocols on a yearly basis and annually reported at exact locations or 1x1km - 5x5 km grid cells. The minimum sampling unit is adequate to generate the EBV at the NUTS 3 level resolution. In addition, a new European monitoring scheme is beeing implemented at the European Pollinator Monitoring scheme (EUPoMS) aiming to monitor at the European scale key pollinator species covered by the EBV. Main monitoring gaps in the generation of the EBV "Community abundance and taxonomic diversity of pollinator insects" include the lack of an ongoing European integration initiative able to produce the EBV, lack of taxonomic coverage and long-term data, low spatial coverage density, and lack of data availability. Specifically, long-term time series (≥10 years) are available for only 37% of the EU-MS. EUPoMS was only implemented in the United Kingdom and thus the taxonomic coverage in incomplete for all EU-MS. The density of sampling sites is likely to be adequate to generate the EBV at NUTS 3 level spatial resolution for only 15% EU-MS. Finally, the raw data is freely available upon request under the signature of a license agreement but only for the countries officially covered by the eBMS. EUPoMS data is not available yet but will be open.
EBV characteristics (target)	
ID	62
Realm	Terrestrial
Class	Community composition
Name	Community abundance and taxonomic diversity of pollinator insects
Step in identification process	User & Policy Needs Assessment
Definition	Total amount (abundance) of pollinator insects within spatial units over time.
Metric	Predicted number of individuals of pollinator insects
Spatial resolution units	Small regions within countries based on the nomenclature of territorial units for statistics (NUTS) from Eurostat (1166 regions at NUTS 3 level)
Temporal resolution units	1-5 years (rotation across years)
Taxonomic/ ecosystem focus group	All pollinator insects as proposed in the species lists of butterflies, wild bees and hoverflies of the EU Pollinator Monitoring Scheme (EUPoMS)
Current monitoring	
Integration initiative **[eBMS and EUPoMS]**	TThere are two European monitoring initiatives collecting data that could provide data to the generation of this EBV: The European Butterfly Monitoring Scheme (eBMS, https://butterfly-monitoring.net/) and the European Pollinator Monitoring scheme (EUPoMS, https://wikis.ec.europa.eu/pages/viewpage.action?pageId=23462107). The **eBMS** is an ongoing monitoring scheme involving a large network of volunteers and scientists (>100,000) to collect abundance data for > 312 butterfly and moth species. It also collects data of other pollinator species (e.g. bumblebees) but only in a small proportion of the transects and the quality of the data is highly variable.

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	The **EUPoMs** is a new monitoring scheme that as being prepared to collect abundance data of systematic surveys of key pollinators, independently from eBMS, at the European level. **EUPoMs** will not integrate existing data. Although the EUPoMs proposal has identified more than 76 pollinator monitoring schemes already collecting pollinators' data across Europe, the variety of sampling methods used makes it difficult to combine the already existing data in these programs to generate pollinator indicators or to estimate abundance trends at the European level.
Country coverage **Very-High [81% EU-MS]**	**eBMS.** There are 29 Butterfly Monitoring Schemes (BMS): - 19 BMS operating across **16 EU-MS:** Austria - AUBMS; Austria (AUBMS; Viel-Falter – VFBMS); Belgium (Flanders – BEBMS); Croatia (HRBMS); Czech Republic (CZBMS); Estonia (EEBMS); Finland (FIBMS); France (FRBMS); Germany (DEBMS); Hungary (HUBMS); Ireland (IRBMS); Italy (ITBMS); Luxembourg (LUBMS); Portugal (PTBMS); Slovenia (SIBMS); Spain (Catalonia - ES-CTBMS, Zerynthia - ES-CBBMS, Spain excluding Catalonia and Zerynthia – ESBMS); Sweden (SEBMS); Netherlands (NLBMS). - 4 BMS operating in **4 non EU-MS**: Andorra (BMSAnd), Norway (NOBMS); Switzerland (CHBMS); United Kingdom (UKBMS). - **1 EU-MS** with subnational coverage only (Belgium). - **5 EU-MS** with a BMS but not officially covered by the eBMS: Bulgaria (BUBMS); Latvia (LVBMS); Lithuania (LTBMS); Malta (MABMS); Romania (ROBMS) and for Estonia (EEBMS). - **5 EU-MS** without BMS: Cyprus, Denmark, Greece, Poland, Slovakia. **EUPoMS.** The Pilot EUPMS monitoring was developed by the SPRING project (https://wikis.ec.europa.eu/display/EUPKH/SPRING+project) in the United Kingdom.
Taxonomic/ Ecosystem coverage **Very-Low [0% EU-MS]**	**eBMS.** All butterflies and moths species. It also collects data of other pollinator species (e.g. bumblebees) but only in a small proportion of the transects and the quality of the data is highly variable (partiall gap). **EUPoMS.** All key pollinator species, including bees, butterflies and hoverflies.
Standardized monitoring **Very-High [81% EU-MS]**	**eBMS.** BMS uses a standardized protocol. The basic and more important methodology of eBMS is the transect counts where we get the most robust information on the butterfly population. Butterfly Monitoring is done during the butterfly season. Ideally, transects should be walked every week, but if this is not possible, they should be walked as often as possible. All the Butterfly Monitoring Schemes (BMS) are made by many different transects in their country. However, due to the difficulty of applying transects in some countries and remote areas, a new methodology 15-min Counts was created to reinforce the monitored data and give more flexibility in its collection. With 15-min counts are expected to increase the butterfly monitored data in Europe, but a BMS should always have as a basis an important number of transects (details in https://butterfly-monitoring.net/sites/default/files/Pdf/Butterfly%20Transect%20Counts-Manual%20v1.pdf). **EUPoMS.** Pilot EUPMS monitoring developed by the SPRING project (https://wikis.ec.europa.eu/display/EUPKH/SPRING+project).

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Time-series data **Very-High [81% EU-MS]**	**eBMS.** Time-series [1976-onwards]. The first BMS began in the UK in 1976 (UKBMS), since then, this methodology has been adopted in many other European countries to monitor butterflies. **EUPoMS.** Start year: 2022-2023 (pilot UK), 2023 full scheme (some countries) and 2024 onwards (all countries).
Long-term monitoring **Low [37% EU-MS]**	**eBMS.** Long time-series (>10 years) not available for 5 MS: Austria, Croatia, Hungary, Italy, Portugal and Spain. Unknown temporal extent for the 10 MS with a BMS but not officially covered by the eBMS and Estonia. **EUPoMS.** Temporal scale: several sampling rounds per year, scheme expected to continue on an annual basis.
Ongoing monitoring **Very-High [81% EU-MS]**	**eBMS.** All the BMS are expected to be ongoing. **EUPoMS.** Monitoring scheme is only ongoing in the United Kingdom.
Sampling frequency **Moderate [56% EU-MS]**	**eBMS.** Annually (every week-month during the butterfly season) for all EU-MS with a BMS: Andorra, Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Ireland, Luxemburgo, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, and United Kingdom. - 5 years: Switzerland - Unknown sampling frequency for the countries with a BMS but not officially covered by the eBMS. **EUPoMS.** Annually (several sampling rounds per year) and assessments every three years.
Spatial Coverage Density **Very-Low [15% EU-MS]**	**eBMS.** The network involves more than 10,816 transects unevenly distributed across countries as from the map of the density of Butterfly Monitoring transects visited per 50x50 km grid cells across all schemes that have contributed to the eBMS database in 2020 (https://butterfly-monitoring.net/bms-schemes). The density of sampling sites is likely to be adequate to generate the EBV at NUTS 3 level spatial resolution for 6 countries: Germany, Ireland, Luxemburg, Netherlands, Switzerland, and the United Kingdom. **EUPoMS.** Number of sites to be defined but expected to be >2,000 across the EU+UK.
Minimum sampling unit **Moderate [59% EU-MS]**	**eBMS.** Exact location of the transect (1-3 km transects). All the MS with a BMS has the minimum target spatial resolution (10x10km). Unknown minimum sampling unit for the 5 MS with a BMS but not officially covered by the eBMS (Bulgaria – BUBMS, Latvia – LVBMS, Lithuania – LTBMS, Malta – MABMS, Romania – ROBMS). **EUPoMS.** Exact location of the transect.
Raw data access **Very-Low [0% EU-MS]**	**eBMS.** The availability of raw data varies across countries. Raw data is open and freely available for Finland. Raw data is freely available upon request for the 19 BMS operating across 17 MS. Unknown raw data available for the 10 MS with a BMS but not officially covered by the eBMS, or with any BMS (Bulgaria, Cyprus, Denmark, Estonia, Greece, Latvia, Lithuania, Malta, Poland, Romania, Slovakia). **EUPoMS.** Data not available yet but will be open.
Monitoring gaps	

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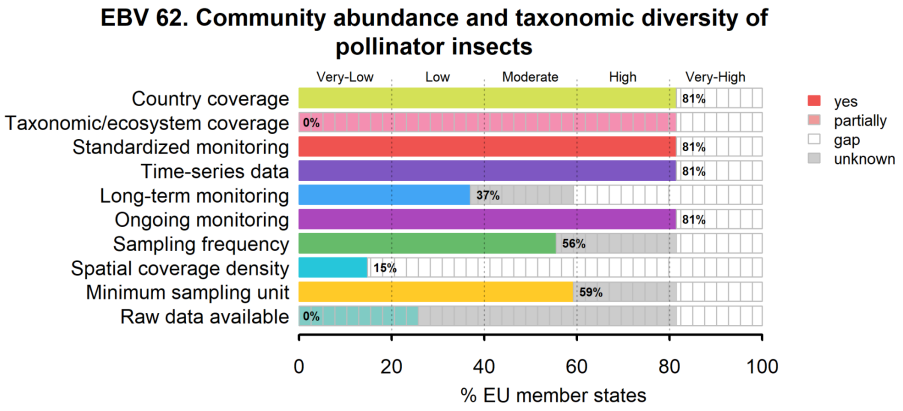
Figure 62.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.



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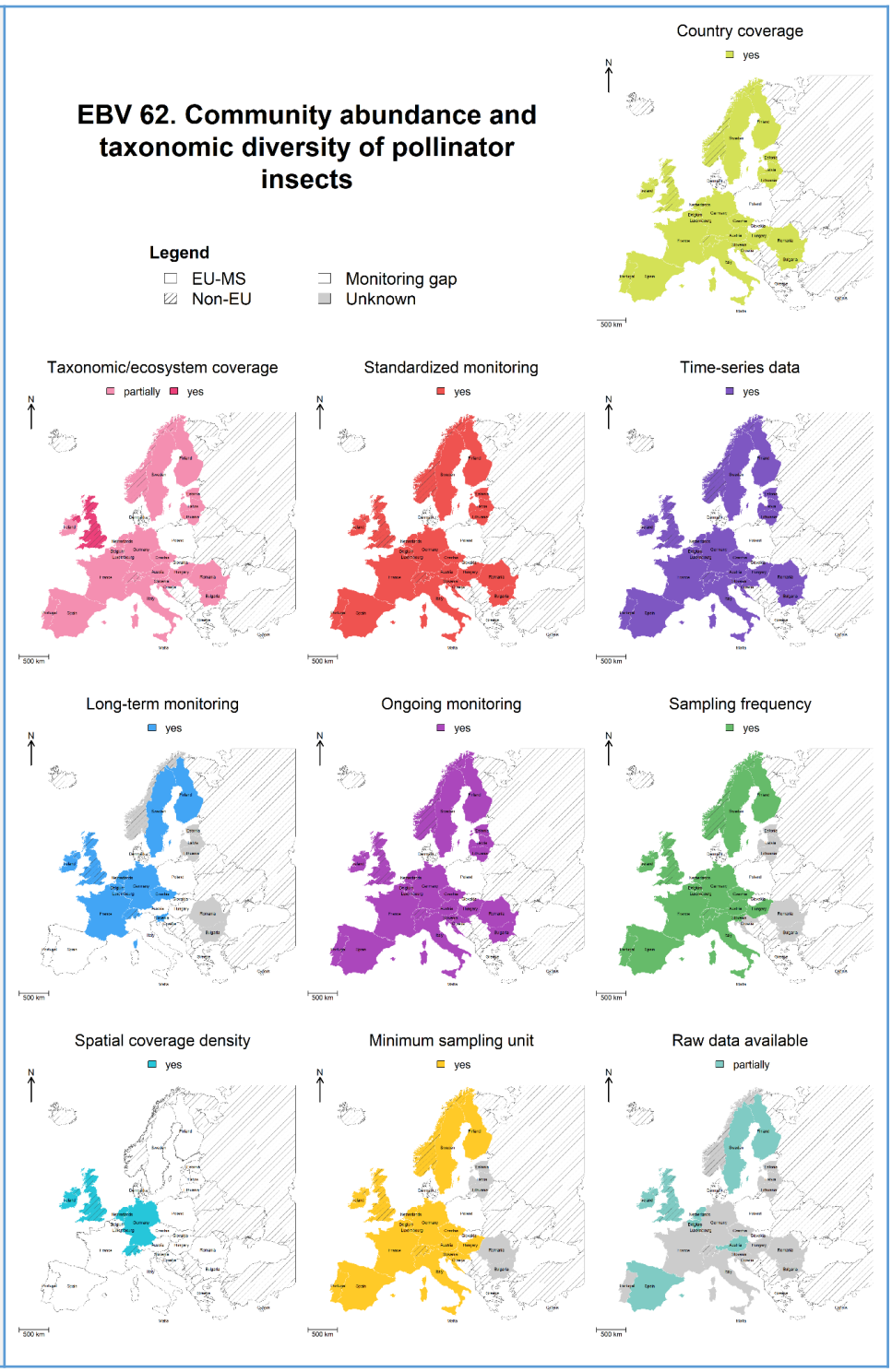

Figure 62.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Aerial biomass of migrating birds, bats and insects**
Summary	Weather radar data needed to estimate migration densities of birds to generate the EBV "Aerial biomass of migrating birds, bats and insects" is provided by the Operational Programme for the Exchange of Weather Radar Information (OPERA). OPERA collects the uncleaned radar volume data, which is needed to extract biological information, every 5-15 minutes, from 35 European countries. Data is used by GloBAM (Monitoring, understanding and forecasting global biomass flows of aerial migrants) to quantify the biomass flows of aerial migrants (birds) across Europe and North America. Main monitoring gaps in the generation of the EBV "Aerial biomass of migrating birds, bats and insects" include lack of taxonomic coverage, long-term data, ongoing monitoring scheme, and data availability. Although some algorithms have already been developed to improve separation of birds and insects, they have not yet been widely tested or deployed. In addition, it is not yet possible to distinguish bats from birds with weather radar. The unclean polar volume data needed to estimate volume and timing of species migration is no longer made available by most countries contributing data to the OPERA repository. Vertical profiles obtained from weather radar volume scans used to estimate aerial biomass are only available for birds (ENRAM data repository for vertical profiles of birds).
EBV characteristics (target)	
ID	63
Realm	Terrestrial
Class	Community composition
Name	Aerial biomass of migrating birds, bats and insects
Step in identification process	User & Policy Needs Assessment
Definition	Biomass flows of aerial migrants (birds, insects and bats) across Europe within contiguous spatial units (grid cells) over time.
Metric	Summary statistics of migration densities of birds, insects and bats derived from vertical profile time series of weather radar data (e.g. hourly averages of bird density and speed)
Spatial resolution units	1x1km - 10x10km
Temporal resolution units	1 day
Taxonomic/ ecosystem focus group	All migratory bird, bat and insect species (by size class)
Current monitoring	
Integration initiative **[GloBAM/OPERA]**	**GloBAM** (Monitoring, understanding and forecasting global biomass flows of aerial migrants, https://globam.science/). GLoBAM is a research project funded by BioDivERsa with partners from across Switzerland, Belgium, Finland, the Netherlands, and the USA. The project has emerged from the European Network for the Radar surveillance of Animal Movement (**ENRAM**, https://www.enram.eu/), a multi-disciplinary network of international scientists who have taken up a world leading position in the use of radar in animal movement studies. **GloBAM**, aims to use weather radar data to quantify the biomass flows of aerial migrants (birds, insects and bats) from regional to continental scales across Europe and North America, over time-scales from days to years. The weather radar data for estimating volume and

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	timing of species migration is provided by the Operational Programme for the Exchange of Weather Radar Information (**OPERA**) which is the radar program of **EUMETNET** (https://www.eumetnet.eu/activities/observations-programme/current-activities/opera/) to provide a European platform wherein expertise on operationally-oriented weather radar issues is exchanged; and to develop, generate and distribute high-quality pan-European weather radar composite products on an operational basis. OPERA coordinates the management of weather radar data for meteorological and hydrological applications across Europe. The only type of data that is useful for extracting biological information is uncleaned polar volume data.
Country coverage **Very-High [100% EU-MS]**	There are weather radar data for estimating the volume and timing of species migration from the OPERA/EUMETNET members covering 35 European countries (https://www.eumetnet.eu/members-partners/).
Taxonomic/ Ecosystem coverage **Very-Low [0% EU-MS]**	Birds. Although some algorithms have already been developed to improve separation of birds and larger insects they have not yet been widely tested or deployed. In addition, small passive flying insects are almost impossible to distinguish from wind. Finally, it is not yet possible to distinguish bats from birds with weather radar in Europe, as they are probably not numerous enough (**partial gap**).
Standardized monitoring **Very-High [100% EU-MS]**	OPERA collects uncleaned volume data needed to extract biological information every 5-15 minutes.
Time-series **Very-High [100% EU-MS]**	Time-series [2016 – 2021].
Long-term monitoring **Very-Low [4% EU-MS]**	10 years data for Netherlands. However, there is a potential for long-term monitoring (**partial gap**).
Ongoing monitoring **Very-Low [0% EU-MS]**	The maintenance of the GloBAM program is compromise because the uncleaned polar volume data needed to estimate the volume and timing of species migration is no longer made available by OPERA due to changes on its data exchange policy from requesting uncleaned polar volumes from national meteorological services to requesting cleaned polar volumes (Shamoun-Baranes et al. 2022).
Sampling frequency **Very-High [100% EU-MS]**	OPERA collects unclean volume data needed to extract biological information every 5-15 minutes. The sampling frequency is adequate to provide the EBV at the desired resolution (1 day).
Spatial Coverage Density **Very-High [96% EU-MS]**	OPERA radars cover the total area or all countries except Italy (https://www.eumetnet.eu/wp-content/themes/aeron-child/observations-programme/current-activities/opera/database/OPERA_Database/index.html). The spatial cover density in likely to be adequate to provide the EBV at the desired spatial resolution for all countries but Italy (**gap**).
Minimum sampling unit **Very-Low [0% EU-MS]**	Data is summarized around a buffer with 5 - 25 km or 5 – 40 km from the radar but with interpolation methods (e.g. Nussbaumer et al. 2020) products may be created at a resolution of 10x10km which correspond to the lower desired resolution for the EBV, but not to the higher resolution (1x1 km) (**partial gap**). However, it is expected that the

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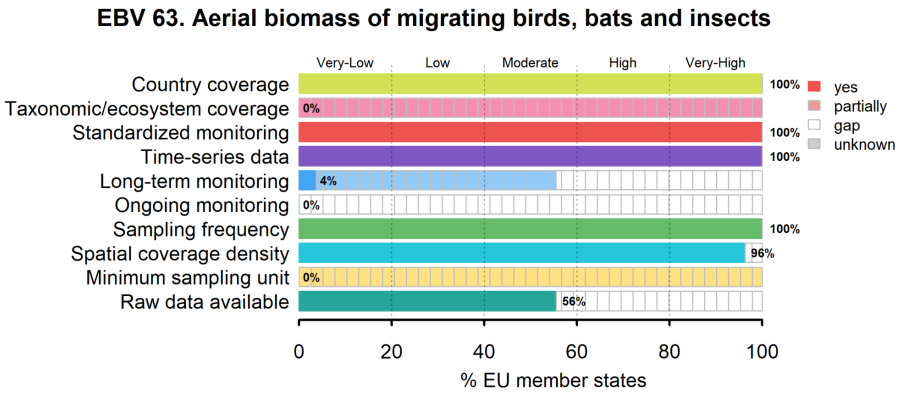
	future implementation of new methods a 100x100m cells resolution could be achieved.
Raw data access **Moderate [56% EU-MS]**	Raw weather data not yet converted into biological data for over 100 radars from 2016 to 2021 are openly available in the "ENRAM data repository for vertical profiles of birds" (https://github.com/enram/data-repository) for 17 countries: Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Switzerland. OPERA serves as a central hub for access to radar data and coordinates data exchange between national meteorological services. However, uncleaned polar volume data needed to estimate the volume and timing of species migration is no longer made available by OPERA due to changes on its data exchange policy from requesting uncleaned polar volumes from national meteorological services to requesting cleaned polar volumes (Shamoun-Baranes et al. 2022).
Monitoring gaps	
Figure 63.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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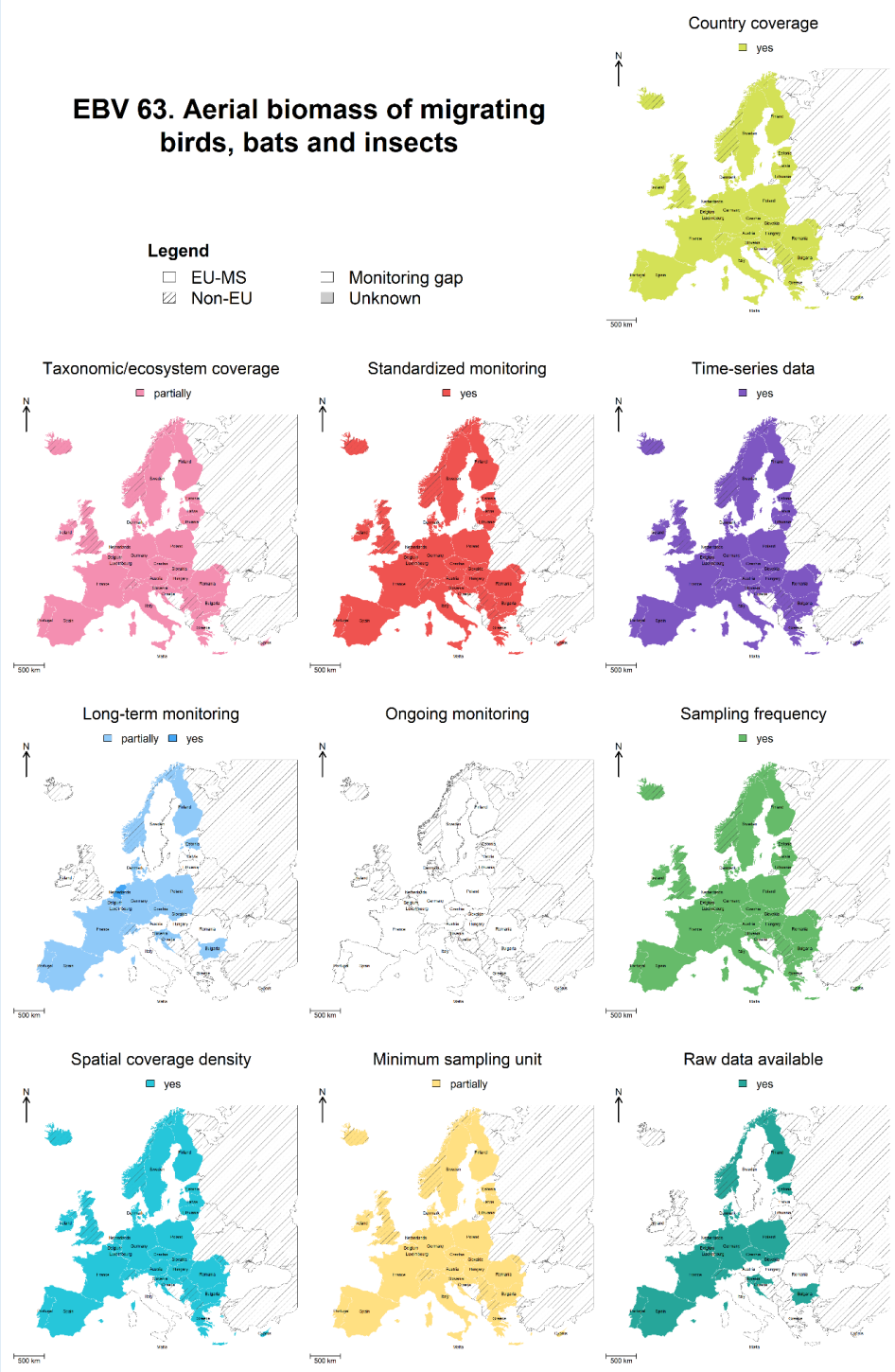

Figure 63.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

REFERENCES

Shamoun-Baranes, J., Bauer, S., Chapman, J. W., Desmet, P., Dokter, A. M., Farnsworth, A., ... & Leijnse, H. (2022). Meteorological data policies needed to support biodiversity monitoring with weather radar. *Bulletin of the American Meteorological Society*, 103(4), E1234-E1242.

Kranstauber, B., W. Bouten, H. Leijnse, B.-C. Wijers, L. Verlinden, J. Shamoun-Baranes and A. M. Dokter (2020). "High-Resolution Spatial Distribution of Bird Movements Estimated from a Weather Radar Network." Remote Sensing **12**(4): 635.

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REPORT GAPS AND IMPORTANT NEW AREAS FOR MONITORING IN EUROPE	
EBV	**Functional composition of soil biota**
Summary	The functional composition and diversity of soil biota is being monitored by since 2028 LUCAS (The Land Use/Cover Area frame statistical Survey) covering all EU-MS. Monitoring is based on a standardised sampling procedure to collect around 0.5 kg of topsoil (0-20 cm) that is dispatched to a central laboratory for analyses of soil biodiversity based on DNA metabarcoding in 1000 points. Surveys are made at exact locations. The minimum sampling unit is likely to be adequate to provide the EBV at the 1x1km spatial resolution. Main monitoring gaps in the generation of the EBV "Functional composition of soil biota" include the lack of long-term data thus reducing the ability of the EBV to establish reliable distribution trends in the short term. In addition, the sampling frequency (every three years) is lower that the desired temporal resolution (1-year). The density of sampling sites is unlikely to be adequate to generate the EBV at the defined spatial resolution (1x1km). Monitoring data needed to estimate the EBV is openly available.
EBV characteristics (target)	
ID	64
Realm	Terrestrial
Class	Community composition
Name	Functional composition of soil biota
Step in identification process	User & Policy Needs Assessment
Definition	The functional composition and diversity of soil biota based on morphological, physiological, phenological and behavioral traits or functional/taxonomic groups.
Metric	- Functional group richness - Functional diversity indices
Spatial resolution units	1x1km
Temporal resolution units	1 year
Taxonomic/ ecosystem focus group	Bacteria, fungi, protozoa, nematodes, collembola, mites, earthworms, larval and adult insects (e.g. Hymenoptera, Coleoptera and Diptera larvae), myriapods, spiders, molluscs and crustaceans).
Current monitoring	
Integration initiative **[LUCAS]**	The functional composition and diversity of soil biota is being monitored by LUCAS (Land Use/Cover Area frame statistical Survey, https://esdac.jrc.ec.europa.eu/projects/lucas). LUCAS is an initiative of the European Statistical Office (EUROSTAT) to organise regular, harmonised surveys across all Member States to gather information on land cover and land use. Monitoring is based on estimates of the area occupied by different land use or land cover types computed on the basis of observations taken at more than 250,000 sample points throughout the EU. Since 2018, LUCAS started to sample and analyse topsoil biodiversity in 1,000 points across all EU-MS.
Country coverage **Very-High [100% EU-MS]**	All European Union Member States are covered by LUCAS soil surveys.

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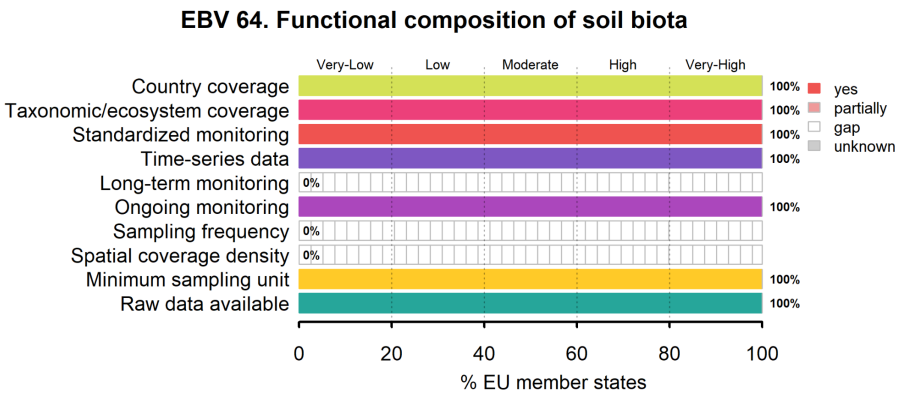
Taxonomic/ Ecosystem coverage **Very-High [100% EU-MS]**	Analysis target Bacteria and Archaea (16S rDNA), Fungi (ITS), Eukaryotes (18S rDNA), Microfauna (nematodes), Mesofauna (arthropods), Macrofauna (earthworms), Metagenomics.
Standardized monitoring **Very-High [100% EU-MS]**	A standardised sampling procedure was used to collect around 0.5 kg of topsoil (0-20 cm). The samples were dispatched to a central laboratory for physical and chemical analyses. The LUCAS Soil survey includes the most extensive EU assessment of **soil biodiversity**, based on DNA metabarcoding in 1000 points.
Time-series **Very-High [100% EU-MS]**	Time series [2018-onwards].
Long-term monitoring **Very-Low [0% EU-MS]**	Although LUCAS to sample and analyse the main properties of topsoil since 2009, soil biodiversity surveys only started in 2018.
Ongoing monitoring **Very-High [100% EU-MS]**	LUCAS soil surveys are ongoing in all European Union Member States.
Sampling frequency **Very-Low [0% EU-MS]**	The surveys are repeated every three years and thus are unlikely to provide the EBV at the desired temporal resolution (1-year) (**gap**).
Spatial Coverage Density **Very-Low [0% EU-MS]**	**Soil biodiversity** is measured in 1000 points across EU-MS. The density of sampling sites is unlikely to be representative of the heterogeneity of soil texture and organic carbon content, land use and land cover, topography and soil type and likely to be adequate to produce the EBV at the 1x1km spatial resolution (**gap**).
Minimum sampling unit **Very-High [100% EU-MS]**	Surveys are made at exact locations. The minimum sampling unit is likely to be adequate to provide the EBV at the 1x1km spatial resolution.
Raw data access **Very-High [100% EU-MS]**	Raw data is freely available and can be downloaded after prior registration through a Request Form (https://esdac.jrc.ec.europa.eu/content/lucas-2018-topsoil-data).
Monitoring gaps	
Figure 64.1 - Loading bars expressing the % of member states that meet the criteria to estimate the EBV.	

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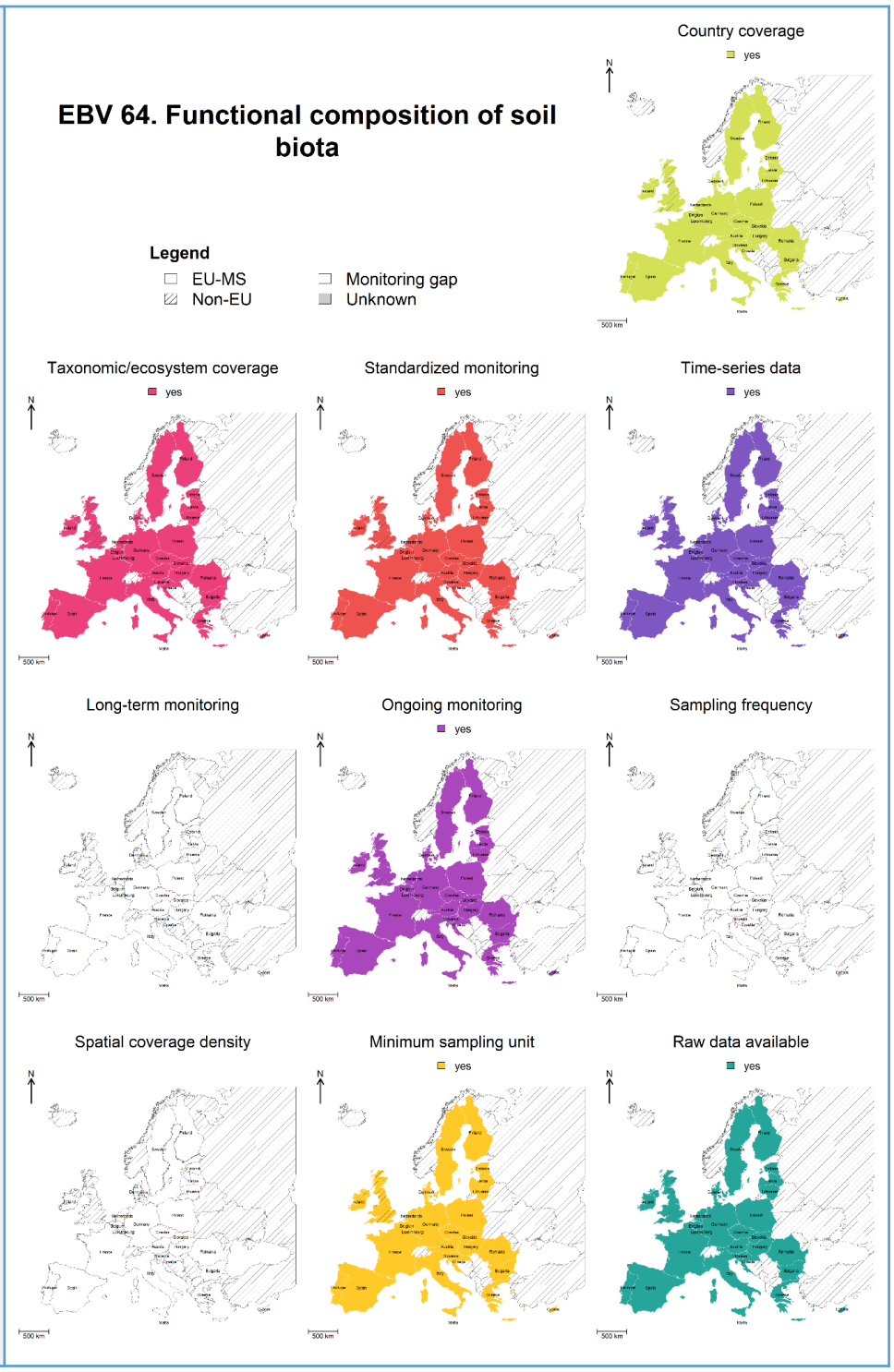

Figure 64.2 - Country-level mapping of the criteria to identify monitoring gaps in the generation of the EBV.

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