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Workshop Report

Important first steps towards designing the freshwater, marine and terrestrial Essential Biodiversity Variable (EBV) workflows for the European Biodiversity Observation Network

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Abstract

The EuropaBON project aims to co-design a European Biodiversity Observation Network by utilising Essential Biodiversity Variables (EBVs) as the foundation for its monitoring system. To co-design the workflow steps for each EBV, the project organised a virtual workshop to engage a diverse group of experts and stakeholders. The workshop focused on describing various workflow components, identifying future needs for EBV implementation and specifying the relative importance of different monitoring techniques for each EBV. With 520 participants from 49 countries, the workshop benefited from a large stakeholder engagement and a wide range of expertise across realms, EBV classes, monitoring techniques and workflow components. During the 3-day workshop (2 hours per day), participants captured different workflows components (i.e. data collection and sampling, data integration and modelling), specified current EU or national initiatives and identified emerging tools and future needs for all 70 currently proposed EBVs. By the end of the workshop, all 70 templates of EBV workflows contained details about workflow components and future needs. Specific future needs for data collection and sampling highlighted by participants were to increase sampling efforts (e.g. number of sites, geographic coverage, sampling frequency and taxonomic scope), to develop and better

incorporate novel monitoring techniques (e.g. eDNA, remote sensing and digital sensors) and to create new or improved sampling designs at a European scale. For data integration, combining and harmonising data from diverse sources and data collectors and developing standards and protocols were mentioned as key needs. For modelling, participants especially highlighted the need to develop spatially-explicit models or improve other types of existing models, ideally with open-source software and code. Next steps for designing EBV workflows are to analyse the gathered workshop information, to provide detailed descriptions of EBV workflows and to formulate specific recommendations for the development of a European Biodiversity Observation Network. Recommendations for each monitoring technique (structured in-situ monitoring, citizen science, digital sensors, genetics, satellite remote sensing and aerial remote setting) will also be identified. The gathered information will contribute to the co-design of the European Biodiversity Observation Network and to supporting the establishment of a Biodiversity Monitoring Coordination Centre in Europe.

Keywords

Essential Biodiversity Variables, biodiversity monitoring, EBV workflows, aata collection, data sampling, data integration, data modelling, monitoring techniques, GEO BON, stakeholder engagement

Date and place

The EuropaBON virtual workshop on Essential Biodiversity Variable (EBV) workflows was held on 22–24 February 2023 during 2-hour online sessions from 11:00-13:00 h CET on each of the three workshop days.

List of workshop contributors

Workshop lead:

- W. Daniel Kissling (University of Amsterdam - UvA)
- Maria Lumbierres (University of Amsterdam - UvA)

Workshop supporters, moderators and facilitators:

- Ian McCallum (International Institute For Applied Systems Analysis - IIASA)
- Ivelina Georgieva (International Institute For Applied Systems Analysis - IIASA)
- Laurence Carvalho (Norwegian Institute for Water Research - NIVA)
- Anne Lyche Solheim (Norwegian Institute for Water Research - NIVA)
- Pier Luigi Buttigieg (Max Planck Institute for Marine Microbiology - MPIMM)
- Roy H. A. van Grunsven (De Vlinderstichting/Dutch Butterfly Conservation)
- Francisco Moreira (BIOPOLIS-CIBIO-InBIO, University of Porto)
- Joana Santana (BIOPOLIS-CIBIO-InBIO, University of Porto)

- Pedro Beja (BIOPOLIS-CIBIO-InBIO, University of Porto)
- Jessica Junker (German Centre for Integrative Biodiversity Research - iDiv)
- Nestor Fernandez (German Centre for Integrative Biodiversity Research - iDiv)
- Jose W. Valdez (German Centre for Integrative Biodiversity Research - iDiv)
- Henrique Pereira (German Centre for Integrative Biodiversity Research - iDiv)
- Aletta Bonn (German Centre for Integrative Biodiversity Research - iDiv)
- Tom Breeze (University of Reading)
- Camino Liquete (Joint Research Centre - European Commission)
- Maria Azeredo de Dornelas (University of St Andrews)
- Bruno Smets (Flemish Institute for Technological Research - VITO)
- Lluis Brotons (Centre De Recerca Ecològica I Aplicacions Forestals - CREAF)
- Yifang Shi (University of Amsterdam - UvA)
- Bart Kranstauber (University of Amsterdam - UvA)
- Marija Milanovic (Helmholtz Centre for Environmental Research - UFZ)

Workshop participants:

- A total of 520 people from 49 countries had registered to participate in the workshop. The exact number of final participants is not known, but on each workshop day between 200 and 300 people were connected to the online sessions. The personal data of the workshop participants were kept confidential to adhere to the EU general data protection regulation (GDPR).

Introduction

The EuropaBON project (https://europabon.org/) aims to co-design a European Biodiversity Observation Network which can bridge the gap between the biodiversity data needs of policy-makers and authorities on the one hand and the existing reporting streams and available data sources on the other hand (Pereira et al. 2013). This has not only to take into account the current reporting obligations (e.g. for the Birds, Habitats, Water Framework and Marine Strategy Framework Directives), but also the future needs of newly-emerging biodiversity policies (e.g. the EU Biodiversity Strategy for 2030 and the currently proposed EU Nature Restoration Law). As a central concept, EuropaBON uses Essential Biodiversity Variables (EBVs) to capture the multiple dimensions of biodiversity change and to provide a standardised framework for monitoring and reporting biodiversity trends (Pereira et al. 2013, Navarro et al. 2017). The EBV framework facilitates the integration and harmonisation of data from different sources (Kissling et al. 2017) and their interoperability for use in trans-national and cross-infrastructure workflows and data streams (Hardisty et al. 2019). Spatially and time-explicit EBV datasets can then be combined with ancillary datasets on pressures (e.g. threats to biodiversity) and responses (e.g. from management and policy) to produce biodiversity indicators that can be used for tracking policy targets and goals at multiple levels.

Through a comprehensive stakeholder and expert involvement, EuropaBON has identified 70 EBVs that are policy-relevant for the EU, measurable with available and existing

technologies and with a proven track record of feasibility in on-going initiatives (Junker et al. 2023). These EBVs represent freshwater, marine and terrestrial realms (Fig. 1a), cover all EBV classes (with species populations being most strongly represented, Fig. 1b) and capture a diverse set of taxonomic groups and ecosystems (Fig. 1c). The full list and current version of EBVs is available from GitHub (https://github.com/EuropaBON/EBV-Descriptions) and contains information on the EBV names, the EBV classes, EBV definitions, potential metrics, their spatial and temporal resolutions and the taxonomic scope or ecosystem focus. We used the EBV list as available on the date of the workshop (version of 22 February 2023, see Suppl. material 1).

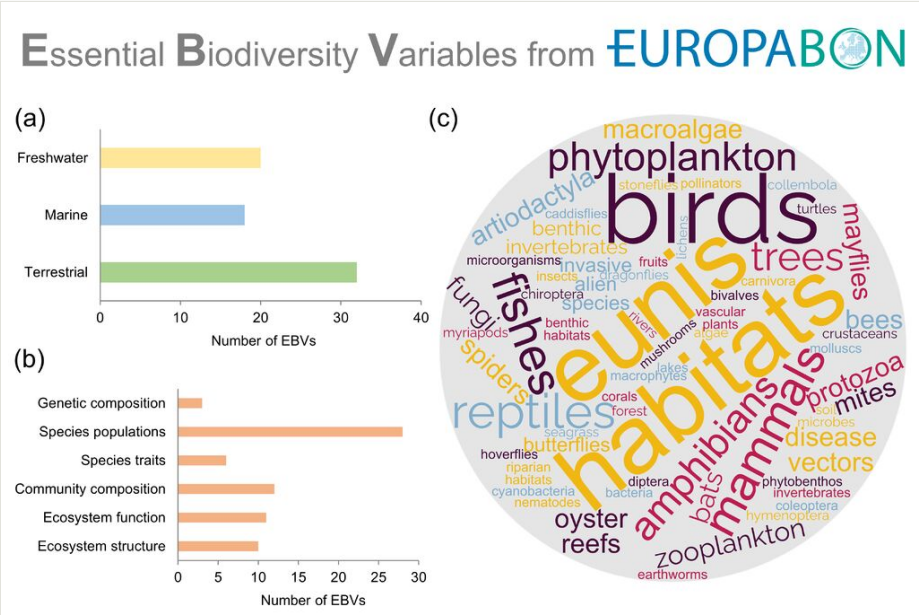

Figure 1. doi

Representation of Essential Biodiversity Variables (EBVs) from the EuropaBON project. (a) Number of EBVs falling into the freshwater, marine and terrestrial realm, respectively. (b) Representation of EuropaBON EBVs within the six EBV classes as proposed by the Group on Earth Observations Biodiversity Observation Network (GEO BON). (c) Word cloud showing the taxonomic and ecosystem focus of the identified EBVs. The figure is based on the taxonomic and ecosystem groups mentioned in the full list of 70 EBVs (available from GitHub, accessed for this figure on 19 May 2023, https://github.com/EuropaBON/EBV-Descriptions).

The EuropaBON project emphasises a co-design approach with stakeholders at all stages of the development of the European Biodiversity Observation Network (Pereira et al. 2022). It is, therefore, not only relevant to define and identify the EBVs with a broad range of stakeholders and experts, but also to collaboratively develop how EBVs can be calculated, i.e. co-designing the workflows for each EBV. EBV workflows can be defined as a sequence of tasks that are needed to process a set of raw data (e.g. from structured in-situ monitoring, eDNA sampling or remote sensing) through data integration (e.g. cleaning, standardising, harmonising and merging data) to modelling the data (e.g. statistical

modelling, geospatial extrapolation or machine learning) (Kissling et al. 2017, Schmeller et al. 2017). Here, we distinguish three primary components of EBV workflows (Kissling and Lumbierres 2023):

1. data collection and sampling;
2. data integration and
3. modelling.

Besides, we also emphasise interoperability and IT infrastructure as important aspects for the co-design (Fig. 2), as they are relevant for trans-national and cross-infrastructure workflows and data streams (Hardisty et al. 2019). Within the EuropaBON project, the co-design of EBV workflows incorporates information from other work packages (Fig. 2), namely the EBV list (Junker et al. 2023), the assessment of gaps and bottlenecks of current EU monitoring activities (Morán-Ordóñez et al. 2023, Santana et al. 2023), the identification of novel technologies for implementation in biodiversity monitoring (Dornelas et al. 2023) and the development of a set of policy-orientated showcases of EBV workflows (Pereira et al. 2022).

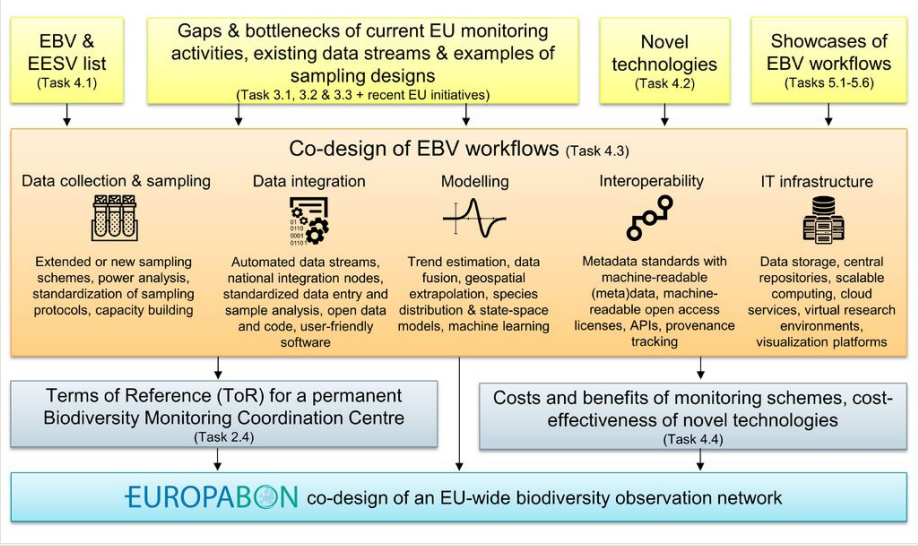

Figure 2. doi

The co-design of the EBV workflows (orange box) is a central part for the co-design of an EU-wide biodiversity observation network. In the EuropaBON project, tasks from various work packages (yellow) feed information into the co-design of the EBV workflows (orange). Together with the Terms of Reference (ToR) for a permanent Biodiversity Monitoring Coordination Centre and a cost-benefit analysis (grey), the overall EuropaBON co-design of an EU-wide biodiversity observation network is developed.

To make the first steps towards co-designing the freshwater, marine and terrestrial EBV workflows for a European Biodiversity Observation Network, basic information on the three primary workflow components needs to be gathered (Kissling and Lumbierres 2023, Fig. 2

). The component ‘Data collection and sampling’ involves identifying the primary observations needed to generate a specific EBV (e.g. national species monitoring programmes, citizen science, eDNA sampling, remote sensing) and the appropriate methods and sampling protocols for data collection, including emerging or novel sampling methods (Fig. 2). The component ‘Data integration’ encompasses understanding the specific data standardisation and harmonisation processes, including automated data streams, protocols for data entry and identification of national or EU integration nodes (Fig. 2). Finally, the component ‘modelling’ involves identifying the types of models and predictor variables required to generate a specific EBV, how uncertainty in model outcomes can be quantified and which (open-source) software and code could be used (Fig. 2).

Since there are large taxonomic, geographic and temporal gaps in existing European monitoring programmes (Santana et al. 2023), as well as strong bottlenecks in current European biodiversity data flows (Morán-Ordóñez et al. 2023), the information available from existing monitoring initiatives may vary widely across EBVs. It is, therefore, important to describe for each workflow component (and each EBV) what is already established, what is currently emerging and which future needs there are for implementing the EBV at a European level (Kissling and Lumbierres 2023). Moreover, while a wealth of novel methods is available for biodiversity monitoring (Dornelas et al. 2023), it remains unclear how each novel method can contribute to generating a specific EBV. We, therefore, organised a virtual workshop in February 2023 to engage a broad range of experts and stakeholders in making the first steps towards designing the EBV workflows for a European Biodiversity Observation Network. In this workshop, we specifically focused on aspects of data collection and sampling, data integration and modelling for each EBV and how different monitoring techniques can contribute to EBV generation.

Workshop organisation and aims

The EuropaBON virtual workshop on EBV workflows was held during three consecutive days on 22–24 February 2023 (Fig. 3). The workshop was structured into two-hour online sessions per day, each around mid-day. This structure promoted maximum participation, allowed time for in-depth discussions and contributions and ensured that individuals from various countries and locations could participate.

Each day of the workshop started with a 10–30 min plenary session containing presentations and explanations for the day, followed by a 70–90 min break-out session for hands-on work and discussion and ended with a 20–30 min plenary session sharing the results from the break-out groups (see workshop agenda in Suppl. material 2). On day 1 and day 2, the break-out sessions focused on filling workflow templates (Google docs) for each EBV (see Appendix A of Kissling and Lumbierres (2023)). Break-out sessions were separated by realm (freshwater, marine and terrestrial). While day 1 focused on describing the current and emerging components of each EBV workflow, day 2 focused on the future needs. Day 3 started with an online survey to capture the importance of different monitoring techniques for each EBV, followed by break-out sessions separated by monitoring techniques (structured in-situ monitoring, citizen science, digital sensors,

genetics, satellite remote sensing and aerial remote setting with aeroplanes, weather radar and drones). These break-out sessions involved a cross-EBV synthesis using an online whiteboard tool (Miro boards) to assess the overarching needs for implementing EBV workflows at the European scale (in terms of data collection, sampling, data integration, modelling, interoperability and IT infrastructure). The Miro boards facilitated real-time online collaboration and allowed participants to create notes, brainstorm, move things around and connect and organise ideas.

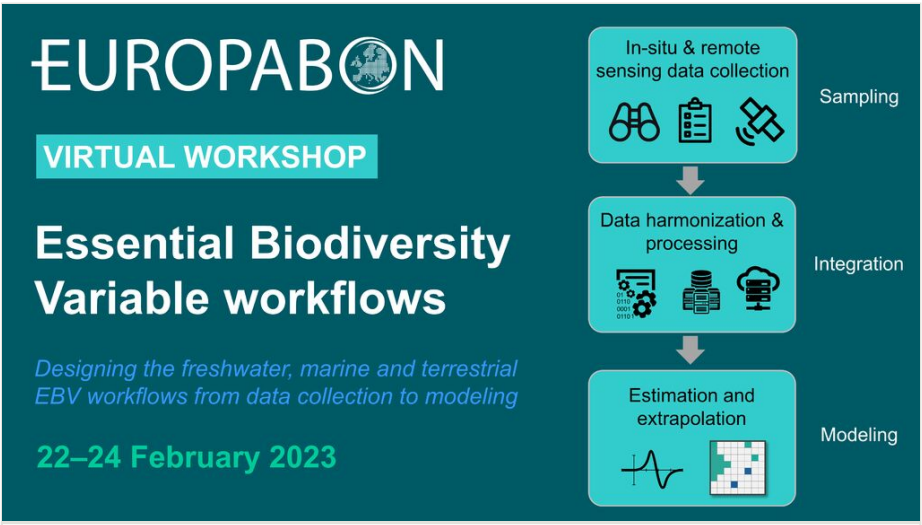

Figure 3. doi

Social media graphics for the virtual workshop on EBV workflows used to advertise the workshop and to encourage experts to register and participate in the event.

The overall aim of the workshop was to make the first steps in designing the freshwater, marine and terrestrial EBV workflows for a European Biodiversity Observation Network. More specifically, the workshop had the following objectives:

- To engage a large and diverse group of experts and stakeholders to jointly co-design EBV workflows for a European Biodiversity Observation Network;
- To describe as many details as possible for each EBV workflow component in terms of current monitoring initiatives, emerging projects and tools (e.g. from new EU pilot projects) and future needs;
- To identify the key future needs for EBV workflows at a European scale in terms of data collection and sampling, data integration and modelling;
- To obtain an overview about the central importance of different monitoring techniques for specific EBVs;
- To summarise the overarching needs for implementing different monitoring techniques at a European scale.

Key outcomes and workshop achievements

Expert and stakeholder engagement

A total of 520 participants from 49 countries registered for the workshop. Between 200 and 300 people were connected during the online sessions on all three days. The expertise of the participants was well-distributed across terrestrial, marine, freshwater and marine ecosystems (Fig. 4a). Participants also represented all EBV classes, with species populations, species traits, community composition, ecosystem function and ecosystem structure being well covered and genetic composition a bit less (Fig. 4a). A total of 440 registered participants (85%) had expertise in data collection and sampling and about 40–50% in data integration and modelling (Fig. 4b). Hence, the three main EBV workflow components were well covered with expert knowledge. For monitoring techniques, nearly 350 registered participants (67%) came with expertise in in-situ monitoring (Fig. 4c), followed by satellite remote sensing or citizen science (each with 37%). About 26% had expertise in aerial remote sensing including aeroplanes, drones or weather radar and 24% in genetics and digital sensors, respectively (Fig. 4c). The expertise of the participants fitted very well to the thematic content of the workshop.

Description of EBV workflow components

To describe the workflow components for each EBV, the participants worked on filling out workflow templates (provided as Google docs) for each EBV (i.e. 70 EBV templates in total). Before the workshop, some workflow templates were already populated with information available from other tasks and work packages in EuropaBON. For instance, information on current data collection and sampling from existing biodiversity monitoring initiatives was extracted from Deliverable 3.2 ‘Report on gaps and important new areas for monitoring in Europe’ (Santana et al. 2023). Similarly, information on current workflow components and data streams of existing biodiversity monitoring initiatives was extracted from Deliverable 3.3 ‘Identification of current monitoring workflows and bottlenecks’ (Morán-Ordóñez et al. 2023). Both deliverables focused on current biodiversity monitoring initiatives that utilise in-situ data collection at a European scale, thus excluding some of the EBVs for which data can be collected with remote sensing or those for which monitoring initiatives currently lack a European integration. Hence, these deliverables provided useful and preliminary information for describing some of the workflow components, but did not provide a comprehensive description of each EBV workflow component for each EBV. For a small set of EBVs, we also gathered detailed information on each workflow component through expert interviews before the workshop. Three examples are provided in the document "Essential Biodiversity Variable workflows: designing the freshwater, marine and terrestrial EBV workflows from data collection to modelling" (Figures 6–8 in Kissling and Lumbierres (2023)) which served as input material into the workshop.

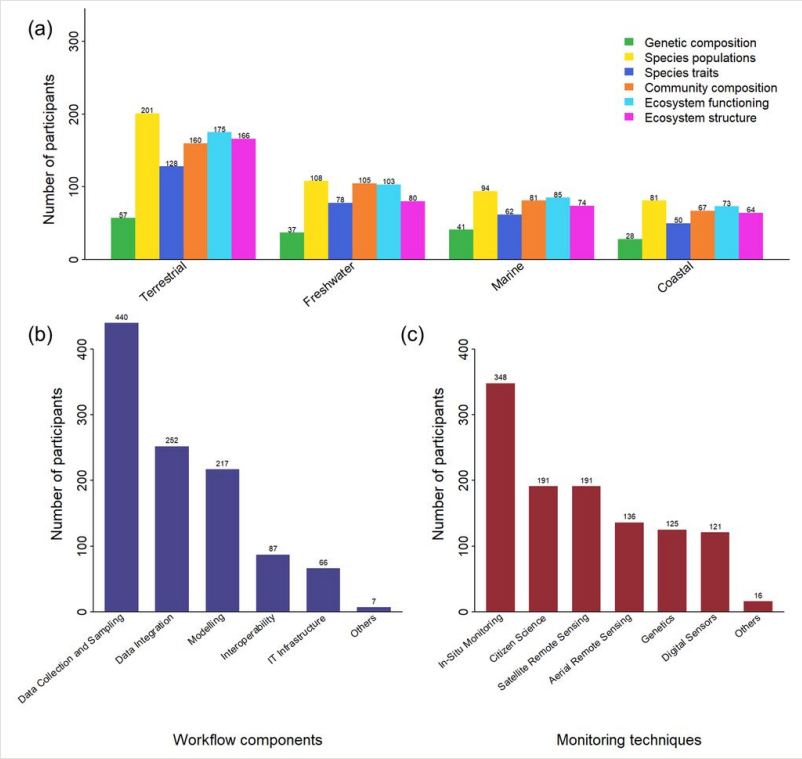

Figure 4. doi

Summary of expertise from 520 stakeholders and experts who registered for the EuropaBON virtual workshop on EBV workflows (22–24 February 2023): (a) Expertise in terrestrial, freshwater, marine and coastal ecosystems and EBV classes (genetic composition, species populations, species traits, community composition, ecosystem functioning and ecosystem structure); (b) Expertise in workflow components (data collection and sampling, data integration, modelling) and aspects of interoperability and IT infrastructure; (c) Expertise in different monitoring techniques.

Each EBV template was designed as a table, with columns for:

- current initiatives;
- emerging tools and projects and
- future needs.

The rows represented the different workflow components, i.e. data collection and sampling, data integration and modelling. Additional sections at the bottom of each template allowed the participants to fill in information on interoperability aspects and IT infrastructure needs, for example, primary data access, metadata standards, open access licences, data portals, cloud computing facilities and general research infrastructure requirements. We asked participants to put emphasis on providing references and sources to ensure the traceability of the provided information.

As an example for a filled EBV workflow template, we illustrate the workflow information that was gathered for the EBV ‘species abundance of butterflies’ (Table 1). For current initiatives, the weekly transect counts (during the season using standardised sampling protocols) from the European Butterfly Monitoring Scheme (eBMS) represent the main data collection and sampling method across several parts of the EU (Table 1). Data integration already exists through an EU-wide integration node (Butterfly Conservation Europe), but data entry varies by country and field guides do not exist for all countries and languages. Population trend estimation is done using several statistical models and R packages (Table 1). For emerging tools and projects, a citizen-science phone application for 15-minute counts is currently developed and data sampling and integration are extended through the ABLE project ('Assessing Butterflies in Europe’) (Table 1). Moreover, integrating different data sources (transect counts, 15-minute counts and opportunistic observations) into statistical models is emerging. For future needs, more support for expanding the monitoring coverage (transects, coordinators, volunteers and paid experts) and improvements in various sampling tools (app usability, regional field guides, sampling protocols in multiple languages) were emphasised (Table 1). Experts also mentioned the need for better integration of different monitoring data types and the development of interfaces between decentralised national databases of butterfly monitoring schemes (Table 1). For modelling, there is a need to develop spatially-explicit models to estimate butterfly abundance continuously (wall-to-wall) across Europe (Table 1).

Table 1.

Example of the information gathered in one of the EBV templates specifying details on workflow components (data collection and sampling, data integration and modelling) and whether they relate to current initiatives, emerging tools and projects or future needs. The bottom of the template was designed to collect additional information on interoperability aspects, IT infrastructure needs and references and sources. The example represents the EBV ‘Species abundance of butterflies'. Note that a separate template was provided for each EBV.

Workflow description for EBV (Species abundance of butterflies)			
	Current initiatives	**Emerging tools and projects**	**Future needs**
Data collection and sampling Data collection method Sampling design (EU-wide monitoring) Type of raw data Novel monitoring methods Capacity building	**European Butterfly Monitoring Scheme (eBMS)** - Weekly transect counts during season **National monitoring initiatives** - Transect routes or time-area counts in Flanders, South Tyrol, Switzerland	**Citizen-science phone application (eBMS App)** - 15-min full counts - 15-min single species counts **Other examples** - Massive collection of opportunistic observations - Adaptive sampling approaches (e.g. DECIDE) - Abundance monitoring in forest and ecosystem restoration projects (Denmark, France)	- Increase the number of transects, coordinators and volunteers across Europe - Development of app usability (local adaptations, translation and species guides) - Increase the number of paid experts to monitor sensible areas and species - Field guides and sampling protocols for other EU regions

Workflow description for EBV (Species abundance of butterflies)			
	Current initiatives	**Emerging tools and projects**	**Future needs**
Data integration Standardisation and harmonisation Preprocessing Protocols and metadata Way of data aggregation Integration nodes Automated data streams	**National and EU-level integration** - EU-wide integration node - Standardised sampling protocols (transect counts), but data entry varies by country - Field guides for different regions in Europe	**Extended data integration** - Data inclusion and data harmonisation for new European countries (ABLE project: 'Assessing Butterflies in Europe') - Extended EU-wide data integration through Butterfly Conservation Europe	- Integration of transect count data (eBMS) and data from the 15-min counts (eBMS App) - Interfaces between decentralised national databases of butterfly monitoring schemes
Modelling Types of models Predictors Estimation and uncertainty Software	**Trend estimation** - Species flight curves with splines and GAMs - Trend estimation with GAI - Combined site index with a GLM - Bootstrapping - R-package 'rtrim'	**Predictive models** - European-wide occupancy models **Integrated models** - Integrated modelling of species distributions and abundance through combining different data sources (transect counts, 15-minute counts and opportunistic observations)	- Models to estimate abundance continuously (wall-to-wall) across Europe
Interoperability aspects (e.g. access to and sharing of primary data, metadata standards, open access licences, APIs, machine readability): • Data currently only available upon request and No legal data sharing agreements in place: • Metadata forms only available as Excel files (not machine-readable).			
IT infrastructure needs (e.g. data portals, use of European Research Infrastructures, data storage, central repositories, scalable computing, cloud services): • Expanded and improved centralised eBMS database with greater functionality; • Centralised (cloud) computing infrastructure for automated calculation of butterfly indicators.			
References and sources (e.g. name and institution of expert who provided information for this template, literature, online sources, web pages of EU project): • Expert input from Roy van Grunsven, Elia Guariento, Simon Rolph, Ward Langeraert, Pablo Denti, Martin Musche; • eBMS (https://butterfly-monitoring.net/), Flanders (https://meetnetten.be), Switzerland (https://www.biodiversitymonitoring.ch), South Tyrol (https://biodiversity.eurac.edu); • Butterfly Conservation Europe (https://www.vlinderstichting.nl/butterfly-conservation-europe/); • Dennis, E. B. et al. (2016): A generalised abundance index for seasonal invertebrates. Biometrics 72:1305-1314. • Sevilleja, C. G. et al. (2019): Butterfly transect counts: manual to monitor butterflies. https://butterfly-monitoring.net/sites/default/files/Publications/Manual_Butterfly_Monitoring%20(English).pdf. • Hilpold et al. (2023): Handbook Biodiversity Monitoring South Tyrol, Bozen/Bolzano. • ABLE project (https://butterfly-monitoring.net/able), DECIDE (https://decide.ceh.ac.uk).			

Before the workshop, preliminary information on workflow components were available for more than half of the 70 EBVs (Fig. 5). More than 20 EBV templates were completely empty and only a handful had sufficient information (Fig. 5), including the three examples that were provided in the milestone document (Kissling and Lumbierres 2023). During the

workshop, major progress was made in populating the EBV templates. For instance, there was no empty EBV template left after the workshop (Fig. 5). Moreover, more than half of all templates had sufficient information for all three workflow components (for current initiatives, emerging tools and projects and future needs) and less than half had at least some preliminary information (Fig. 5). Hence, the workshop was efficient in terms of describing as many details as possible for each EBV workflow component within a relatively short time.

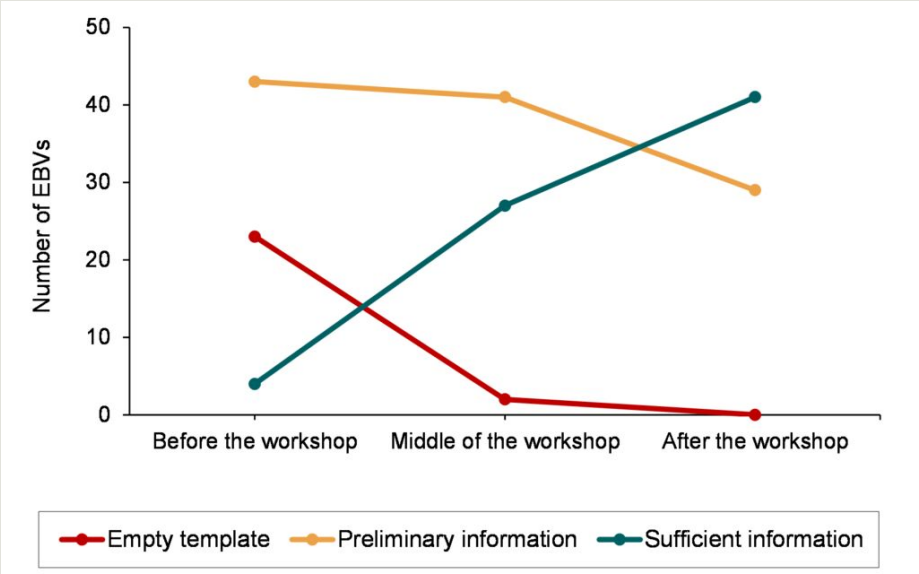

Figure 5. doi

Progress in completing the EBV workflow templates during the EuropaBON virtual workshop on EBV workflows. The graph depicts the amount and completeness of information content (empty, preliminary, sufficient) of EBV templates (n = 70 in total) at three stages: before the workshop, in the middle of the workshop and after the workshop. The red line shows the number of empty EBV templates, the yellow line represents templates with preliminary information and the blue line indicates templates that were sufficiently filled.

Key future needs for EBV workflows

To summarise the key future needs, we scored and grouped the content from all EBV workflow templates after the workshop into broader categories for each EBV workflow component (Fig. 6). For data collection, there was consensus on the need to amplify sampling efforts in all realms (Fig. 6), for instance, through increasing the number of sites, expanding geographic coverage, enhancing frequency of sampling and broadening the taxonomic/ecosystem representation. Moreover, the development of novel monitoring techniques (e.g. eDNA, remote sensing and digital sensors) and new sampling designs were generally emphasised as important needs (Fig. 6). For data integration, harmonising and integrating data from diverse sources and developing standards and protocols were

seen as the most important needs for developing EBV workflows across all realms (Fig. 6). For modelling, the development of new (e.g. spatially-explicit) models and improving existing models was seen as the most important future need (Fig. 6).

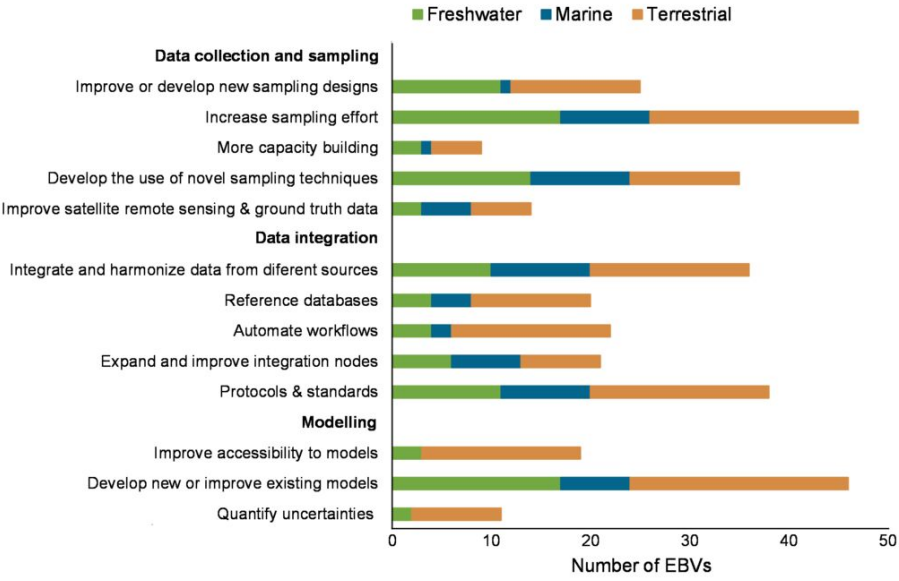

Figure 6. doi

Summary of future needs for developing EBV workflows at a European scale. The information was obtained by grouping the content from the EBV workflow templates (n = 70) into the categories of the y-axis, representing the three major EBV workflow components (i.e. data collection and sampling, data integration and modelling).

Importance of different monitoring techniques for specific EBVs

On day 3 of the workshop, workshop participants were asked to fill out a 5–10 min online survey in which they had to link the 70 EBVs to the importance of a monitoring technique. Depending on their expertise, the participants could choose one out of six monitoring techniques:

1. structured in-situ monitoring;
2. citizen-science observations;
3. genetics (e.g. AFLP/microsatellite, SNPs and metabarcoding eDNA);
4. digital sensors (e.g. cameras, acoustic devices, GPS tags);
5. satellite remote sensing and
6. aerial remote sensing (incl. drones, airplane surveys and weather radar).

We offered a Google form for each monitoring technique (see example in Fig. 7a) and asked whether the specific technique is of central importance for monitoring a particular EBV. Participants could choose one of the answers "yes", "partially", "no" and "I don't

know". The results (one example in Fig. 7b) indicate how crucial a monitoring technique is for a particular EBV. For instance, digital sensors (e.g. GPS tags or hydrophones) are seen as particularly relevant for the EBV ‘Species distributions of freshwater mammals’, whereas digital sensors have rather little relevance for monitoring the Ecological Quality Ratio (EQR) of phytoplankton in lakes (Fig. 7b).

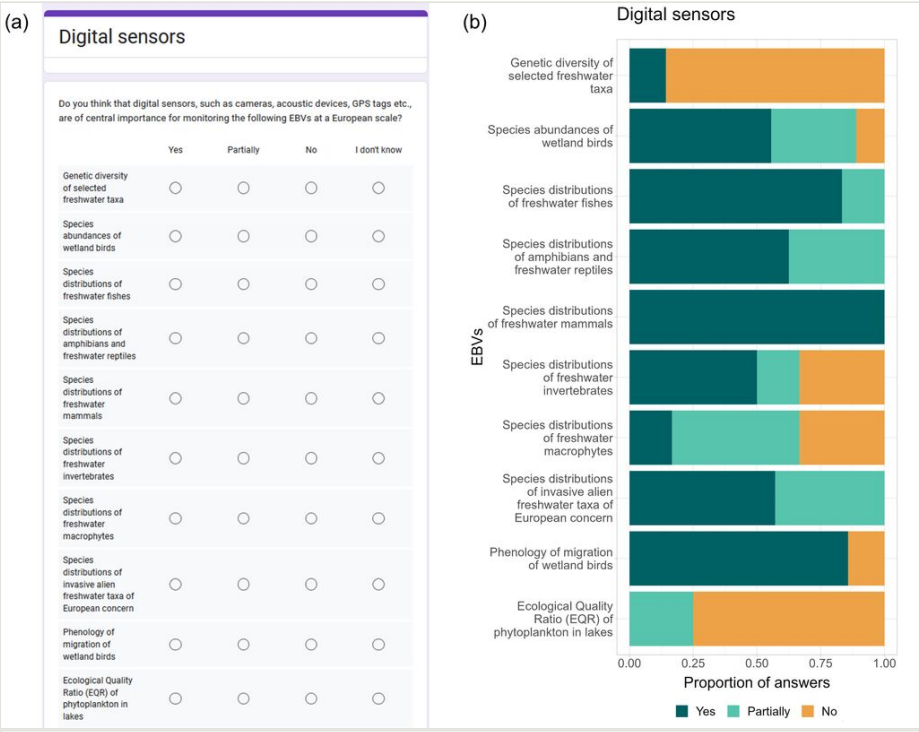

Figure 7. doi

Online survey on the importance of monitoring techniques for generating EBVs. (a) Example showing the upper part (first 10 out of 70 EBVs) of the survey on digital sensors (Google form). A separate form was provided for each monitoring technique (structured in-situ monitoring, citizen-science observations, genetics, digital sensors, satellite remote sensing and aerial remote sensing); (b) Example of survey responses (incl. answers "yes", "partially" and "no") specifying the importance of digital sensors for monitoring a specific EBV. Responses for the first 10 (out of 70) EBVs are shown (sample size of answers varies between 6 and 12).

Overarching needs for implementing different monitoring techniques at a European scale

To better understand the overarching needs for implementing each monitoring technique at a European scale, we organised the break-out sessions on day 3 around the question which emerging tools and future needs are relevant for implementing a specific monitoring technique. Each Miro board (i.e. each break-out group) was focused on one of the six

monitoring techniques. The structure of the boards (i.e. upper row of coloured boxes in Fig. 8) was prepared before the workshop to guide the participants in categorising their responses according to different workflow components (data collection and sampling, data integration and modelling) or interoperability aspects and IT infrastructure needs. In the first part of the break-out session, the participants could write down their suggestions in online sticky notes and add relevant references or sources. In the second part of the break-out session, a discussion was fostered amongst participants to group the identified needs into broader thematic topics (yellow circles in Fig. 8). This allowed us to synthesise the overarching needs both within and across monitoring techniques.

Figure 8. doi

Example of a Miro board used for identifying the overarching needs for implementing digital sensors for collecting and sampling data for EBV workflows at a European scale. Participants were asked to specify key requirements for different workflow components (data collection and sampling, data integration and modelling), interoperability aspects and IT infrastructure needs (coloured boxes in upper row). Information in the online sticky notes (coloured squares) was entered by participants and were later grouped into broader thematic topics (yellow circles).

Conclusions and future steps

The workshop successfully achieved its five main objectives: engaging a wide and diverse group of experts and stakeholders in the co-design process; obtaining comprehensive descriptions of each EBV workflow component, based on current monitoring initiatives and emerging projects and tools; outlining future needs for each workflow component and EBV;

establishing links between monitoring techniques and specific EBVs; and ascertaining the main future needs for implementing each monitoring technique. The participants' contributions helped to gather a large amount of information on EBV workflows.

This workshop built on various efforts within the EuropaBON project and extended them by gathering detailed information on workflow components and examining the links between EBVs and several monitoring techniques. The current version of the EBV list (Junker et al. 2023) served as the building block for the workshop and will be fundamental for the co-design of the European Biodiversity Observation Network. Through defining and implementing EBV workflows, it will ultimately become possible to monitor changes in various complementary dimensions of biodiversity across the EU. Subdividing workflows into current initiatives, emerging tools and future needs helped to identify workflow components that are already working well, those that are currently being developed by pilot projects and those that must be developed entirely from scratch.

A priority now is to analyze the gathered information and to provide detailed workflow descriptions. Additionally, recommendations will be developed for the design and implementation of a European Biodiversity Observation Network, based on the future needs identified during the workshop, including suggestions for a new Biodiversity Monitoring Coordination Centre in Europe. The full implementation of the proposed system will require to expand the current monitoring network, to implement new sampling networks, to support data standardisation and data integration, to develop new modelling tools and to ensure the effective incorporation of new monitoring techniques. These tasks align well with the European Biodiversity Partnership Biodiversa+ (Pozo and Body 2022, Hoye et al. 2022) which works in close cooperation with the EuropaBON project to contribute to the EU ambition that nature in Europe comes back on a path of recovery. Co-designing the European Biodiversity Observation Network will also contribute to a global biodiversity observation network that is based on a harmonised monitoring framework using EBVs (Navarro et al. 2017).

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Conflicts of interest

The authors have declared that no competing interests exist.

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Supplementary materials

Suppl. material 1: EuropaBON list of Essential Biodiversity Variables doi

Authors: Maria Lumbierres & W. Daniel Kissling
Data type: Table
Brief description: EuropaBON list of Essential Biodiversity Variables (version 22 of February 2023)
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Suppl. material 2: Agenda of EuropaBON virtual workshop on EBV workflows

doi

Authors: Maria Lumbierres & W. Daniel Kissling
Data type: Table
Brief description: Agenda of EuropaBON virtual workshop on EBV workflows (22–24 February 2023)
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