Europa Biodiversity Observation Network:

Proposal for an EU Biodiversity Observation Coordination Centre (EBOCC)

EUROPABON

European Commission

Horizon 2020
European Union funding
for Research & Innovation

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European Commission

International Institute for Applied Systems Analysis

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UNIVERSITY OF AMSTERDAM

NIVA Norsk institutt for vannforskning

iDiv

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De Vlinderstichting

biodiversa+ European Biodiversity Partnership

GBIF Global Biodiversity Information Facility

CREAF

Citation:
Liquete, C., Bormpoudakis, D., Maes, J., McCallum, I., Kissling, W.D., Brotons, L., Breeze, T.D., Ordóñez, A.M., Lumbierres, M., Friedrich, L., Herrando, S., Solheim, A.L., Fernández, M., Fernández, N., Hirsch, T., Carvalho, L., Vihervaara, P., Junker, J., Georgieva, I., Kühn, I., Grunsven, R.V., Lipsanen, A., Body, G., Goodson, H., Valdez, J.W., Bonn, A., Pereira H.M. (2024). EuropaBON D2.3 Proposal for an EU Biodiversity Observation Coordination Centre (EBOCC). 68pp.

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Acknowledgements:
We gratefully acknowledge the valuable contributions of numerous biodiversity experts in policy, implementation and research, including scientific networks, NGOs and citizens science platforms. Their sharing of insights and expertise through EuropaBON's surveys, workshops, questionnaires and review of final outputs has been crucial to this proposal's development. We also thank the European Environmental Agency (EEA) colleagues for their significant assistance in shaping a proposal that meets current EU data flows and policy needs. We appreciate Biodiversa+ and GBIF members for their pivotal role in advancing discussions and thorough reviews, essential in defining the EBOCC's key elements and practical expectations. The "European Commission Biodiversity Monitoring ad hoc Group," comprising the Directorate-General for Research and Innovation (DG RTD), the Joint Research Centre (JRC), the Directorate-General Environment (DG ENV), the Directorate-General Agriculture and Rural Development (DG AGRI), the EEA, the Directorate-General Climate Action (DG CLIMA), the European Research Executive Agency (REA) and other external experts, deserves special thanks for their consistent, valuable input, enhancing EuropaBON's policy relevance and user orientation. We are grateful to the 317 anonymous respondents of the December 2023 public consultation for their invaluable feedback. Lastly, we are particularly thankful to the European Union Parliament members. Their belief in an EBOCC's value and their decision to fund a pilot action is greatly appreciated.

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Layout / Design:
Cover: **Christian Langer**, Martin Luther University Halle-Wittenberg / German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
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This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003553.

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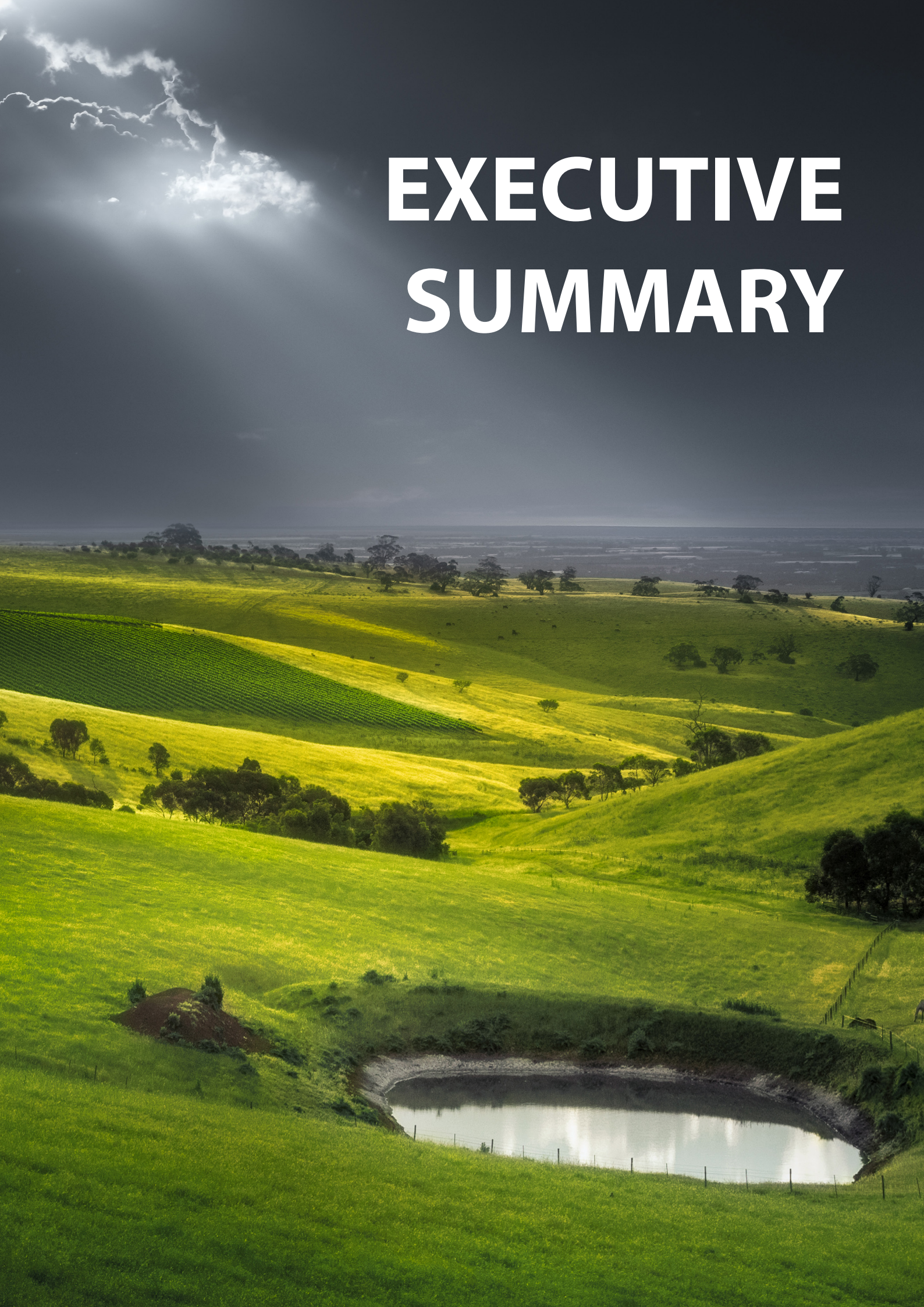
LIST OF ABBREVIATIONS

ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
API	Application Programming Interface
BCE	Butterfly Conservation Europe
Biodiversa+	European Biodiversity Partnership
BISE	Biodiversity Information System for Europe
BON	Biodiversity Observation Network
CAP	Common Agricultural Policy
CARE	Collective Benefit, Authority to Control, Responsibility and Ethics
CBD COP	Conference of the Parties to the Convention on Biological Diversity
CFP	Common Fisheries Policy
DACs	Data Access Committees
DiSSCo	Distributed System of Scientific Collections
DwC	Darwin Core standard
EASIN	European Alien Species Information Network
EBBA	European Breeding Bird Atlas
EBCC	European Bird Census Council
eBMS	European Butterfly Monitoring Scheme
EBOCC	EU Biodiversity Observation Coordination Centre
EBP	EuroBirdPortal
EBV	Essential Biodiversity Variable
EC	European Commission
ECSA	European Citizen Science Association
eDNA	Environmental DNA
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
EIA	Environmental Impact Assessment
ELIXIR	European Life-Science Infrastructure
eLTER	Long-Term Ecosystem, critical zone and socio-ecological Research
EMBRC	European Marine Biological Resource Centre
EMODnet	European Marine Observation and Data Network
EOOS	European Ocean Observing System
ERIC	European Research Infrastructure Consortium (see Supplementary Material 1)
ESA	European Space Agency
ETC-BE	European Topic Centre on Biodiversity and Ecosystems
EU	European Union
EUPoMS	EU Pollinator Monitoring Scheme
EVA	European Vegetation Archive
FAIR	Findability, Accessibility, Interoperability and Reusability
FISE	Forest information system for Europe
FTE	Full Time Equivalent
GBIF	Global Biodiversity Information Facility
GKSSB	Global Knowledge Support Service for Biodiversity
GOOS	Global Ocean Observing System
HBD	Habitats & Birds Directives
INSPIRE	Infrastructure for Spatial Information in the European Community
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
JRC	Joint Research Centre
LUCAS	Land Use and Coverage Area frame Survey
LULUCF	Land Use Land Use Cover and Forestry
MSFD	Marine Strategy Framework Directive
NGO	Non-Governmental Organsations
NRL	Nature Restoration Law
OBIS	Ocean Data and Information System
PECBMS	Pan-European Common Bird Monitoring Scheme
TDWG	Biodiversity Information Standards, originally called the Taxonomic Databases Working Group
UNEP-WCMC	UN Environment Programme World Conservation Monitoring Centre
WFD	Water Framework Directive
WISE	Water information system for Europe

EXECUTIVE SUMMARY



EXECUTIVE SUMMARY

Europe has the data to fight biodiversity loss, but it's scattered and hard to use (Sections 3.1, 3.2 & 3.3). Addressing the biodiversity crisis requires up-to-date information on species and habitat state, trends and drivers of change. However, despite the advances in biodiversity monitoring in recent years, the landscape of biodiversity data in Europe is still fragmented, access to underlying observations is limited, and novel technologies have not been fully adopted in current reporting and assessment approaches. The main bottleneck from current biodiversity data flows, across all variables and realms, is data integration and data accessibility. Only half of the monitoring programmes evaluated by EuropaBON have a (partial) automation and harmonisation of the data streams and, again, only half of them have sufficient data available to derive essential biodiversity variables. At present, there is a clear need for increased sampling effort and use of novel monitoring techniques in all realms; main future needs include the development of new models and an improved accessibility to them.

We lack crucial data on birds, habitats, and marine life, hindering efforts to track progress on EU biodiversity goals (Section 3.2). For example, population data is missing for 14% of bird species protected at EU level and trends are unknown for almost a third. The proportion of unknown assessments is highest for marine mammals at 78%. The percentage of unknown or missing environmental status assessments in EU marine regions ranges from 20% to 70%. Between 4 and 12% of water bodies in the EU have unknown ecological status, while other assessments often based on expert judgement rather than observation. All these assessments may be based on similar biological parameters, but these are not necessarily collected and managed in a harmonised way. Apart from breeding birds and butterflies, there is virtually no Europe-wide, harmonised and interoperable data on the occurrence and abundance of species or the condition of their habitats. According to EuropaBON results, only 25% of countries across the EU consistently meet key criteria for biodiversity monitoring, such as data availability and long-term sampling. This reveals significant gaps, particularly in genetic data. Other notable gaps exist in the monitoring of species traits (30%), species populations (48%) and ecosystem structure (58%). Thus, only five of the sixteen targets of the EU Biodiversity Strategy have indicators at EU level, and most of these only partially cover the target.

Uninformed decisions: Europe lacks data to properly manage biodiversity (Sections 3.2 & 5.4). As a result, policies on natural resources, agriculture, spatial planning, regional development, climate, nature conservation and ecosystem restoration are based on incomplete information on the status and trends of species and habitats, which are the main components of biodiversity.

We need better data to track Europe's biodiversity, just like we track climate (Sections 5.4 & 6). This needs to change. Just as scientists and policy makers can rely on comprehensive global climate and weather monitoring, the biodiversity crisis must be addressed based on the observations of a much more performant biodiversity monitoring system. Now is the time to strengthen coordinated biodiversity monitoring across Europe. As part of the European Green Deal, the implementation of the EU Biodiversity Strategy to 2030 and in particular the upcoming Nature Restoration Law, EU Member States and institutions must make a concerted effort to base their decisions on nature conservation and ecosystem restoration on comparable and interoperable data, rather than expert judgement or qualitative assessments. In addition, EU-wide coordinated biodiversity monitoring also serves to report on ecosystem accounts, as proposed by Eurostat, and to provide data under the Kunming-Montreal Global Biodiversity Framework monitoring framework.

A European Biodiversity Observation and Coordination Centre (EBOCC) could give us the data needed to protect biodiversity (Section 5.1 & 5.6). We propose here the establishment of a European Biodiversity Observation and Coordination Centre (EBOCC) to coordinate the implementation of a European-wide biodiversity monitoring system. Such a system will deliver up-to-date data on a set of Essential Biodiversity Variables (EBVs) tailored to policy design, evaluation and implementation to end-users such as national authorities, European institutions, Natura 2000 managers, and the scientific community.

EBOCC can break down data silos to give us a clearer picture of biodiversity (Section 5.2). EBOCC needs to focus on resolving current obstacles in biodiversity data workflows by encouraging data sharing and interoperability. It should collaborate with all involved parties to establish a supportive environment for data sharing, ensuring that credit is given to data providers, sensitive information is safeguarded, and long-term monitoring funding sources are fostered. Achieving interoperability will involve publishing data with proper metadata and adhering to data and metadata standards.

EBOCC can unlock the hidden potential of existing data to track biodiversity (Sections 5.2 & 5.3). EBOCC will make better use of existing data through integration of different data sources, modelling and novel technologies. EBOCC will map and complete workflows for each of the 84 EBVs identified by EuropaBON, taking a progressive approach and starting with a set of pilot variables. These workflows identify the different monitoring programs and involve the responsible organisations, propose modelling approaches to fill in spatial-temporal gaps, and offer tools for the analysis of the resulting EBV datasets, particularly for driver's attribution, indicator development and, when relevant, scenario building. The workflows can be implemented by organisations participating in the EBOCC or by the EBOCC itself in collabora-

tion with those organisations. The digital infrastructure for the EBV workflows can be provided by EBOCC in collaboration with national and international data infrastructures.

EBOCC can plug the holes in biodiversity monitoring programs (Section 5.2). EBOCC will enhance data gathering by supporting the establishment of new monitoring programs to address the gaps in current biodiversity monitoring programs. For several of the EBVs, there are no monitoring programs in place in most European countries; also, some of the existing monitoring programs could become more efficient. Developing new or improved monitoring programs requires a substantial new effort. EBOCC needs to have discussions with Member States and monitoring organisations to explore the potential development of these programs and determine if the EBOCC should have a role in their deployment. The expansion of the monitoring programs should be progressive, covering first the EBVs for which major gaps exist.

EBOCC can train experts to fill data gaps and develop new biodiversity monitoring programs (Section 5.2). EBOCC will develop capacity building activities to assist competent authorities and monitoring organisations in the implementation of EBV workflows and the development of novel monitoring programs. Several Member States have indicated that lack of technical capacity is a limitation to the collection, curation, analysis and use of biodiversity data. EBOCC can work with the scientific community and monitoring organisations to develop training activities and collaborative fora, starting with topics such as data exchange and standardisation, and progressively covering other needs related to data collection, modelling, citizen science, the use of novel technologies or financing options, among others.

EBOCC needs the right tools to succeed: a clear mission, steady funding, and a broad team to share knowledge and track progress (Section 5.5). To achieve its objectives, EBOCC needs a clear policy-related mandate, a sustainable funding mechanism, and a governance structure that enables accountability, transparency and the engagement of all stakeholders and knowledge providers. We propose a hybrid governance model with a central authority or agency providing oversight and hosting an operational secretariat, a decentralised network based on national biodiversity monitoring hubs, and including the collaboration with transnational organisations involved in biodiversity data collection and data management. Concrete EBVs' work will be performed by thematic hubs of experts building on existing communities and working groups. EBOCC will operate on the principle that it will not replicate existing efforts but partner with and support ongoing initiatives.

Setting up EBOCC is an investment in Europe's environment, but the long-term benefits outweigh the upfront costs (Section 5.7). Implementing the most urgent tasks described in this proposal for six initial EBVs can potentially be achieved with EUR 12 million over 5 years. Scaling up such limited EBOCC pilot to cover all the EBVs proposed by EuropaBON brings an approximate cost of EUR 54 million per year plus an initial investment of EUR 68 million. The collection of biodiversity data is not part of this cost estimate, nor are the associated costs that must be borne by Member States or other organisations in order to work effectively with the EBOCC. Such costs will be included in the upcoming EuropaBON deliverable about a modern and efficient European biodiversity observation network (D4.3). To fully implement the proposal for the EuropaBON biodiversity observation network, including coordinating the monitoring of EBVs, organising data collection, maintenance and analysis of the data, will require approximately EUR 465 million per year plus an initial investment of EUR 501 million. EBOCC's investment costs (until operational status is achieved) are significantly higher than the annual maintenance costs, and the benefits of EBOCC activities may lag years behind the costs, but are likely to be substantial and benefit multiple sectors of the economy and society through reduced costs, increased engagement and lower risks from biodiversity losses.

Biodiversity data is scattered and hard to use

Biodiversity data in Europe is Fragmented.

Bottlenecks in data accesibility and integration

Automation and harmonisation of data streams in only half of the monitoring schemes

Half of the key identified Essential Biodiversity Variables (EBVs) need increased sampling efforts

Missing crucial data hindering to track on EU biodiversity goals

Present EBVs monitoring and data gaps:

of genetic data

of species traits

of species populations

of ecosystem structure

Proposed solutions

Coordination

Enhanced coordination and cooperation

Data

Data collection, integration and sharing

Methods

Novel monitoring technologies & AI models

Capacity

Capacity building and stakeholder engagement

Resources

Financial resources and long-term funding

EBOCC will help implementers to ensure the completion of the following data-to-knowledge chain:

In-situ & remote sensing data collection → Data harmonisation & processing → Estimation and extrapolation → Essential Biodiversity Variables → Indicators tracking policies

A European Biodiversity Observation Coordination Centre (EBOCC) to monitor and protect biodiversity

Final goal:

The realisation of a EU-wide coordinated biodiversity monitoring system that delivers up-to-date data on a set of EBVs tailored to support policy decisions

Key tasks:

Coordination between all monitoring actors

Data mobilisation, integration and interoperability

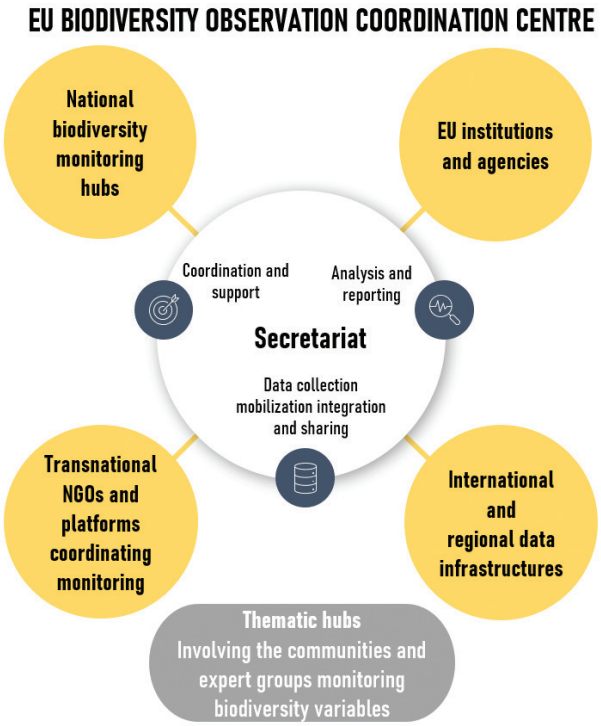
Design and promotion of new innovative monitoring schemes

Capacity building

Harmonisation of existing monitoring efforts

Analysis and visualisation of the information for decision-makers

Hybrid governance structure



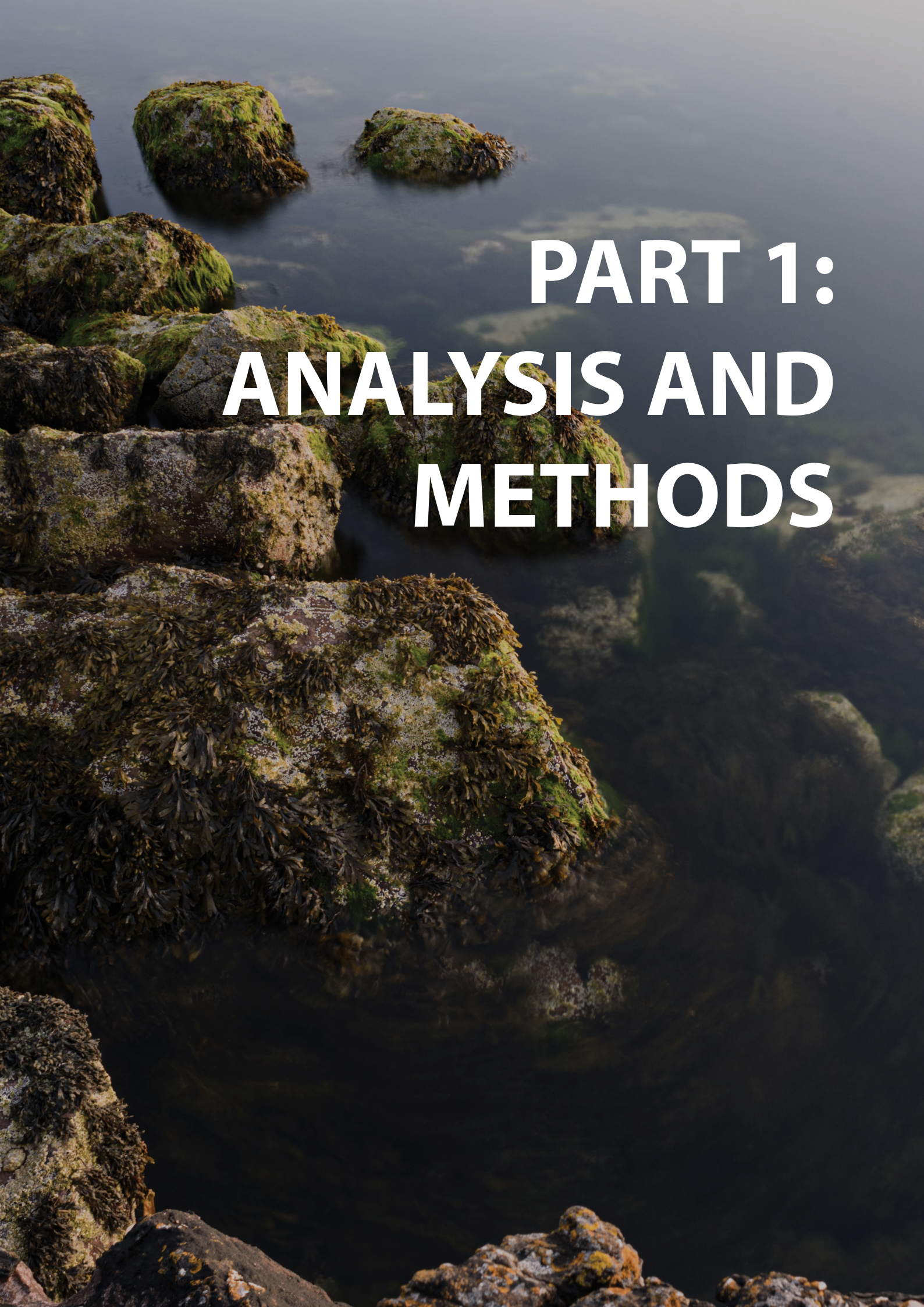
Investment for EBOCC

€ 12 million
in 5 years for a pilot of six EBVS

€ 280 million
in 5 years to cover all EBVs

Substantial Benefits for multiple economy and society sectors through reduced costs, increased engagement and lower risks from biodiversity losses.

Benefits will outweight costs over time.



PART 1: ANALYSIS AND METHODS

1 INTRODUCTION

Observations are key to understand the state of nature, the drivers of biodiversity loss and their impacts on ecosystem services and ultimately on people. Many EU policies and initiatives call for reliable, unbiased, integrated and regularly updated data on biodiversity and ecosystem services. However, biodiversity monitoring efforts are spatially and temporally fragmented, taxonomically biased and not integrated across Europe. EuropaBON has tried to address this gap by developing an **EU-wide framework for biodiversity monitoring**. To this end, EuropaBON (Nov. 2020-May 2024) has identified key user needs (Moersberger *et al.* 2022), monitoring initiatives (Morán-Ordóñez *et al.* 2023a), a list of essential biodiversity variables (Junker *et al.* 2023) and the corresponding existing gaps in data collection (Santana *et al.* 2023). The project will soon publish a proposal for a modern and efficient European biodiversity observation network to monitor Europe's biodiversity and ecosystems and to serve a wide range of policy needs.

With this deliverable, EuropaBON proposes **the terms of reference for a permanent biodiversity monitoring coordination centre for Europe that could implement and oversee the EU biodiversity observation network**. Such a centre represents one of the key solutions to overcome the critical challenges of biodiversity monitoring in Europe. The name of this coordination centre has evolved into the **EU Biodiversity Observation Coordination Centre (EBOCC)** to align with a recent preparatory action of the European Parliament to be implemented by the Commission (see below). Addressing the key biodiversity monitoring needs will deliver more up-to-date, high-quality and comparable data at all temporal and spatial scales. This can ensure an effective tracking of the progress towards policy goals and targets, as well as an early anticipation of emerging trends requiring additional policy responses.

The proposed form of the EBOCC is the result of more than two years of analyses and intense discussions with key actors from the European Commission (EC), the European Environment Agency (EEA), the European Space Agency (ESA), the European Biodiversity Partnership (Biodiversa+), competent authorities from EU Member States, the Global Biodiversity Information Facility (GBIF), Non-Governmental Organisations (NGOs), citizen science platforms, private industry, and a long list of scientists, research projects and research infrastructures. We believe this proposal represents a well-designed solution, a good technical balance between ambition and feasibility and a broad stakeholders' agreement.

In particular, Biodiversa+ has a task that aims at **establishing a transnational network of harmonised national biodiversity monitoring schemes**, by mobilising the relevant ministries, agencies, EU Commission services and initiatives. Currently, Biodiversa+ includes 80 partners (both research funders and environmental policy actors) from 40 countries. EuropaBON and Biodiversa+ tasks have run in parallel establishing all possible bridges to build some common perspectives. In 2023, Biodiversa+ led an operational guidance for transnational biodiversity monitoring schemes and for possible national biodiversity monitoring hubs (Vihervaara *et al.* 2023a). More publications are under development, hopefully following the legacy of this EBOCC proposal.

The proposal for EBOCC needs testing and implementation. A grant from the European Parliament in the form of a preparatory action makes this possible[1]. The preparatory action aims to coordinate and strengthen the collection of biodiversity monitoring data in order to make informed policy decisions at local, national, European and international levels. It focuses on the operationalization of key biodiversity variables relevant for policy and decision-making, including capacity building for taxonomic expertise and citizen science. The initiative contributes to the development of a transparent data-knowledge chain and demonstrates the value of investing in clear access to and coordination of biodiversity data. It supports more robust implementation of public policies, facilitates impact assessment, removes barriers for investors and businesses in identifying capital flows that benefit nature and allows for collaborative scientific studies integrating multiple data sources at European level. Specific activities include piloting an EU biodiversity observation service, implementing harmonised EU-wide biodiversity data workflows, providing technical support to Member States and capacity building through training. The preparatory action needs to be coordinated with other Horizon projects, parliamentary initiatives, the Knowledge Centre for Biodiversity[2], the European Environment Agency[3] and the Global Knowledge Support Service for Biodiversity[4] adopted at CBD COP15.

This deliverable starts by explaining the methodology and process followed to build the EBOCC proposal. Then, it presents the variety of governance models that can be considered for a coordination centre. Later, it deepens into the diagnosis of the problem, the analysis of the existing monitoring landscape in Europe and key messages about the main challenges, needs, examples and lessons learnt. Once all this background information is presented, the deliverable presents a proposal for the terms of reference for the EBOCC. This part includes the long-term vision and the broadly agreed mission of EBOCC; a detailed technical mandate describing the tasks that the centre should fulfil; a preliminary prioritisation of topics (biodiversity variables) to be tested in the first years; the policy framework on which the centre should operate; an overview of the key stakeholders that should take part in the EBOCC; the presentation of the selected governance structure for EBOCC; and an analysis of the operational costs of the centre. The deliverable ends with some concluding remarks.

1 See the last item in https://data.consilium.europa.eu/doc/document/ST-15238-2023-ADD-5/en/pdf
2 https://knowledge4policy.ec.europa.eu/biodiversity_en
3 https://www.eea.europa.eu/en
4 https://gkssb.chm-cbd.net/

2 METHODOLOGY

2.1 Overall methodology

This deliverable has been built following different steps and methodologies. The three main sources of information have been: desk studies (literature reviews and interviews), results and conclusions from other EuropaBON work packages, and a broad consultation process that lasted 18 months to allow for proper brainstorming and deliberations. Based on these sources and the expertise held by the EuropaBON consortium, the authors have narrowed down the options and elaborated the structure and functions of the EBOCC trying to balance the major and most urgent needs, the most feasible solutions, and the most broadly agreed (or at least not rejected) options.

This task started with a wide screening of all possible options for the EBOCC in terms of technical mandate, legal mandate, governance model and financing model. The expertise of all the partners ensured a good coverage of the possibilities. The screening was enriched by key collaborators (notably from EEA, Biodiversa+ and GBIF). This screening was the basis for the brainstorming and early discussions held during 2022.

During 2022, we mapped and explored the characteristics of key biodiversity monitoring initiatives in Europe via desk-based research and interviews with key informants. We investigated existing governance structures, mandates, and lessons learned from operational, large-scale monitoring schemes and data aggregation infrastructures, not necessarily in Europe. The literature analysis was structured around 18 topics or characteristics of large coordination initiatives[5]. This included a national case study used to illustrate some common gaps, governance structures, and future prospects from a Member State perspective. The national case study included eight structured interviews to national experts (civil servants, researchers, NGO employees and consultants) run in November 2022. Their expertise covered habitats, birds, freshwater, pollination, protected areas, forest and mammals' monitoring. The analysis of lessons learned included three more structured interviews to implementers of large-scale monitoring initiatives run in December 2022. Their expertise covered land use and species monitoring.

In 2023, other EuropaBON work packages provided key evidence to develop a robust diagnosis of the problem (notably about the monitoring challenges, bottlenecks, workflows and costs). We integrated all those results in the first draft terms of reference, narrowing down the choices and identifying the most feasible and relevant options for the EBOCC. The first version was significantly improved based on a broad and inclusive consultation process, open to all interested stakeholders. The most intensive dialogues were around the mandate of the EBOCC and the different alternatives for an organisational structure.

We list in Figure 1 the major steps on the consultation and dissemination of this proposal. Apart from these events, we had intense discussions and revisions within the consortium and with external experts coming from organisations or projects working on the topic of biodiversity monitoring. Within this process, we conducted some stakeholder focus group analysis, based on recordings and outputs, especially on issues related to: mission and vision of the EBOCC; technical and scientific mandate; possible stakeholders, users and beneficiaries; and governance structures. The information received from all these discussions was structured and integrated in the deliverable (to the extent possible).

The final online consultation allowed for broad participation of interest groups and helped understanding to what extent stakeholder groups would want to contribute to the EBOCC. Participants were asked 14 questions in a multiple-choice and open-answer format about the key ideas proposed for the EBOCC, while they could also comment on the draft deliverable. In total, the consultation reached up to 317 responses, with 196 incomplete and 121 complete surveys. Supplementary Material 2 shows the questionnaire and a detailed analysis of the complete surveys, including statistical results and the main important findings and comments. The key messages have been integrated in the relevant sections of this deliverable.

5 Adaptability; capacity building & education; planning stage considerations; long-term sustainability; mission/ mandate; human resources; monitoring scheme design; costs; citizen science; reporting; legitimacy, accountability and justice; governance; institutional politics; overarching advice; partnerships & participation; coordination; data design & principles; and visibility & dissemination.

Figure 1: Timeline with the main events for consultation and dissemination of the EBOCC proposal. In all these events, the proposal was still named "Biodiversity MonitoringCoordination Centre" as in the original EuropaBON work plan.

2.2 Estimating costs of EBOCC

The costs of the future EBOCC activities are difficult to accurately estimate as they will vary depending on the quality and quantity of data available, the number of relevant monitoring activities and number of national experts available to participate. As such, where possible, we estimate the costs required to establish and maintain workflow and coordination activities (Section 5.7) based on:

1. The costs incurred by the INSPIRE programme, a large-scale EU effort to standardise, harmonise and make available spatial data from across Europe. In particular the Slovakian INSPIRE programme who provided detailed breakdowns of activity time.
2. The time involved in the development of the EU Pollinator Monitoring Scheme (EUPoMS), which developed many aspects of monitoring itself.
3. Discussions with actors who have undertaken similar activities (European Butterfly Monitoring Scheme, OBIS, Living Norway, EEA, Dutch Butterfly Conservation, the Flemish Institute for Technological Research, GBIF, Natureforecast, Swedish Museum of Natural History, Wageningen University, Fruitwatch and JRC).

Most activities have been approximated to the nearest 0.1 Full Time Equivalent staff. Adjustments have also been made based on the relative scale of the EBOCC's work compared to other actors – for example, activities based around large spatial data are much larger than those required for biodiversity. Some, less intensive, annual activities are assumed to be part of the main remit of the EBOCC core staff and thus captured by the costs of the core staff and materials.

3 DIAGNOSIS OF THE PROBLEM

3.1 The challenges for biodiversity monitoring

Biodiversity monitoring is the process of determining status and tracking changes in living organisms and the ecological complexes of which they are a part. The EU has a long tradition of biodiversity monitoring developed to understand species trends and monitor the success of conservation programs. This is based on public monitoring programs, volunteers such as birdwatchers, research activities, and importantly also provides input to policies for environment, agriculture, fisheries and other issues. Biodiversity monitoring is a complex and costly task that is usually under the responsibility of different competent authorities and sectors from EU Member States. For some species groups, such as birds but also plants and some insect groups like butterflies or dragonflies, the engagement of expert volunteers in natural history societies is an important backbone to biodiversity recording, at the local, national and European level.

According to EuropaBON's User and Policy Needs Assessment (Moersberger *et al.* 2022), the most highly ranked **challenges to biodiversity monitoring** (for more than 350 expert stakeholders from policy, research and practice) are:

- Insufficient financial resources
- Lack of long-term policies for monitoring
- Insufficient spatial coverage
- Underrepresentation of taxa
- Lack of human and technical capacities
- Lack of integration between in situ and remote sensing data
- Monitoring frequency too low to detect trends
- Lack of data integration at different geographical scales and sectors
- Lack of (raw) accessible data and metadata
- Underrepresentation of ecosystem types and their habitats

In line with these results, we have collected perspectives from officials of the EC (from the services related to environment, research, agriculture, fisheries, climate, defence and statistics) that identify the following as top challenges for tracking the implementation of EU legislation and programmes and trying to develop evidence-based policies related to biodiversity:

- Inaccessible and insufficient raw data
- Not harmonised or interoperable measurements and indicators
- Concern about the reporting and financial burden
- Confusing network of knowledge holders
- Lack of an EU IT infrastructure for biodiversity monitoring

As a first step to explore a transnational network of harmonised national biodiversity monitoring schemes, Biodiversa+ has carried out a survey and some interviews across its partners (experts from 23 EU and associated countries contributed) to map the current state of national and sub-national biodiversity monitoring networks and coordination (Vihervaara *et al.* 2023b). Most of the national respondents thought that the best option would be "both national and European biodiversity monitoring coordination, including well-defined roles and areas" (Table 1). This could be implemented, for instance, via creation of national (cross-sectorial) coordination hubs represented in an EU coordination body.

The **solutions** identified by EuropaBON to tackle these challenges to biodiversity monitoring are (Moersberger *et al.* 2022 and Figure 2):

1. Better coordination and synchronisation of monitoring efforts, possibly adopting a common approach across Europe (e.g. a European biodiversity observation network) and a common platform that can integrate data and/or metadata at national and EU levels.
2. Harmonisation, enhanced data gathering and sharing. This includes filling the identified gaps in monitoring of taxa, ecosystem types and habitats, level of spatial detail

Table 1: Biodiversa+ survey results.

HOW DO YOU WISH TO SEE THE INTERPLAY OF BIODIVERSITY MONITORING COORDINATION IN THE FUTURE?	NUMBER OF REPLIES
More focus on national coordination centres	3
More focus on a European biodiversity coordination centre	5
Both national and European coordination centres, with well-defined roles and areas of collaboration between national and EU biodiversity monitoring coordination centres	23
Separate thematic coordination networks across Europe (e.g. expert networks on pollinators or birds alone; and extending to those that cover other taxa)	16
Unknown or other	2

and temporal frequency by establishing new monitoring programs and/or strengthening existing monitoring schemes. Both EuropaBON and Biodiversa+ propose to address standardisation through the application of Essential Biodiversity Variables (EBVs) and other essential variables like essential ecosystem services variables.

3. Taking advantage of digitalization and novel technologies (including multi-scale earth observation data, in-situ digital sensors and DNA sampling) as well as improved statistical methods for the analysis of biodiversity monitoring data.
4. Increased funding and long-term perspective for biodiversity monitoring efforts in Europe, along with better cross-country, cross-institutional, and cross-sectoral coordination of existing funding.
5. Capacity building, increase of human resources, better use of and substantial support for citizen science and stakeholder engagement within the monitoring process.

The creation of an EBOCC for Europe is one of the key actions proposed by EuropaBON and Biodiversa+ to facilitate and help implement the solutions listed above.

3.2 The monitoring landscape in Europe

Monitoring gaps

The EuropaBON project has conducted a first analysis of monitoring gaps based on a compiled list of monitoring initiatives coordinated at supranational and European levels, complemented with some national and subnational monitoring programs[7], Morán-Ordóñez *et al.* 2023a). Currently, biodiversity monitoring and the biodiversity data aggregation landscape in Europe comprises thousands of different schemes, programmes, agencies and infrastructures. They are fragmented and operate across Europe at international, national, regional or local scales. Often, they geographically overlap with little coordination between them. They sometimes share similar mandates or missions, yet few synergies are actively sought out. This creates a range of gaps and bottlenecks for current biodiversity data flows across Europe, especially in terms of data harmonisation, standardisation and integration.

7 https://monitoring.europabon.org/

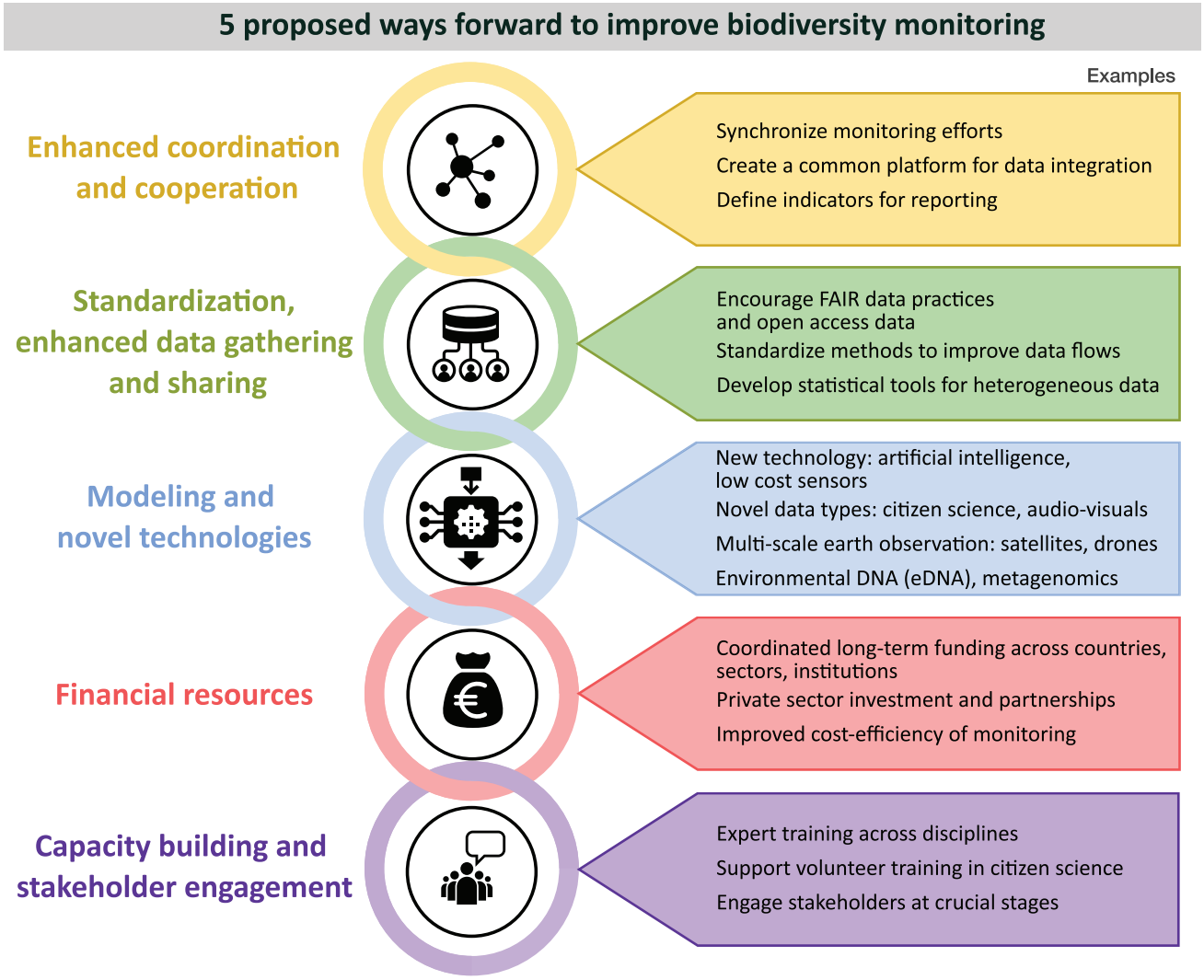


Figure 2: Five ways forward suggested by stakeholders to improve biodiversity monitoring and thereby policy impact in Europe. From Moersberger et al. (2024).

Some key findings are:

a) major thematic gaps exist regarding biodiversity attributes rarely covered by monitoring programs, such as the genetic composition of species populations and the distribution and abundance of most taxonomic groups;
b) the number of existing coordinated monitoring programs greatly differs between EU countries, and often such coordinated programs only include few EBVs;
c) long-term monitoring programs are an exception and they can only inform a small number of EBVs.

According to EuropaBON D3.2 (Santana *et al.* 2023), only 25% of countries across the EU consistently meet key criteria for biodiversity monitoring, such as data availability and long-term sampling. This reveals significant gaps, particularly in genetic data. Other notable gaps exist in the monitoring of species traits (30%), species populations (48%) and ecosystem structure (58%).

Despite they provide important insights, this and other previous monitoring gap analyses are not enough to design improved monitoring networks. First, we ignore the characteristics of the data collected by national, regional and local administrations. For example, much of the biodiversity information used for the national reporting under the Habitats, Birds, Water and Marine Directives could not be traced to the data origins. Second, we ignore the spatial coverage of many existing coordinated monitoring programs, e.g. biogeographic regions, ecosystem types, or density of observations. Finally, many other monitoring initiatives, not necessarily coordinated yet at the national or European levels, could provide valuable information and expertise (e.g. protected areas monitoring).

Main bottlenecks

According to EuropaBON findings, the main bottleneck from current biodiversity data flows, across all variables and realms, is data integration (Morán-Ordóñez *et al.* 2023b), and pursuing such data integration needs a large effort on standardisation (of data collection methods, metadata, etc.). Some data infrastructures, such as GBIF, provide an efficient solution with regard to integrating species-level monitoring data; however, participation in this data infrastructure is incomplete across European states, and even among participating countries, there is great variability in the sharing and integration of data across different agencies and organisations. There is also a gap in advanced statistical/modelling technical skills. Only half of the monitoring programmes evaluated by EuropaBON have a (partial) automatization and harmonisation of the data streams from biodiversity collection to data integration at different levels. In addition, data are most often not FAIR ('findable, accessible, interoperable and reusable'), and web tools and apps only exist in a few cases to facilitate data harmonisation and standardisation (Morán-Ordóñez *et al.* 2023b). The development of trans-national and cross-infrastructure biodiversity data workflows further requires improved interoperability between IT infrastructures and institutional databases, for instance (a) building upon existing common data structures such as Darwin Core, (b) development of human- and machine-readable metadata, (c) standardised procedures to ascertain quality assurance and quality control, and (d) accessibility through common, standardised Application Programming Interfaces (APIs) (Hardisty *et al.* 2019). This harmonisation and coordination is key to success, if current biodiversity monitoring efforts are to support the assessment of EU legislation and EU services requiring biodiversity information (environment, maritime affairs, agriculture, statistics, research, etc.).

Data flows for policies

EuropaBON's analysis of monitoring programmes indicates that most European-wide monitoring networks are coordinated and run by national or subnational environment agencies responding to the monitoring required for the implementation of EU Directives, such as the Birds and Habitats Directives (BHD), the Water Framework Directive (WFD) or the Marine Strategy Framework Directive (MSFD). Vihervaara *et al.* (2023b) describes the key national/sub-national authorities, institutes and monitoring networks in 23 countries. Data are aggregated to variables used for assessing status and trends in species, habitats and biological communities. The aggregated data and/or the final interpretation (assessment) are submitted to the EEA to fulfil the reporting requirements to the EC. The information submitted is subject to automated quality assurance rules and used for European level assessments. The assessments reported by Member States are stored in the EEA Reportnet 3.0[8], which is the Central Data Repository for environmental policies. The information can be analysed and presented by the EEA as interactive dashboards and indicators. However, the underlying raw data at species or habitat level are only stored at national or subnational level, and are therefore – practically – not available for synthesis and in-depth analysis. Even if they were available, in some cases the variables/criteria and their underlying data are not harmonised and, thus, not comparable across Member States.

The conservation status of 4% of habitats, 10% of species and 14% of bird populations protected at EU level are unknown, as well as 21% of the habitat's trends and 31% of the species' trends (EEA, 2020); but those percentages refer only to the number of assessments reported by Member States (ignoring 'not assessed' species and habitats). Some regions, like Macaronesia, can reach 100% of unknown status. The percentage of unknown or 'not assessed' environmental status in EU marine regions ranges between 20% and 70%[9]. There is an unknown ecological status in between 4 and 12%[10] of EU's water bodies; moreover, such assessments are frequently based on expert judgement. All these assessment can be based on similar biological parameters, but not necessarily collected and stored in a harmonised way. One of the key messages of EU ecosystem assessment (Maes *et al.*, 2020) was that the EU needs

8 https://reportnet.europa.eu/
9 https://water.europa.eu/marine/data-maps-and-tools/msfd-reporting-information-products/ges-assessment-dashboards/msfd-story-map
10 https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd

a better performing biodiversity observation network and more consistent ecosystem condition reporting. With these limitations, at present only eight of the sixteen targets of the EU Biodiversity Strategy have indicators published at EU level[11], and most of them only partially cover the target.

The EEA and its 38 member country network, Eionet, have a range of tasks related to the compilation of environmental data, environmental reporting and assessment, as well as data dissemination on all environmental domains[12]. The EEA has established several thematic information systems to provide information to policy makers and the public, covering biodiversity (BISE), forest (FISE), freshwater and marine (WISE). Via a dedicated biodiversity team and the European Topic Centre dealing with Biodiversity and Ecosystems (ETC-BE), EEA has supported for over 20 years the development of reporting standards under the BHD and provided training and assistance to EU Member States to report under these directives. This represents a great investment to achieve better comparability, but still there is a long way to go.

Other EU policies, like those regulating agriculture, fisheries, forestry or maritime spatial planning, also generate a wide range of biodiversity monitoring activities and data that is not always accessible for researchers or citizens. There are more and more examples of complementarity, like the new Land Use and Coverage Area frame Survey (LUCAS) modules monitoring the state of biodiversity (see below), or the fisheries Data Collection Framework[13]. Both the environmental and the sectoral EU policies promote the coherence and the reuse of the aggregated information (assessments), however so far it has not been enough to ensure the coordination, harmonisation and re-use of the underlying data across institutions and sectors.

LUCAS is a survey that collects harmonised data on the state of agricultural land and the environment across the EU Member States (e.g. various aspects of land use, crops, natural vegetation) (Eurostat, 2012). The data collected through LUCAS is used to assess the impact of agricultural and environmental policies, and supporting decision-making in various sectors (Hiederer and Durrant 2010, Baruth and Hiederer 2013). Some LUCAS modules focus on soil (properties and erosion) and landscape features, which are essential for sustainable land management and environmental protection.

Other monitoring organisations

There are many other monitoring networks coordinated and run by natural history societies, NGOs, protected areas and research institutions or a mix of both; they sum up 83% of the institutions integrating monitoring data in the EuropaBON monitoring database (see examples in Box 2). Overall, a rich and diverse landscape of people and organisations, with a diversity of motivations and expertise, independently engages in biodiversity monitoring (Kühl *et al.* 2020). By understanding gaps and barriers, this provides opportunities for integration to foster a sustained and resilient biodiversity monitoring to inform policy and practice.

To date, however, the lack of long-term secured funding for those networks (often research- or charity-based, see for example Urbano & Cagnacci 2023) is one of the main bottlenecks these monitoring networks face:

- limits their capacity to collect data (e.g. the number of sampling sites and visits per site) as well as its geographic coverage,
- constrains the capacity building and training of the monitoring network, as well as
- limits their capacity to support volunteers or, importantly,
- hire specialists for data management, archiving and analysis (e.g. data managers, modelling technicians, taxonomists, IT professionals) or to
- create and maintain IT infrastructure for data entry and archiving, or for the automatization and harmonisation of data flows.

In addition, there have been myriads of EU funded research projects that have collected biodiversity observations and have developed monitoring tasks for a short period of time. Research Infrastructures established by ERICs have a longer and larger scope. For example, the "Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research Infrastructure" planned for 2015-2032 will cover a wide range of abiotic measurements and more than a dozen "standard observations" related to biodiversity across more than 500 eLTER sites (Zacharias *et al.* 2022). Supplementary Material 1 and Section 3.5 of this deliverable review some key aspects and lessons learned from those infrastructures.

The situation in marine waters

In Europe's seas, the marine biodiversity community has established observation networks and infrastructures, including national observation and monitoring programmes delivering data to national environment agencies, to the MSFD and to global initiatives (e.g. MarineBON, GOOS)[14]. Data gets mostly integrated by Regional Sea Conventions at the regional level (e.g. the North-East Atlantic region, the Baltic Sea), with Southern and Eastern European waters less well covered by permanent biodiversity monitoring programmes (Jessop *et al.* 2022). The recent review of Member States' 2020 reports on MSFD monitoring programmes (Tornero Alvarez *et al.* 2023), together with the analysis of 2018 reports on species biological diversity (Palialexis and Boschetti 2018), point to the key issues and also the progress achieved in consistency, adequacy and coherence of the national monitoring systems.

11 https://dopa.jrc.ec.europa.eu/kcbd/dashboard/

12 The collected information is used for EU-wide thematic assessments such as the State of Nature, State of Water, State of Marine or State of Environment Reports, as well as indicators and other information products designed for social media.

13 https://dcf.ec.europa.eu/index_en

14 This includes marine research infrastructures (e.g. LifeWatch-ERIC, EMSO-ERIC, EMBRC); major research observation initiatives (e.g. JERICO-NEXT, eLTER, e-Science European Infrastructure for Biodiversity and Ecosystem Research, Integrated Infrastructure Initiative); as well as European components of global networks (e.g. GOOS Regional Alliances, EOOS, EuroGOOS, MarineBON Europe, European OBIS node).

Box 1: Examples of long-term monitoring by NGOs based on (expert) citizen science

European Bird Census Council (EBCC)

The EBCC steers bird monitoring and atlas work to inform and improve bird population management and conservation in Europe. It supports national partners and ornithologists through knowledge exchange and fundraising, which is crucial in countries with low capacities to monitor bird populations. Three main projects (EBBA, PECBMS, EBP) under the EBCC contribute to a comprehensive understanding of European bird populations for EU evaluation. EBCC collaborates with Wetlands International for winter waterbird monitoring, complementing EBCC projects.

The European Breeding Bird Atlas (EBBA) documents European breeding bird species distribution and changes. The latest EBBA2 (from the 2010s) involved 120,000 participants, providing huge amount of validated data. Ongoing efforts focus on the EBBA Live concept to update bird distributions and changes on a frequent basis. The Pan European Common Bird Monitoring Scheme (PECBMS) uses common birds as indicators for large-scale and long-term monitoring of breeding populations across Europe. Yearly systematic counts of breeding birds by expert volunteers aim to track EU policy impacts. The Euro Bird Portal (EBP) establishes a European data repository for aggregated data on birdwatchers' year-round activities across Europe. Although that data are gathered following simple protocols, or in some cases no protocols, the vast amount of data and extensive geographical coverage offer potential for research on birds' distribution in large geographical areas.

Butterfly Conservation Europe (BCE)

The European Butterfly Monitoring Scheme (eBMS) is co-ordinated by BCE and gathers data on butterfly numbers and trends. Systematic counts of butterflies occur weekly or fortnightly during the adult season, primarily on standardised Butterfly Monitoring Transect walks (fixed routes). These are supplemented by 15-minute timed counts of butterflies, aimed to monitor rare species or remote areas. The ButterflyCount app eases data collection, in addition featuring AI-based photographic identification for moths. BCE gathers the data annually from national schemes into a central database.

The volunteer butterfly monitoring network is active since 1976 and expanded notably in the 1990s and after 2018 thanks to some projects funded by EU Parliament that supported further coordinators and national schemes. Until present, over 100,000 people from 23 European countries have contributed to nearly one million counts from over 12,000 sites. The resulting database is used to generate a suite of EU and pan-European indicators.

About 650 European marine biodiversity monitoring programs, ranging from pan-European to local, were recently identified (Jessop *et al.* 2022). More than 90% of these programs were national or subnational, but large-scale multinational efforts also exist, such as the European Mammal Assessment for cetaceans and pinnipeds (28 countries) and the European Network on Invasive Species (18 countries). Some 41 programmes operate within regional areas (e.g. the North Sea, the Baltic Sea) or are global monitoring programmes conducted within EU marine waters. In general, the Baltic and North Seas were better monitored than the Mediterranean Sea, and coastal areas have far greater coverage than the high and deep seas. A key bottleneck is that 65% of the programs surveyed had poor descriptive metadata for their activities.

Furthermore, Palialexis *et al.* (2021) in their review of MSFD reporting across all European Seas note that despite significant advances in monitoring, expert and MS coordination, and funding, bottlenecks remain. Lack of consistency and coordination in the reporting detail and quality, deviation from proposed reporting guidelines, gaps in data availability, different monitoring starting dates, and variations in compliance history and experience between Regional Sea Conventions 'jeopardise a harmonised and comprehensive synopsis of the biodiversity monitoring programmes at the regional and EU-wide level'. They stress that beyond measuring the same parameters, sampling techniques, strategies and analyses harmonisation, common data and metadata handling and infrastructures, and agreement upon how to measure trends also need to prioritised.

Overview

Due to the unstable nature of funding and the changing governance architectures of monitoring networks, the EU monitoring landscape is highly fragmented across institutions. This fragmentation leads to a lack of data harmonisation among different monitoring schemes and regions (different sampling protocols, metadata standards, different indicators) and hampers the capacity to generate EBV metrics and indicators. Keeping to just some of the large-scale or pan-European schemes, we can see (Table 2) the heterogeneity in the monitoring methods, funding streams, governance arrangements and the type of entity of these schemes. The present monitoring landscape lacks clarity, accountability, and, importantly, cross-sector, cross-biome, cross-taxon, and cross-theme coordination.

A cross-EU comparison of national monitoring and/or biodiversity aggregation data efforts would reveal characteristic heterogeneity. Wide differences in monitoring cultures, monitoring histories, scientific, technical and financial capacities, and influence over EU regulation and laws, have led to divergent approaches in how Member States monitor elements of biodiversity – or not. But this is not a characteristic of government-run monitoring programmes only. For example, PECBMS, in collaboration with Statistics Netherlands, have devised particular statistical methods that account for the heterogeneity between participating countries (data collection, scheme design, etc.) post-data collection. Nationally, responsibilities and financing for biodiversity monitoring are often spread across multiple sectors and ministries (see Section 3.4), and national focal points are still "rare or dysfunctional" (Révelard *et al.* 2022). Biodiversity monitoring therefore needs a culture of integration (Kühl *et al.* 2020). The community around monitoring has already made enormous efforts to counteract this fragmented ecosystem. Public authorities, NGOs, EU institutions and agencies, universities, research institutes, etc. are forming networks, building large collaborative projects and infrastructure, and promote new developments and approaches to biodiversity and ecosystem services monitoring. Through networking, shared training, collective projects and initiatives, the monitoring ecosystem has become better defined, the actors better engaged and the challenges more accurately known, with the mobilisation of data, anchored on the pan-European harmonisation and integration of *in situ* and remote sensing data, at the core of new frameworks (e.g. EBVs).

3.3 Future needs for workflows from data collection to modelling

A key requirement for efficient large-scale multinational monitoring is the harmonisation of biodiversity measures estimated at lower (national, regional, local) scales (UN Economic Commission for Europe 2023). Essential Biodiversity Variables (EBVs) are standardised measures, employing common, flexible methodologies that enable interoperability between biodiversity data collected at lower scales (CBD 2022). EBVs may have a central role in the Kunming-Montreal Global Biodiversity Framework[15].

In the context of EuropaBON, experts in the field of biodiversity monitoring, data collection, data integration and modelling have identified a range of future needs for developing workflows of EBVs within the context of an EU-wide biodiversity observation network (Lumbierres and Kissling 2023). For data collection (orange bars in Figure 3a), there is a clear need for increased sampling effort (e.g. more sites, larger geographic coverage, higher temporal frequency, and broader taxonomic/ecosystem representation) in freshwater, marine and terrestrial ecosystems. Additionally, the development and use of novel monitoring techniques (e.g. eDNA, remote sensing, digital sensors) for EBV generation is a key need across realms (Figure 3a). For freshwater and terrestrial EBVs, improvements of existing sampling designs or the development of new ones has been highlighted by experts whereas for the marine realm improvements in satellite remote sensing are specifically mentioned (Figure 3). For data integration (green bars in Figure 3a), experts emphasise the need for integrating and harmonising data from various sources (e.g. from different sampling methods) as well as developing protocols and standardisation procedures (e.g. standardising metrics and data collection) for freshwater, marine and terrestrial EBVs. The expansion of European integration nodes is especially important for marine EBVs (e.g. coordination at the EU level and improved integration and communication among regional/national nodes) whereas the automation of workflows (e.g. automated EBV generation or apps for improving sampling data flows) are emphasised for terrestrial EBVs (Figure 3a). For modelling (blue bars in Figure 3a), the development of new models (e.g. spatially explicit models for extrapolating data to sites without measurements, or models that connect EBVs to drivers of biodiversity loss) and an improved model accessibility (e.g. user friendliness and open code) are identified as the main future needs for developing EBV workflows.

In addition, a number of interoperability aspects and IT infrastructure needs have been identified for developing EU-wide EBV workflows (Figure 3b). Data accessibility is highlighted as the key bottleneck for freshwater and terrestrial EBVs (grey bars in Figure 3b), with an urgent need for access to the raw data. The implementation of metadata standards is also repeatedly mentioned by experts across freshwater, marine and terrestrial EBVs. For IT infrastructure, experts highlight the need for centralized portals and data repositories as well as a centralized cloud computing facility to generate EBVs and other data and information products (yellow bars in Figure 3b). Another option, depending on the scale and type of biodiversity data in focus, is a set of national infrastructures which could be interlinked with some centralised European infrastructures (GBIF, BISE, DigitalBON, etc.).

The diverse range of future needs for EBV workflows, as identified by hundreds of experts (Lumbierres and Kissling 2023), reflects the varying levels of development of each EBV and

15 https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-05-en.pdf

Table 2: Some large-scale or pan-European biodiversity-related data collection or data aggregation networks and infrastructures. This is not an exhaustive list but it illustrates the variety of initiatives pursuing different (but related) objectives (see also Table 3).

	Centralised governance	Hybrid governance	Distributed governance
Global		- Global Biodiversity Information Facility (GBIF)	
EU	- Land use and land cover survey (LUCAS) - Forest information system for Europe (FISE) - Water information system for Europe (WISE and WISE Marine) - Copernicus - Biodiversity Information System for Europe (BISE)	- European Topic Centre on Biodiversity and Ecosystems (ETC-BE)	
EU and Member States	- European Environment Information and Observation Network (Eionet) - Water Framework Directive (WFD) - Habitats & Birds Directives (HBD) - Marine Strategy Framework Directive (MSFD)		
Network		- European Marine Observation and Data Network (EMODnet)	- European Ocean Observing System (EOOS)
NGO			- European Bird Census Council (EBCC) - Butterfly Conservation Europe (BCE)
European Research Infrastructure Consortium (ERIC)			- LifeWatch - Long-Term Ecosystem, critical zone and socio-ecological Research (eLTER) - European Life-Science Infrastructure (ELIXIR) - European Marine Biological Resource Centre (EMBRC) - Danubius - Distributed System of Scientific Collections (DiSSCo)

is strongly influenced by the existence or lack of monitoring initiatives across Europe. It also reflects unique aspects of the current state of monitoring and reporting in different realms (freshwater, marine and terrestrial), highlighting the need for a unified framework based on EBVs across Europe.

3.4 An example from a national case study: the situation in Greece

Similar to many other Member States, the Greek biodiversity monitoring system exemplifies the European and national challenges in biodiversity monitoring, as acknowledged in the EuropaBON's User and Policy Needs Assessment (Moersberger *et al.* 2022). It emphasizes the significance of institutional continuity, the vulnerabilities associated with market-based competitive funding, and the shortage of human resources and trained staff. Biodiversa+ is currently working on comprehensive national analyses, including a review of governance structures, data management, and interoperability solutions of national biodiversity monitoring schemes, as detailed in Lipsanen *et al.* (2024).

Our research yields three key findings. Firstly, large-scale operational monitoring in Greece is primarily conducted in accordance with EU environmental legislation, such as the HBD, WFD, and MSFD. The only exceptions are charismat-

Table 3: Mission of the pan-European biodiversity-related networks and infrastructure listed in Table 2.

Name	Mission / Mandate
BCE	To report on the state and change of the European butterfly populations (see Box 1).
BISE	Be a single entry point for data and information on biodiversity in the EU. Bringing together facts and figures on biodiversity and ecosystem services. It links to related policies, environmental data centres, assessments and research findings from various sources. It is developed to strengthen the knowledge base and support decision-making on biodiversity.
Copernicus EU	To monitor and forecast the state of the environment on land, sea and in the atmosphere, in order to support climate change mitigation and adaptation strategies, the efficient management of emergency situations and the improvement of the security of every citizen.
Danubius	'…to facilitate and contribute excellent science on the continuum from river source to sea; to offer state-of-the art research infrastructure…'
DiSSCo	'…place EU natural science collections at the centre of data-intensive scientific excellence and innovation…'
EBCC	To report on distribution and temporal changes of birds in Europe via three main projects (Box 2).
Eionet	A partnership network of the European Environment Agency (EEA) and its 38 member and cooperating countries that aims to gather data from available datasets, and develop knowledge and advice to policy makers about Europe's environment.
ELIXIR	'…coordinate, curate, store, archive, integrate and disseminate the life-science data produced by life science researchers in Europe and elsewhere…'. To help researchers find and share their data. The distributed infrastructure includes databases, software tools, training materials, cloud storage and supercomputers.
eLTER	To provide researchers with access to over >500 sites and >50 larger LTSER Platforms across Europe, and biogeographical regions, establishing and offering harmonised and standardised data (including biodiversity), services and training.
EMBRC	'We provide access to marine resources, as well as cutting-edge services and facilities that allow researchers, from both academia and industry, to study the ocean and develop innovative solutions to tackle societal issues.'
EMODnet	To assemble existing marine data and to create contiguous and publicly available information layers which are interoperable and free of restrictions on use.
EOOS	'…integrate Europe's ocean observing communities and facilitate coordinating the multiple organisations operating, supporting and maintaining ocean observing and monitoring infrastructures.'
ETC-BE	Support EEA with harmonisation of environmental information of the Member States, the processing of databases, the analysis of information and the presentation of information to support policymaking.
FISE	An entry point for sharing information with the forest community on Europe's forest environment, its state and development. It brings together data, information and knowledge gathered or derived through key forest-related policy drivers.
GBIF	To mobilise the data, skills and technologies needed to make comprehensive biodiversity information freely available for science and decisions addressing biodiversity loss and sustainable development
HBD	Assessment, monitoring and reporting of conservation status under Article 17 of the Habitats Directive and Article 12 of the Birds Directive.
LifeWatch	Become the Research Infrastructure providing access to the world's biodiversity content, services and communities in one click. 'Accelerate the research effort of the scientific community...'
LUCAS	To identify changes in the EU in land use and land cover. The data collected by LUCAS provides harmonised information for studying a range of socio-environmental challenges, such as land take, soil degradation or biodiversity (see Box 1).
MSFD	Assessment, monitoring and reporting on the state of Europe's seas, on the pressures affecting them, and on the actions taken to protect and conserve the marine environment. In particular, the assessment of marine waters (including biodiversity) under Article 8 and the reporting of programmes to monitor the environmental status under Article 11.
WFD	Assessment, monitoring and reporting of ecological status under Article 18, including data on single biological quality elements in rivers, lakes, transitional and coastal waters. Data are also reported annually as EQR-values for each single biological quality element under WISE.
WISE & WISE Marine	Provide a web-portal entry to water related information ranging from inland waters to marine, namely thematic assessments in the context of EU water related policies, reference documents, indicators, interactive maps & charts. It is developed to strengthen the links to the datasets and knowledge base and support decision-making on aquatic biodiversity.

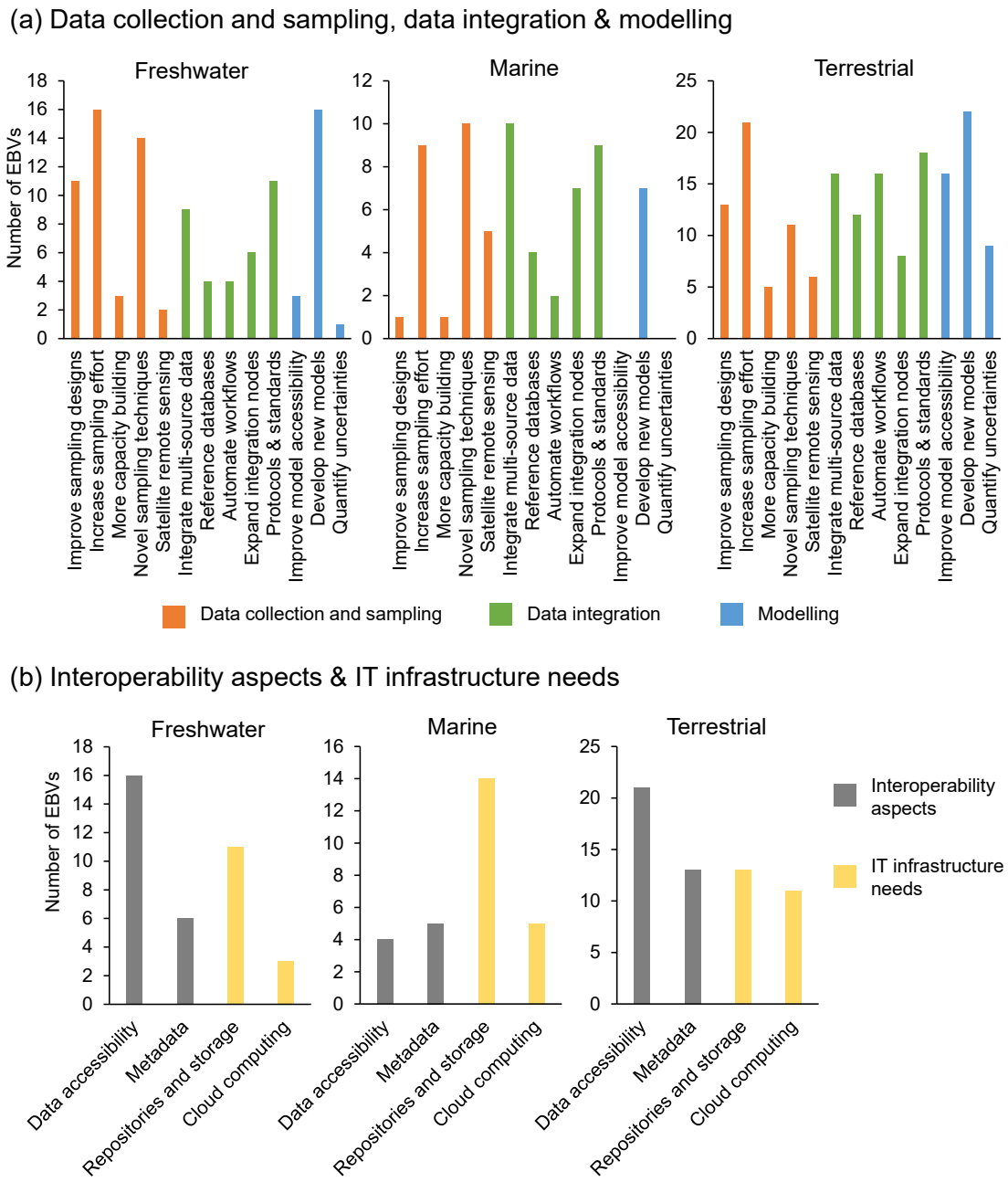


Figure 3. Future needs for developing workflows of Essential Biodiversity Variables (EBVs) in the context of an EU-wide biodiversity observation network. (a) Aspects of data collection and sampling, data integration & modelling, and (b) interoperability aspects & IT infrastructure needs. Information was obtained from experts during an EBV workflow workshop held by EuropaBON from 22-24 February 2023. The experts provided workflow information for 70 EBVs identified by EuropaBON (https://github.com/EuropaBON/EBV-Descriptions). The information was subsequently grouped into the categories as represented on the x-axis.

ic fauna and birds, which are monitored by relevant NGOs (wolves and bears: Calisto; birds: Hellenic Ornithological Society; seals: MOM, Archipelagos; sea turtles: Arhelon, Archipelagos; whales and dolphins: Archipelagos). However, their data are not made publicly available.

Secondly, government agencies lack the mandate and human resources to conduct monitoring themselves. The Greek ministry and responsible agency outsource the operational coordination of Natura2000 monitoring, a common practice in many other Member States. Ministry agencies employ more administrative and management staff than those with scientific and technical skills, which contrasts with their previous capacity to monitor various aspects of biodiversity (forests, fisheries, protected areas).

Thirdly, the public administration in Greece is not only geographically complex, but also temporally diverse. The basic administrative and organisational structures undergo constant changes and experience high staff turnover. For instance, the restructuring of administrative units for protected areas has led to the merging of these units (which were independent bodies with local management boards) into a new agency for biodiversity and climate change (NECCA).

After conducting a desk study and eight interviews with national monitoring experts, we have identified several issues in the monitoring system in Greece:

Spatial gaps: Monitoring is not consistent in areas outside of the Natura2000 network, unless they contain charismatic or flagship fauna and flora (such as wolves or sea turtles), leading to spatial data gaps for various species and monitoring in general.

Temporal inconsistencies: Changes in governance and organisational structures have resulted in historical inconsistencies in data collection methods, data and metadata standards, and monitoring schemes, making it difficult to establish time-series data.

Taxonomic gaps: Efforts mainly focus on monitoring HD Annex-listed species, leaving many species without sufficient data and an unknown conservation status.

Lack of institutional learning: The constantly changing actors and methods in the monitoring ecosystem have hindered institutional learning and continuity.

To address these issues, there is a need for a well-staffed, long-term funded national organisation capable of:

- coordinating monitoring schemes across terrestrial, freshwater, and marine realms,
- funding new monitoring schemes based on gap analysis,
- aggregating national monitoring data according to common (EU) data standards,
- compiling biodiversity indices and publishing reports and data, and
- representing the country in higher-level organisations such as GBIF or IPBES (on which it is currently not involved).

3.5 Key lessons learned from previous experiences and from literature

Creating, planning, building, implementing and integrating large-scale, data-driven environmental monitoring is a complex undertaking. Nevertheless, we can glean valuable insights from the wealth of experience and knowledge found in published literature and within relevant institutions in the EU. To extract these lessons, we conducted a desk study and three interviews with experts in large-scale monitoring. Our focus here is on the 'social' aspects of the 'socio-technical' spectrum of large-scale environmental monitoring infrastructures (Bowker 2000; Baker and Bowker 2007; Pritchard *et al.* 2022; Urzedo *et al.* 2022).

Mandate. Biodiversity monitoring must hold a prominent place on the political agenda, as evidenced by existing regulations, laws, and the proposed Nature Restoration Law. In many instances, it has been noted that "legislation mandating monitoring" needs to be established before implementing systematic monitoring schemes (Wright *et al.* 2020), or at the very least, there should be substantial pressure for reporting quantitative evidence. It is essential to establish a compelling agenda with high, yet attainable objectives, and the ultimate goal should be to provide not just data, but clear information and knowledge on biodiversity (Portillo-Quintero *et al.* 2014).

Leadership and guidance. The majority of current or upcoming large infrastructures or projects related to biodiversity monitoring are led by active researchers or educational institutions, and often have science-driven objectives. This is particularly true for biodiversity-related ERICs, as their mission reflects a focus on research and innovation to serve the research communities in their respective fields. There is a need for a biodiversity monitoring infra-

Box 2: Monitoring governance, resources and data re-use in Greece

During the previous monitoring period, post-collection data aggregation was not able to produce harmonised and re-usable data. The previous period's HBD monitoring scheme was organised as follows: each of the 36 protected areas governance units was put in charge of monitoring Annex-listed habitats and species that fall within Natura2000 sites. Many of the governance units did not have the technical capacity to implement monitoring (mainly taxonomic, field, and technical knowledge and staff), so they outsourced this work to private companies, individual consultants, university staff, research institutes and NGOS to implement monitoring. Others did have the capacity to monitor some species and/or habitats, so they implement it themselves (e.g. bird monitoring in Dadia National Park). The diversity of groups collecting the data created a complex landscape with diverse expertise, monitoring culture, experience, principles, coordination, and data management skills. As a result, while all data was added to a central database system by the relevant Ministry, they could not be meaningfully aggregated as they do not share metadata standards, data standards, collection standards, database standards, etc. Furthermore, data re-use is extremely difficult.

Currently, the biodiversity management and monitoring system is being re-organised. Care is taken to produce harmonised and re-usable data and efforts are being made to set-up and maintain a National Biodiversity Information System and a National Biodiversity Database (Life EL-BIOS programme).

structure that is research-based but not research-driven (where agencies guide, research organisations advise, and stakeholders implement). One example is the EEA with its European Topic Centres, which are primarily composed of partners from large research institutes across Europe. However, the EEA's mandate does not extend to the harmonisation of data collection and observations or the integration of all types of biodiversity data, including not officially reported.

Coordination. Large-scale monitoring systems necessitate some form of central coordination or a higher-level framework to play a strategic role in establishing an operational monitoring network. Among the responsibilities of central coordination should be the coordination of all existing monitoring efforts to prevent duplication, providing guidance on data standards and sharing, and ensuring the use of appropriate tools and technologies to facilitate monitoring and ensure data integration. An additional requirement, as advised by Vořišek *et al.* (2008) from EBCC, is that the coordinators must be "enthusiastic."

Governance architectures[16]. The primary challenge in establishing a monitoring network is not data sharing (Ryan and Swanson 2014); rather, it is creating an organisational structure that can foster a community of biodiversity monitoring practitioners and scientists to collaborate on designing and implementing effective long-term monitoring. Presently, European biodiversity monitoring governance can be characterized as polycentric, with numerous consortia and organisations sharing the mission of monitoring different aspects of biodiversity. In such cases, a central authority would not aim to take on all monitoring activities but rather have a subsidiary function, carrying out 'only those tasks which cannot be performed' (Tanhua *et al.* 2019) at more local levels or by existing organizations. Each governance architecture has its own advantages and disadvantages, so governance should be tailored to the specific task at hand.

Stakeholder participation. As previously mentioned, biodiversity monitoring in Europe involves multiple actors and scales. It is crucial to maintain a close and trustful relationship with partners at the local and international levels to identify strengths, gaps, and barriers, forming integrated, robust networks (Vořišek *et al.* 2008, Kühl et al 2020). Early consultations with existing monitoring schemes, networks, partnerships, statisticians, surveyors, and national agencies are essential for developing a system that meets policy and user needs. In addition, engaging partners throughout the value chain, including data providers and users, is important (Tanhua *et al.* 2019). Biodiversity managers and practitioners should also establish direct relationships with the system to address societal needs and identify scientific gaps, while local and national engagement is vital for understanding biodiversity dynamics and ensuring legitimacy and buy-in.

Legitimacy, accountability and justice. It is crucial to prevent any institution or Member State from dominating decision-making during the design, construction, or operational phases of an EU monitoring system. Broad representation of less-resourced countries is necessary, requiring capacity development, strong partnerships, new funding models, and updated training approaches (Vořišek *et al.* 2008; Klein *et al.* 2019; Tanhua *et al.* 2019). Taking into consideration different monitoring cultures, including methodologies, sampling schemes, and data standards, is essential. Considerations of technological independence and autonomy are crucial, not only in terms of FAIR data but also in terms of tools (e.g. software) and database access (Portillo-Quintero *et al.* 2021). Resources can be more easily mobilised from more developed to less developed regions, taxa, or organizations when the overall purpose is shared. Engaging critics of the future system (EBOCC) is also important to understand barriers and challenges, ensuring that they comprehend the intent and mandate of the infrastructure and potentially provide support to the system (Wright *et al.* 2020).

16 Tanhua *et al*. (2019) list of characteristics for operational infrastructures: '(a) Responsiveness: Governance must respond to the needs of stakeholders across scales, and sectors (b) Purposeful: Governance must demonstrate purposefulness for, and on behalf of, the community; (c) Clear objectives; (d) Transparency: Transparency and openness must be a priority, to ensure broad and public access to and benefit from the system; (e) Efficiency and Effectiveness; (f) Adaptiveness; (g) Sustainability; (h) Authoritativeness; (i) Accountability: monitoring and feedback to measures of success and performance.'

4 ALTERNATIVE DESIGN OPTIONS

Our approach to analyse and find agreements around possible governance options was based on the central role played by the technical mandate. This is the factor that will mostly influence the governance structure, funding and legal forms of the future EBOCC (Figure 4). We discussed and narrowed down the tasks allocated to the centre in an iterative way, in order to present a clear technical mandate and, hence, limit the possibilities for the governance structure, legal mandate and funding options.

Regarding the governance of large-scale monitoring programmes there are three main approaches to biodiversity monitoring: decentralised, centralised, and hybrid. Each approach has its own set of benefits and limitations, which we describe below and in Supplementary Material 3, and is not mutually exclusive but can be applied for different monitoring tasks. This categorisation reflects ideal types, i.e. heuristic simplifications of complex reality, as reflected in Silva del Pozo *et al.* (2023) survey of 14 transnational monitoring protocols across countries. Centralisation and decentralisation here refer to wider governance structures and organisational forms and not strictly in data analysis, collection or reporting.

Decentralised biodiversity monitoring involves the participation of multiple stakeholders, such as local communities, government agencies, and non-profit organisations, in the strategic and everyday decision-making and usually in the collection, reporting and analysis of data. One of the main benefits of decentralised monitoring is that it can provide a more comprehensive and representative view of biodiversity, as it takes into account the knowledge and perspectives of a wide range of individuals and groups. In addition, decentralised monitoring can be more cost-effective since it tends to rely on the voluntary participation of stakeholders rather than requiring contracts for all the activities. Decentralised systems can also be more inclusive, as they allow a greater number of stakeholders to participate in the monitoring process. This can be particularly important in areas where there is a diverse range of interests and perspectives, as it allows for a more comprehensive understanding of the local socio-ecological system. Importantly, decentralised systems can be more effective at engaging local communities and create joint ownership and social licence, as they are more likely to involve local people directly in the monitoring process.

One of the main limitations of decentralised monitoring is that it can be more difficult to ensure the quality and standardisation of the data collected (see review by Silva del Pozo *et al.* 2023). Without central oversight, there is a greater risk of errors or biases in the data, which can compromise the accuracy of the results. In addition, decentralised monitoring can be more time-consuming, as it requires coordination and communication between multiple stakeholders, which can be challenging in large scales or complex ecosystems. Finally, decentralised systems may struggle to pool resources and expertise in the same way that centralised systems can, which can limit their ability to conduct more complex and specialised analyses.

In practical terms, a decentralised EBOCC would be based on the benefits of self-organising efforts. A small central partnership organisation (independent and voluntary), outside of the EU institutions would be set up. The central organisation could be an association/secretariat and would be headquartered in any EU location. It would have a diverse membership, including Member States' agencies and government bodies, research institutes, universities, private companies, NGOs, citizen science organisations, ERICs, etc. A general assembly with all members would be

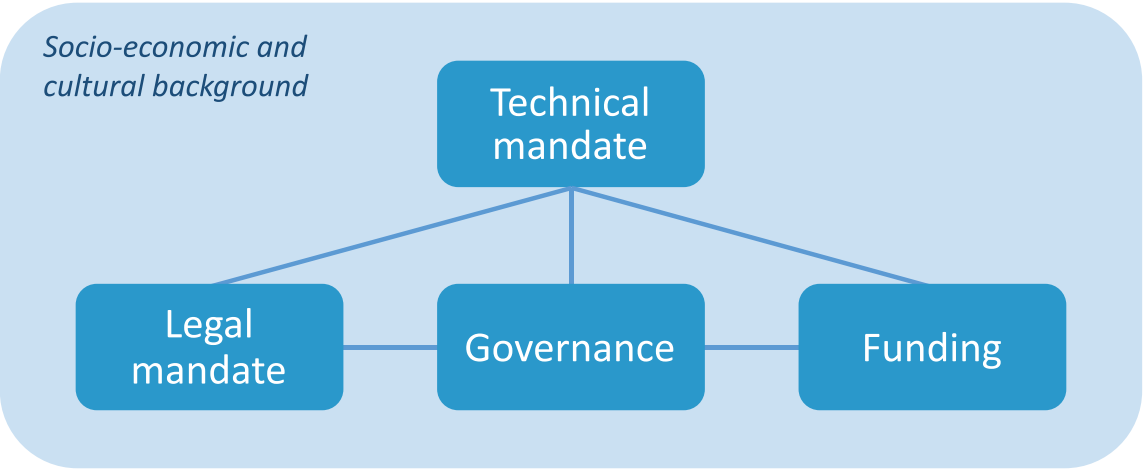


Figure 4: The mandate for a EBOCC is the most important decision; it greatly influences the options that are available for governance, legal structure and funding. Along with the socio-economic and cultural background, the mandate is the largest determining factor.

the decision making organ. Members would have equal voting rights to decide on the strategic orientation, and to develop new and evaluate existing partnerships.

Centralised biodiversity monitoring involves the collection and analysis of data by a dedicated team of professionals or experts under the oversight of a central authority or agency. It could be somehow similar to the LUCAS surveys[6]. One of the main benefits of centralised monitoring is that it can provide a more consistent and standardised approach to data collection, which can help to ensure the accuracy and reliability of the results. In addition, centralised monitoring can be more efficient, as it allows for the use of specialised equipment and techniques that may not be available to individual stakeholders.

One of the main limitations of centralised monitoring is that the coordination centre itself can be more expensive, as it requires the dedicated resources of a team of professionals, even if the cost of monitoring (observations) can be reduced through the implementation of shared transnational surveys. In addition, centralised monitoring can be less representative of the broader ecosystem, as it is based on the observations and interpretations of a single group of individuals rather than taking into account the knowledge and perspectives of multiple stakeholders. Centralised systems may be less inclusive and less effective at engaging local communities, as they are more likely to be seen as external authorities imposing their views and priorities. Finally, centralised systems may be more vulnerable to political interference or manipulation, as they rely on a single authority to collect and report the data. Still, if the data are open, the analysis and interpretation can be transparent and replicated by anyone.

Thinking about a potential EBOCC, a centralised system would be led by some organisation within the EU (an agency such as the EEA, a programme, a Directorate General, etc.). The EBOCC would be a network and a partnership based on a legal mandate by the EU coordination body. It would rely on cooperation between the EU coordination body and Member States. Member States collect and process national data, while the EU coordination body follows implementation, ensures harmonisation of the information, may complement the national observation systems with EU-level surveys, disseminates official biodiversity statistics and organises knowledge exchange.

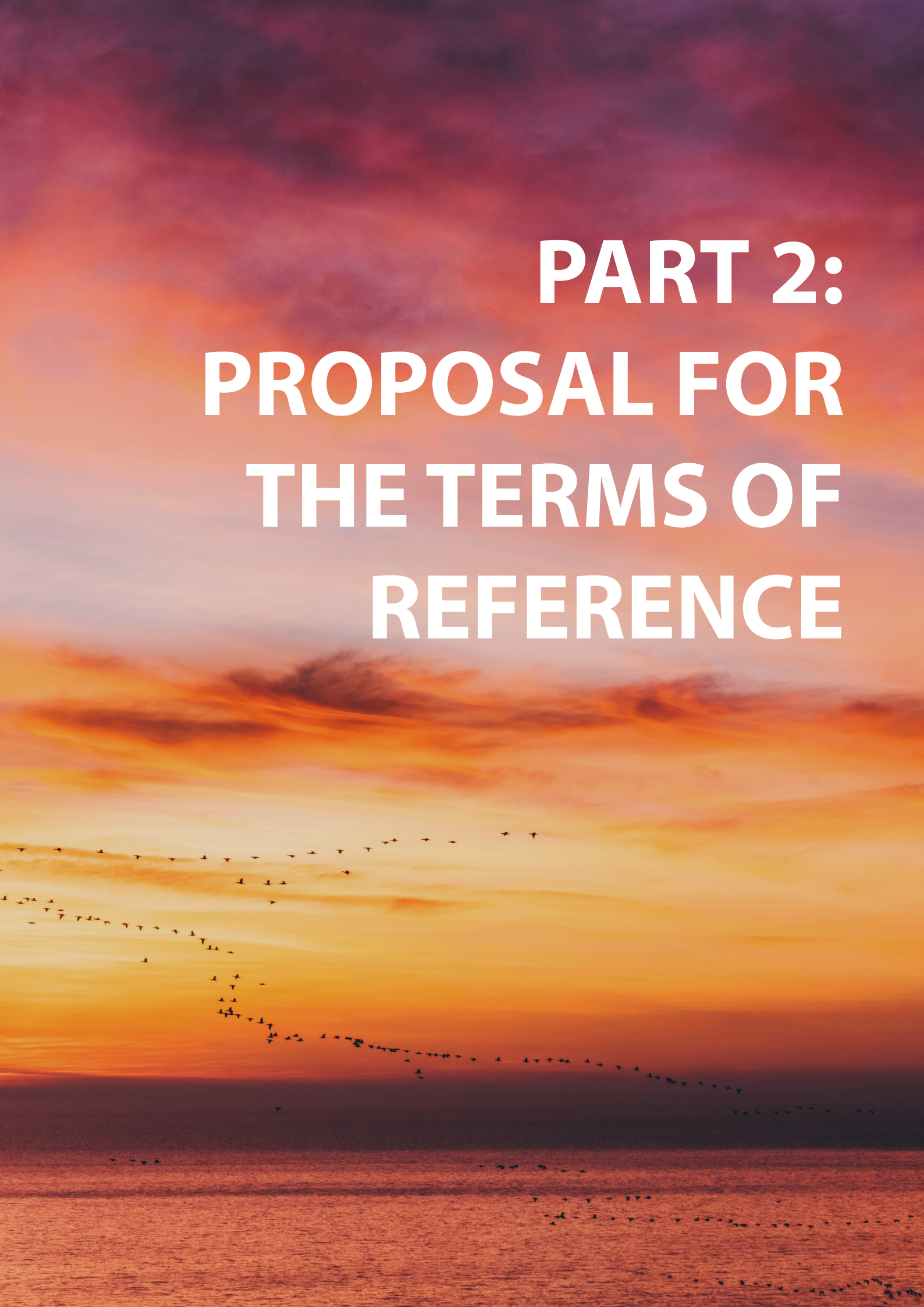
In this structure, the EU coordination body would have the following responsibilities: leadership of the system; management; technical organisation, data validation and harmonisation; administration; verification; data collection (through tenders) if gaps in national efforts are insurmountable considering Member States' capacities; develop data and ethical standards; act as EBOCC representative.

Hybrid biodiversity monitoring combines elements of both decentralised and centralised approaches. Oversight and support are usually provided from a central authority or agency and data collection involves multiple stakeholders in the data collection process (including national agencies, environmental consulting companies, universities, NGOs, citizen scientists). Standards/guidelines can be proposed. One of the main benefits of hybrid monitoring is that it can provide a more comprehensive and representative view of biodiversity, while also ensuring the quality and consistency of the data collected. In addition, hybrid monitoring can be more cost-effective and resilient, as it relies on the voluntary participation of stakeholders while also leveraging the expertise and resources of a central authority or agency. An integrated hybrid model may draw on the strengths of different actors, while securing a standardised backbone of structured monitoring, and may thereby also create more ownership of different actors and ultimately resilience (Kühl *et al.* 2020).

One of the main limitations of hybrid monitoring is that it can be more complex to implement and coordinate than the previous options, as it requires the participation of multiple stakeholders and the oversight of a central authority or agency. In addition, hybrid monitoring may be less efficient than centralised monitoring, since the coordination of multiple stakeholders can be time- and effort-consuming. However, an inclusive structure with national nodes is functioning in the EEA (with Eionet), in GBIF, and seems the preferred option by Biodiversa+ partners. A full description of this governance model is proposed in Section 5.5.

It is important to reiterate that these three characterisations of biodiversity monitoring governance are "ideal types" designed to enable a better grasp of the fragmented landscape of biodiversity monitoring. The actual implementation demonstrates that some assumed truths regarding monitoring (e.g. centralisation begets harmonisation) may not be as true on the ground.

6 https://ec.europa.eu/eurostat/web/lucas/overview



PART 2: PROPOSAL FOR THE TERMS OF REFERENCE

5 TERMS OF REFERENCE FOR AN EU BIODIVERSITY OBSERVATION COORDINATION CENTRE

5.1 Vision and mission

The **strategic vision is to operationalise harmonised biodiversity monitoring data flows** for the conservation and sustainable use of Europe's terrestrial, marine, and freshwater ecosystems. By 2030, the EBOCC will help the EU to coordinate and streamline a system of observations, data assimilation methods, models, knowledge and capacity building efforts to deliver regular information on the state and trends of biodiversity in Europe. This implies establishing a biodiversity monitoring framework at Member State and EU level, in ways that promote integration and re-use of data and allow further analysis to be done. Such approach can benefit all EU citizens and institutions.

There are three key principles.

1. EBOCC should not replicate existing biodiversity monitoring efforts, but build on them.
2. Member States' and stakeholders' participation and buy-in are fundamental for an efficient EU biodiversity monitoring framework.
3. Governance should be accountable, transparent and reflect the point of view of all stakeholders and knowledge providers.

Driven and mandated by policy goals, **EBOCC's mission is to help coordinate biodiversity-related monitoring efforts in Europe and establish a shared European biodiversity monitoring framework** by:

a) Supporting coordination between Member States and organisations involved in monitoring, and assisting them to maintain, enhance and align existing monitoring schemes and developing novel techniques.
b) Integrating the results of the monitoring schemes and implementing clear data flows in ways that allow the harmonisation or at least the interoperability of EU, national and local monitoring data.
c) Analysing the information at EU level, including quality control and modelling to derive indicators and to support policies and stakeholders (provided there is no other institution doing this role).

In this proposal, the EBOCC could be involved in designing new monitoring schemes where gaps exist, but the data collection usually stays under the responsibility of the competent authorities.

This mission seems to be broadly agreed by all stakeholders consulted, and it leads to the technical mandate described in the following section. In particular, 61% of the respondents of the open online consultation of this deliverable felt that the *coordination* of biodiversity networks, Member States and stakeholder groups should be a main role of the EBOCC, especially the coordination for standardisation (of protocols, methods, definitions) and harmonisation of data. *Building capacity* (e.g. on monitoring techniques, on data harmonisation) is perceived as the second most important assignment, to match the existing capacities with the increasing demand for good biodiversity data. Respondents highlighted the importance to provide equal opportunities across Europe and to better cooperate with private industries.

We complement this mission with some expectations expressed by national authorities via Biodiversa+ (see Lipsanen *et al.* 2024), given their central role in the EU monitoring system. According to them, EBOCC could:

- provide a joint mandate and a new collaborative space to support monitoring coordination and harmonisation between Member States,
- enable and facilitate access to transnational data on biodiversity, help define biodiversity baselines and goals for restoration and develop indicators and Essential Biodiversity Variables in coordination with respective agencies,
- assist in securing stable dedicated funding of biodiversity data governance at the European levels and assess pan-European priorities in this domain,
- provide coordinated metadata management and promote data standardisation and advocate for open science principles and adherence to FAIR principles,
- enhance data analysis and evaluation, providing guidelines and jointly developed conclusions regarding species, habitats and other biodiversity components,
- provide assistance and input to national monitoring and strengthen the position of national biodiversity monitoring centres.

5.2 The technical mandate

The EBOCC should develop tasks related to (i) coordination and support to authorities and stakeholders; (ii) data collection, mobilisation, integration and sharing; and (iii) anal-

ysis and reporting to support stakeholders (Table 4). An extensive number of tasks has been proposed under each of these categories (Supplementary Material 4), covering the needs identified by hundreds of experts and stakeholders along our consultation process (Figure 1). Most of these tasks were also EuropaBON and Biodiversa+ responses to some of the deficiencies found in the EU monitoring landscape. The large number of tasks proposed were scrutinised, categorised and filtered. **The size, requirements and governance model of the EBOCC largely depends on the level of ambition to cover all the proposed tasks**.

Table 4 represents our proposal to prioritise the wide variety of tasks collected in Supplementary Material 2, based on their urgency and relevance. After this summary table, we describe in more detail the most urgent and relevant tasks marked in green. This can give an idea of the first implementation steps for the set-up of an eventual EBOCC. As with any other EU initiative, the **principle of subsidiarity** should prevail, meaning that action at the EU level is only needed if it is more effective than action taken at the national, regional or local level.

Table 4: Proposed EBOCC functions evaluated depending on their urgency and their relevance. The wide range of tasks gathered during the participatory processes is filtered and selected here to point to the most urgent and crucial tasks (in green), the tasks that could be developed at a later stage (in yellow) and those that should be re-evaluated (no colour). H: high, M: medium, L: low. The relative low relevance assigned to some task for the EBOCC can indicate that the work could be outsourced or better developed by other institutions and/or at another level (typically, at national level).

		URGENCY			RELEVANCE		
Category	Topic	H	M	L	H	M	L
Coordination and support functions	Coordination 1: Support coordination between Member States and institutions	X			X		
	Coordination 2: Collaborate and engage with external knowledge holders	X			X		
	Coordination 3: International coordination		X				X
	Capacity building 1: Support data exchange, analysis and standardisation	X			X		
	Capacity building 2: an overarching role		X				X
	Capacity building 3: Data collection		X			X	
	Capacity building 4: Design of national monitoring schemes		X			X	
	Capacity building 5: Support to citizen science		X			X	
	Capacity building 6: New techniques and approaches		X			X	
	Funding 1: Allocation of funds to sponsor monitoring schemes		X			X	
	Funding 2: Capacity building on financing options		X				X
Data collection, mobilisation, integration and sharing	Data 1: Data mobilisation, integration and harmonisation	X			X		
	Data 2: Improved sampling designs and standardisation of data collection		X		X		
	Data 3: Data infrastructure and tools	X			X		
	Data 4: Develop data access and data sharing policies	X			X		
	Data 5: Field data collection and monitoring implementation		X				X
Analysis and reporting to support stakeholders	Analysis 1: Modelling, Statistical analysis and visualization		X		X		
	Analysis 2: Support official reporting			X		X	
	Analysis 3: Web portals for dissemination of analyses		X				X
	Analysis 4: Gap analysis, both on monitored data and on information	X			X		
	Analysis 5: Develop and standardise analysis tools		X				X
	Analysis 6: FAIR principles and justice/transparency		X		X		

The final online consultation of this deliverable overall backs up the proposal of Table 4, with a few remarks (see Supplementary Material 2). *Mobilisation, integration and harmonisation of existing biodiversity data across different sectors* was identified as the most important task, with comments asking to include the development of standards for novel methods. Two other tasks, *Improvement of sampling designs* and *Support of coordination between Member States and institutions to harmonise observations and connect infrastructures* were equally rated as the second most important task. Our proposal is less aligned with the responses of the final questionnaire regarding two aspects. First, the *Allocation of funds to sponsor monitoring schemes* is moderately supported (45%) as a priority task. While we acknowledge that sufficient and long-term funding is the most necessary factor to ensure high-quality monitoring schemes, in the present context (i.e. without a dedicated EU fund for biodiversity or environmental protection, and with the large number of institutions distributing funds for research and sustainable practices) we don't believe that EBOCC could receive a clear and strong mandate on such task. Still, it can support stakeholders on finding funding schemes and EU/national institutions on improving access to and distribution of funds. Secondly, the task *Collaborating and Engaging with external knowledge holders* does not have a high relevance for the respondents (29%), but in our opinion is a crucial step to progress on data integration.

Coordination 1: Support coordination between Member States and institutions

To achieve the main goal of helping coordinate biodiversity-related monitoring efforts in Europe and establishing a shared European biodiversity monitoring system framework, the EBOCC needs to connect the key actors running monitoring schemes and their data infrastructures. Optimally, Member States would have a **national biodiversity monitoring hub** representing competent authorities responsible for biodiversity monitoring and involving all national or subnational organisations and institutions compiling relevant biodiversity data. The starting point would be Member States' representatives implementing EU environmental directives (starting with habitats, birds, water and marine regulations) as well as agricultural, forestry and fisheries policies, National Statistical Institutes, Eionetfocal points and potential GBIF nodes. Ultimately, these national hubs may evolve to become national biodiversity monitoring centers. Some countries have recently established such national biodiversity monitoring centers (e.g. Germany).

It must be noted that there are long-term working groups and information systems that have been collecting and using relevant data on biodiversity, and streamlining information from the ground to EU decision making (for example the European alien species information network EASIN[17] or

the European Marine Observation and Data network EMODnet[18]). EBOCC should build on these initiatives, enhance the coordination with counterparts, and support them by complementing potential gaps in the work- and data-flows.

Within this task, the EBOCC should:

- Build on and promote the role of the EU Biodiversity Partnership (Biodiversa+) on the mobilisation and promotion for the set-up of national biodiversity monitoring coordination hubs and the exchange between them. The national hubs should have some policy or representation mandate (to sit in the general assembly of the EBOCC) and should be able to identify the national and sub-national policy users, relevant experts and monitoring schemes of the EBVs whose workflows will be analysed.
- Provide a forum where biodiversity monitoring schemes are discussed at technical level (design, targets, methodologies, data formats). This forum is a common output of the tasks Coordination 1 and 2. As EBOCC evolves, this forum will become a platform to analyse the national and transnational monitoring schemes/standards/protocols with a view on the harmonisation or interoperability of results. Probably, for each EBV at stake, there are already EU working groups, international organisation and/or infrastructures in place. EBOCC should not duplicate or create further administrative structures, but should ensure all relevant actors are connected, data/EBVs can be integrated and sustain in the long-term, all necessary technical and support functions to are covered and, if gaps exist, work to fill them.
- Based on the results of the tasks related to data, discuss the best technical and organisational alternatives to integrate and re-use different sources of data, ranging from official monitoring to research and citizens science.
- Advocate for the standardisation of data collection

17 https://easin.jrc.ec.europa.eu/. EASIN is the official information system facilitating the implementation of the EU Regulation on invasive alien species provides its input directly to policy DGs and other relevant bodies, and assists scientists in their efforts to tackle biological invasions.

18 https://emodnet.ec.europa.eu/en Established in 2009 as the EU's service for marine in-situ data, to transfer knowledge from marine data to stakeholders, it contributes to the implementation of the EU's Marine Knowledge 2020 strategy, regional sea assessments and the Marine Strategy Framework Directive.

and the interoperability of the resulting assessments.
- Screen the EU and international policy needs to feed as many policy indicators and processes as possible with the efforts deployed to monitor individual EBVs. The goal is also to facilitate the role of national governments and EU institutions to serve the increasing number of data users and policies requiring evidence-based information on biodiversity.

Coordination 2: Collaborate and engage with external knowledge holders

The EBOCC faces the critical task of optimizing the utilization of biodiversity data, which is currently amassed and managed by diverse knowledge holders, each possessing a spectrum of expertise and governance structures. With this task, the EBOCC should bridge the gap between the overarching policy biodiversity requirements, national authorities which fund and steer biodiversity monitoring (i.e. ministries of environment, environmental protection agencies), and the extensive scientific community, stakeholders and experts in the field of biodiversity monitoring that are not part of governmental organisations. This task will need to facilitate the exchange of knowledge and expertise at the stakeholder level thus allowing the EBOCC to tap into the wealth of insights, data and expertise held by external knowledge holders, including research institutions and infrastructures, non-governmental organisations and local communities involved in monitoring.

To allow an effective collaboration and engagement with external knowledge holders, the EBOCC will need to deploy targeted actions aimed at allowing such stakeholders to link and contribute to the network being developed. The main actions to be developed within this task could be:

- Generate and update a database of key knowledge holders in the EU biodiversity monitoring panorama including their contribution to collect pan European observations and to derive biodiversity information. This could be build on the EuropaBON members network database. Even if the EBOCC should focus on supranational organisations, this database should be cross-checked with national and subnational counterparts to make sure that relevant stakeholder involvement aligns across responsibility scales.
- Promote and coordinate thematic groups allowing relevant stakeholders to discuss, exchange and agree on topics of relevance for the EBOCC. These groups may have different nature and be occasional or more stable depending on the topics to be discussed or the objectives agreed upon. The EBOCC should coordinate with its stakeholders and institutional networks for the creation of thematic groups in order to avoid duplication of already existing efforts and rather explore the possibility of using them for the purposes of this task.
- Keep track and map current workflows and monitoring initiatives in Europe to identify what information is currently collected, aggregated and eventually used and link this information with the relevant actors responsible for such endeavours. EuropaBON's monitoring database[19] and the national biodiversity monitoring mapping efforts developed by Biodiversa+ could be used as a basis.
- Forge strategic collaborative agreements. Identify and develop specific partnerships and agreements between EBOCC and information holders to involve key actors in the EBOCC's tasks. EBOCC would need to explore the tools required to link on a range of collaboration typologies (from short to long term) with key stakeholders once specific workflows have been identified requiring the involvement of such expertise in their development.

A key challenge for this task is to ensure the long-term engagement and motivation of external knowledge holders. This requires exploring the needs of each of them and find the operational or institutional arrangements to respond to them. For example, for the bird and butterfly monitoring schemes[20], their present short-term project funding (draining on scarce NGO resources for the preparation of bids) is too fragile to ensure their sustainability. They urgently need long-term funding for EU level coordination and for country-level coordination. If they are to reach their potential and continue to provide regular and reliable trends on Europe's biodiversity, they require a commitment to annual long-term funding. The specific needs, more detailed in Section 5.7 (e.g. develop country schemes, collate and manage data, produce indicators, communicate, update website), can be approximately 2.5 dedicated coordinators to sustain the butterfly scheme and up to 4 to substantially improve it. Similarly, EBCC would require a little but continuous contribution for 4 full salaries dedicated to the coordination of national nodes, maintenance and development of IT tools, production of EBVs and project coordination.

Capacity building 1: Support data exchange, analysis and standardisation

The EBOCC could play an important role in offering capacity building to improve and promote data exchange, analysis and standardisation. As these aspects could potentially pose a technical barrier for some stakeholders, the EBOCC could provide tools and knowledge that make these processes accessible to all monitoring communities. Additionally, the implementation of these tools could optimise various other aspects of the data workflow, such as the automatisation of data processing and the model production.

A crucial task for the EBOCC will be to establish clear, step-by-step protocols for standardising the different workflow steps when they do not exist. Especially important is to standardise the data entry and registration process

19 https://europabon.org/?page_id=2513

20 See Box 1. Both schemes have developed their unique networks of volunteers and provide high-quality and peer-reviewed indicators. The role of the coordinators is essential to recruit, train and support volunteers; validate records; ensure timely reporting to the central database and provide reports of results.

with clear metadata standards and common files, when possible. EBOCC can try to develop European Standards[21] for different steps of the workflow and different EBVs. Accompanying these protocols, the EBOCC should create user-friendly guides and documentation to facilitate the widespread adoption of these standardised protocols. Additionally, it is important to periodically review and update the protocols to integrate new methodologies and technologies when they become available. Many monitoring communities have discussed standardisation issues for decades and it remains a very costly and controversial task. EBOCC should avoid restarting discussions that already took place in other monitoring communities or policy working groups, but should build on them and offer the technical capacity to get, at least, interoperability of the EBV data.

To complete the adoption of a standardised protocol and accommodate the use of different monitoring techniques, the EBOCC could develop a data model or work with those already available to make compatible different data types. These data models enable integration and enhance interoperability, thereby fostering a more cohesive and efficient data exchange process within the monitoring network, at the same time promoting the use of novel monitoring techniques allowing the integration of different systems in one unique network.

To facilitate the adoption, dissemination and comprehensive understanding of the standardisation protocols and integration tools, EBOCC should conduct training programs, workshops, and seminars for the different stakeholders about the standardisation of data, analytical methods, data collection & collation, data quality assurance and archiving, publishing data, how to use the data for different purposes, etc.

A core component of the EBOCC should also be concerned with decision support, ensuring there's effective knowledge transfer to decision-makers. This not only helps in the interpretation of information but also coaches individuals to develop their own insights. Recognizing the potential technical hurdles faced by Member States, the EBOCC should offer regular training sessions and webinars. Topics could range from the basics of data entry and management to advanced analytical techniques using the latest tools, all while emphasizing the importance of drawing actionable insights from the data.

Capacity Building 2-6: Other tasks

Even if the first phase of implementation of the EBOCC would probably lack time and resources to develop all desired capacity building tasks (Table 4), it is important to highlight their relevance for future developments. Considering that lack of human and technical capacities is recognised as a main impediment of effective biodiversity monitoring in Europe, one of the central tasks of EBOCC can be to engage in capacity building and to be a catalyser for knowledge exchange.

EBOCC should make an efficient use of existing programmes. For example, some international data infrastructures have broad experience in capacity building, such as GBIF, which operates a training and capacity enhancement programme as a core component of its services, and OBIS, which has a 'mandate and institutional framework for continual capacity building as a core function' and has close alignment with the Ocean Teacher Global Academy (Klein *et al.* 2019). Also, the EEA supports the development of reporting standards for the major environmental directives and provides training and other assistance to EU Member States in support of reporting under these directives. The EBOCC, together with the EEA, could also help build capacities by collecting, synthesizing and distributing best practice from Member States regarding the implementation of some environmental directives.

The capacity building topics should be decided on demand and could include a wide variety of topics (see Supplementary Material 4). Some examples are:

- Monitoring schemes: guidance to design new monitoring schemes, guidance to review and make compatible existing national schemes, workshops and reports to apply protocols and standards for data collection, requirements of in-situ observations for the calibration of remote sensing products, best practices for implementation of monitoring schemes, seminars and guidelines for data exchange and standardisation, specific training on new methods and techniques, guide the co-existence of traditional and novel techniques, requirements for the data management and archiving using new tools.
- Citizen Science: citizen science initiatives can be a reliable source of biodiversity data since many taxon experts engage in biodiversity recording, they can have a broad coverage at negligible cost, and they tend to contribute to internationally-harmonised schemes. They obviously face some limitations (Wright *et al.* 2020). However, including more expert naturalists and citizens in monitoring biodiversity would be an invaluable element of the EBOCC as an operational infrastructure (Garcia-Alaniz *et al.* 2017), for example by ensuring sustainable funding for high quality data management and infrastructures. Capacity building activities could focus on methods and taxon training for volunteers, data management and mobilisation training for coordinators, webminars about protocols.
- Taxonomy: An important issue that requires the attention of the EBOCC is to enlarge and strengthen taxonomic expertise across Europe (Buyck 1999; Kholia *et al.* 2011; Feitosa *et al.* 2023; Löbl *et al.* 2023) and ensure the engagement of taxonomist in monitoring schemes – even schemes that deploy advanced molecular or other technologies for species identification and/or description (van Leeuwen and Michaux 2023). To overcome this 'taxonomic impediment'

21 https://www.cencenelec.eu/european-standardization/european-standards/

(Wheeler *et al.* 2004; Agnarsson and Kuntner 2007) technical solutions are not enough (Engel *et al.* 2021) and EBOCC should foster existing training networks and collaborations with universities, natural history societies, museums and botanical gardens.

- Funding: EBOCC should identify activities to enhance the capacities of monitoring stakeholders to find funding sources, including new funding models. The EU has several guidance documents and studies reviewing funding possibilities, but they may need specialisation. Training and materials could focus, among others, on facilitate access to funding, funding for NGOs and natural history societies, financially support new monitoring schemes, pay for standardised data archiving in Member States.
- Capacity justice: the EBOCC should promote open, free, transparent methods, data and data standards, and be sensitive to the needs of different Member States and stakeholders. Many experts suggest that methodologies should be 'tailored to each country's specific needs and context', 'considerations of data and tool access should be made', moving to 'open cloud-based services should be considered' (Portillo-Quintero *et al.* 2021). In this context, some capacity building tasks should be devoted to exchanges that represent all the voices in the field (in terms of capacities and regional needs), concentrate capacity building activities on countries and institutions most in need, facilitate the sharing of knowledge between high and low-capacity actors, and provide training using an open science approach.

Data 1: Data mobilisation, integration and harmonisation

Mobilisation of data involves the identification, retrieval and transformation of datasets assembled for a variety of specific purposes and projects, expressing it in consistent and standardised formats, and sharing it via platforms that enable onward uses and applications. An important function of the EBOCC will be to support mobilisation of data across a wide range of monitoring programmes, to encourage and facilitate the integration of such data for the purposes of EBV generation. If possible (agreed with the data owners) it should also enable such data to be freely discoverable and accessible for further analysis and re-use. Improved systematic and professionalised metadata sharing across established systems is also a priority, especially for the marine community.

Optimally, this includes the 'unlocking' of data collected for example for *ad hoc* scientific studies or to feed national assessments that cover EU reporting obligations (e.g. conservation status of EU habitats), but seldom shared or published. Sometimes, such underlying datasets contain rich and high-resolution data of great value to inferring status and trends of biodiversity (when the assessments are not simply based on expert judgement), and this value is lost if the raw data remains hidden and unmobilized. The EBOCC's role in this regard should be:

- to encourage and facilitate retrospective mobilisation of data held in research institutions/infrastructures, Member State ministries and agencies (e.g. through the development of national data repositories with well-functioning APIs) or NGOs, thus improving the baseline data available for monitoring of biodiversity trends, and enabling the construction of historic time series data to better understand the context of contemporary and future observations; and
- to develop guidance, EBV workflows and provide tools to ensure that future reporting includes standard recommended steps to harmonise and publish the underlying data. It is important that these workflows make the best use of monitoring data by using state of the art modelling tools, including AI approaches. In the case of some EU Directives, the EBOCC could facilitate with this task the compliance with some reporting obligations that prove to be challenging for Member States (e.g. Art. 19(3) of the Marine Strategy Framework Directive requiring access to the underlying datasets on which the assessments of environmental status are based).

We are aware of the difficulties and huge efforts necessary to collate raw biological monitoring data. Often, pan-European datasets are very limited and aggregated, and there is a lot of actors and coordination roles at different levels, including complicated sub-national structures that we are not reviewing in this report. The EEA, with its Eionet network and the different European Topic Centres, has advanced significantly regarding aggregated assessments but with modest progress regarding underlying data (with some examples of freshwater data).

Due to its relevance and widespread use for the biodiversity community, this task can involve formatting data using the Darwin Core (DwC) standard, and eventually the GBIF unified common data model that enables a broader range of attributes, both biotic and abiotic, to be included. However, depending on the theme, other relevant standards, data infrastructures and networks (such as those mentioned in the next paragraph) should be explored and used. This task can be supported by a number of Horizon Europe projects working on relevant dataflows, such as the B-cubed project that develops the data cube format for selected EBVs.

EMODnet is a key European hub for marine data that follows international standards and makes information freely available as interoperable data layers and data products (e.g. distribution of marine species or species traits on the Biology thematic unit; seabed habitat maps and observations on the Seabed Habitats portal). SeaDataNet is a distributed marine data infrastructure for the management of large and diverse sets of data deriving from in situ of the seas and oceans. The Ocean Biodiversity Information System (OBIS) is a global interface for marine biodiversity data with a European sub-network, EurOBIS. It coordinates a global community of practice of over 1000 institutions with national, regional, and thematic nodes. It connects key international networks policy and scientific OBIS operates as a sister network of GBIF, with which it closely collaborates at global and national levels. Both OBIS and EMODnet are federated with global partners via IOC-UNESCO's Ocean Data and Information System and its Ocean InfoHub. The EBOCC should build on and collaborate with all the relevant initiatives, to ensure there is a clear mandate to advance on the modernisation and accessibility of EU biodiversity data. EBOCC can assist OBIS and GBIF ensure complete and deep interoperability for all European records.

Without pre-empting other collaborations with international data infrastructures, we propose to establish close working relationships with GBIF national nodes in the Member States where they exist, as these are often a key repositories of skills and facilities to enable mobilisation, integration and harmonisation of data. GBIF national nodes should therefore support the work of the national biodiversity coordination hubs. To strengthen this framework, we propose the establishment of a GBIF node at EU level to support the EBOCC in tasks such as: a) conveying advice to GBIF national nodes on the formats and specifications for national datasets to be most useful for the purposes of EU biodiversity monitoring; and b) in cases where no GBIF node currently exists, collaborate with the national hubs providing guidance for data mobilisation, integration and harmonisation. A GBIF node at EU level would also enable the EBOCC to benefit from global developments and collaborations to support data mobilisation.

With the scope of reinforcing the data flow on alien species to policies, we propose, concerning specifically this data, to establish a direct link to EASIN. This system unlocks raw data collected from a variety of scientific, citizen science, and Member States' official sources to feed policy assessments and research. Data in EASIN are already formatted using the DwC standards and data can be accessed and provided using efficient interoperable services (e.g. APIs). Thus, the EBOCC could communicate directly with EASIN for data mobilisation on this specific data type. Similar situations could be found for other data types. Hence, the EBOCC should review during its planning phase the landscape of data mobilisers and infrastructures potentially serving policy needs, to avoid duplications.

Data 2: Improved sampling designs and standardisation of data collection

Improved sampling and standardised collection of biodiversity data across the EU is an essential pre-requisite for a robust assessment of biodiversity change at national and EU levels (UN Economic Commission for Europe 2023). Current biodiversity monitoring schemes in the EU have major spatial, temporal and taxonomic gaps and bottlenecks. This severely limits the representative and unbiased tracking of national and EU biodiversity targets. The EBOCC, working in close collaboration with the thematic hubs and with the (sub)national authorities represented therein (see Figure 5 about the organisational structure), should become a reference point on biodiversity sampling designs and data collection methods in the EU, with the expertise structured around a limited list of themes or EBVs.

Within this task, the EBOCC could:

- Generate and maintain an overview (e.g. a database or web portal) of existing monitoring protocols for all taxa, realms and habitats. This should build on the databases developed by EuropaBON and other Horizon projects. This could be integrated or complementary to the tracking of monitoring initiatives mentioned under the task Coordination 2.
- Mobilise the communities of experts and practitioners of each taxa/theme to develop in-depth analyses of existing protocols, in order to identify best practice monitoring methods and to develop guidelines for promoting standardised data collection across the EU. This includes the identification of minimum requirements of monitoring efforts together with the thematic expert groups. Optimally, the coordination (networking) and technical tasks of the EBOCC would allow to get a better alignment of sampling strategies, field protocols, techniques, and site selection procedures across Europe. Otherwise, the task Data 1 would have to find other pragmatic (yet, less

appropriate) ways of making compatible datasets which have been collected with different methods. Biodiversa+ is exploring this field with the creation of national EBV dashboards. All these recommendations and technical knowledge will be transferred to the tasks related with capacity building.

- When needed and demanded, the EBOCC could support the identification of optimal sampling designs and cost-efficient monitoring schemes. Although the design is highly dependent on the theme or EBV to be monitored and the questions to be answered, it is possible to identify the best performing sampling design that allows co-monitoring of multiple biodiversity variables, ranging from species populations to community composition at continental scale. For instance, in a comparative study at EU-scale, grid-based sampling of habitats listed in Art.17 of the Habitats Directive is outperforming random design in detecting the highest percentage of rare and common habitats, whereas stratified sampling success is influenced by the type of stratification (amount of sites in each stratum proportional to the area coverage of the habitat or same amount of sites per each stratum). The EBOCC would support the selection of the optimal sampling design that provides a representative assessment of habitat extent and condition or species occupancy and range. In particular, it is necessary that the selected sampling design allows for trend detection, considering the relevant influence of drivers like climate change and land-use change in determining biodiversity change.

Closely related to the previous task (optimising sampling designs), the following objectives were proposed by stakeholders and could be considered as specific tasks for the EBOCC:

- Identify, develop and promote specific sampling needs to detect and monitor rare species and habitats.
- Provide recommendations and best practices for sampling designs and monitoring methods with novel technologies (e.g. eDNA, digital sensors), develop protocols when possible, and identify requirements for metadata collection.
- Ensure the standardised collection and reporting of covariates and environmental variables (e.g. land use, land cover, weather conditions, equipment used etc.) for the analysis of collected biodiversity data to allow attribution to, and analysis of, pressures and drivers.

Data 3: Data infrastructure and tools

Recognizing that data is the essence of robust monitoring, the diversity, scale, and granularity of biodiversity data necessitates a solid infrastructure for collection, storage, management and analysis (that could be distributed infrastructure).

Within the confines of this task, the EBOCC should:

- Propose and develop a robust data framework for the selected EBVs, planning for an increasing mandate as the EBOCC evolves. The centre should collaborate closely with Member States, EU institutions and agencies, and international organisations working on biodiversity observations or data collections to craft an integrated data infrastructure. This should consider the varied nature of biodiversity data, ranging from genotypic sequences to large-scale ecosystem observations. Central to this design will be adhering to FAIR principles to ensure data consistency and utility, and CARE principles (Collective Benefit, Authority to Control, Responsibility and Ethics) to ensure justice and indigenous data sovereignty. Where possible, the EBOCC should encourage the adoption of open-source platforms and open data standards, further aligning with these principles and ensuring scalability and adaptability. Specifically for data on alien species, it is recommended to link directly to EASIN, which characteristics already respond to these requirements (e.g. sharing data with webservices, data accessibility and security, interoperability, and standardisation), and which services already feed into policy implementation.
- Implement and promote tools for data integration: Given the fragmented nature of existing biodiversity datasets and initiatives in the EU, the EBOCC should be at the forefront of promoting and creating tools that facilitate data ingestion, quality check, integration, and harmonisation. This endeavour includes the development of API services that enable efficient data exchange between systems. Additionally, the EBOCC should focus on crafting software or plugins that allow for seamless integration of data from diverse sources, whether from citizen science projects, traditional monitoring, or advanced eDNA studies.
- Strengthen data accessibility and security: While the push for open data is commendable, EBOCC must ensure that data storage and retrieval systems are both secure and efficient. The development of a clear and transparent data sharing framework and agreements is crucial. This includes provisions for data providers to obscure or aggregate sensitive information or keep

it behind restricted access, ensuring their concerns and the data's integrity are being addressed. The use of cloud-based solutions, paired with rigorous access controls and encryption, can strike the right balance between transparency and data protection.
- Ensure interoperability and standardisation: In line with coordination efforts, the EBOCC should continuously advocate for and work towards common data standards. Actively engaging with communities of practice and experts, such as TDWG Biodiversity Information Standards and the Catalogue of Life for taxonomic concerns, is essential. This collaborative approach would not only ensure consistent data quality but also facilitate smoother data integration and sharing across borders.

Completing this task effectively would require the EBOCC to collaborate with a diverse set of stakeholders. It is pivotal to harness the insights and expertise of IT specialists, data scientists, ecologists, and policymakers to develop an infrastructure that truly serves the needs of European biodiversity monitoring.

Data 4: Develop data access and data sharing policies

The basis of any monitoring scheme is the data. The EBOCC should play an important role in the mobilisation of data on biodiversity and facilitate data sharing. Developing data policies has several aspects related to the FAIR principles of digital assets, which makes this task be closely related to Analysis 6. Here, we describe the technical requirements of FAIR to be taken into account when developing data policies; in the following sub-section we introduce the socio-technical hurdles and how to overcome them; and under the task Analysis 6 we present how the key principles can be followed in practice by a EBOCC. Data policies should follow the principles of the European data strategy[22] and the European Data Act[23].

Important aspects of this task are:

- Findability of biodiversity data: Data on European biodiversity is currently spread over many databases and the findability is low for much of this data. Some data is available through well-known portals but many databases are not easily located. Therefore it is essential that EBOCC increases the visibility of existing datasets and facilitates access to them. Documentation on the (harmonised) data and its metadata should be made available as well.
- Interoperability of data: Data should be made interoperable, and therefore harmonised. For this, the databases of the different data-owners/monitoring schemes do not need to have an identical structure. Many monitoring schemes do have preexisting databases that differ in structure. A real standardisation of these data and databases would require heavy adjustment of the workflows of the organisations collecting and working with the data already. This may not be necessary if there is a common minimum level of aggregation where data can be harmonised representing the same thing. Databases could be transformed to such harmonised level, e.g. with a single coordinate system, date notation, taxonomy, etc. The EBOCC, with the help of other notable digital and research initiatives, should facilitate the availability of these harmonised versions.
- Accessibility of data: The EBOCC should facilitate data access. It should provide an overview of existing data with the option to either directly access the data or submit a request for the data that are not openly available. For this, data sharing policies should be developed that optimize the use of data while acknowledging the sensitivity and legislative limitations. Where detailed data cannot be made openly available (e.g. because of data ownership, sensitive species or local legislation) the aim should be to make data openly available in a way that is acceptable. There are several possibilities to do this, crucial are embargo periods, anonymization and coarse location information.
- Reuse of data: The data will be reused for the (re-)assessment of EBV's and indicators. The data in the databases will remain available. Specific attention should be given to the legacy of data-owners and managers that may discontinue their tasks; EBOCC should make sure that their data is not lost.

Based on the initial coordination tasks of the EBOCC, it should be able to develop and agree on flexible data access and data sharing policies with the relevant data holders. Note that more than half of the respondents to our online consultation saw in *Data ownership, Data quality, Funding and Harmonisation* the most sensitive issues or overlaps.

Controversies and possible solutions about data sharing and open data

Access to high-quality spatial data emerged as a concern and debate among EuropaBON partners and invited stakeholders to the conferences and workshops. Numerous organisations hesitate to share the data they collect without restrictions. These are government agencies, NGOs, pan-European monitoring schemes, universities, individual scientists, or companies that are involved in monitoring. The arguments given for this hesitancy include ethical, financial and conservation reasons, and are not easy to be addressed. As participants argued, data sharing is part of the "social challenges that need to be overcome" through a combination of technical, financial and governance solutions. While data should be as open as possible, there are various cases when a case for "ethical open access" can be made (Baker *et al.* 2017). For example, endangered species, archaeological sites, commercial and community interests, or the ethics of dealing with traditional and local knowledge are cases where not all data can be made open. These issues require vigilance, nuance, and the development of socio-technical approaches that can navigate this complex terrain.

In this context, it can be useful to look for inspiration from existing experiences originated from research fields (and

22 https://digital-strategy.ec.europa.eu/en/policies/strategy-data
23 https://digital-strategy.ec.europa.eu/en/policies/data-act

their data infrastructures) that deal with large, sensitive, often financially important data, such as EU health research or maritime transport route optimisation.

In health research, data are collected from various actors across the public-to-private spectrum, and they come with significant ethical and financial concerns. For example, individual health data come under the EU's General Data Protection Regulation, and thus cannot and should not be openly and freely accessed. Furthermore, health data are often under proprietary licences, and cannot be legally accessed. One of the proposed ways to address these issues in health research while allowing the establishment of large-scale infrastructures combines technology with governance innovations in what is called a "cloud-based federated system architecture" (Aarestrup *et al.* 2020). Giving the example of the Medical Informatics web-portal, Aarestrup *et al.* (2020, p. 5) note that we can use a cloud-based "software framework, based on federated and distributed computing, that allows researchers to mine clinical data stored on hospital and laboratory servers, without moving the data from the servers where they reside and without compromising patient privacy".

Another innovation from the biomedical community in this aspect is "Data Access Committees" (DACs) in bio-banking institutions. DACs are "chartered to review requests for data and samples from outside researchers" (Contreras and Knoppers 2018, p. 441) and can be found in the US's National Institute for Health, the Wellcome Trust Case Control Consortium and the International Cancer Genome Consortium. Two key characteristics of DACs are their "organisational independence from the consortium or biobank/database and the inclusion of individuals who have information technology and other relevant expertise (*ibid*)".

In the field of maritime transport route optimisation, companies are not willing to share data required to mathematically optimise energy (fuel) use – aside from GPS signal – such as energy efficiency or load from the ship. Giannopoulos *et al.* (2023) developed an approach based on "federated learning" (McMahan *et al.* 2017) that can model fuel use without the data ever leaving the ship. Each ship trains a "local" machine learning model and only the learned model parameters are sent to a trusted centre. The trusted centre combines the parameters to an aggregate global model for a shipping fleet.

In the context of EBOCC, such approaches would let parties retain the data under their control, while allowing modellers and other accredited parties to "bring the algorithms to the data rather than centralizing the data" (Aarestrup *et al.* 2020). This option seems widely acceptable also by Member States and local level actors, as reflected in Biodiversa+ discussions. Thus, a local NGO that collects occurrence and abundance data on species would be able to participate and be credited in the EBOCC analyses and at the same time retain the raw data ownership. Local models could be built locally in the servers of the NGO, and the EBOCC would aggregate to a pan-European model of, for instance, species distribution. This is how EBCC and breeding bird distribution maps are developed at these two scales. National and sub-national raw data is owned by EBCC partner organisations and shared with the EBCC European coordination only for specific initiatives and uses. In the case of EBOCC, that could be the production and provision of EBVs. The EBCC could contribute to harmonise the bird-related EBVs across scales.

Furthermore, in the field of data ethics and access, it is proposed that the EBOCC has a "Data governance and ethical committee" (see Figure 6) that reviews data requests to ensure agreed upon terms for ethics, confidentiality and security are met. The EBOCC should build on the experience gained within the biodiversity data community through GBIF, where barriers and hesitancy have been addressed through a number of mechanisms including effective tools for data citation using DOIs, promotion of data papers in journals, and visibility of data-sharing institutions through metadata supplied with datasets published via GBIF.org

Analysis 1: Modelling, statistical analysis and visualisation

As we said in task Capacity Building 1, the EBOCC should be devoted to decision and policy support, ensuring there is effective knowledge transfer to decision-makers. Once the EBOCC ensures the collaboration of all relevant institutions and stakeholders around certain EBVs or topics, and once the workflows and data flows (together with the data policies and infrastructures) are clarified, the added value of the EBOCC should be demonstrated by deriving some policy-relevant indicators based on the integrated information and in close collaboration with experts of the thematic groups. EBOCC could also assist stakeholders in reconciling their reporting requirements with clear prioritisation of information flow to European needs, then onward to EBVs, with minimal redundancy. Some examples of tasks that would be related to this objective are:

- Key statistical analyses and representation of EBVs, with a special focus on the needs of those stakeholders missing the capacity to do it. Automate the production of statistical analyses and maps/graphs to ensure the dynamic processing of new data. Provide support for data analysis to the stakeholders that demand it.
- Development of new models, for example spatially explicit models for extrapolating data to sites without measurements, or models that connect EBVs to drivers of biodiversity loss.
- When possible, automate the production of EU-level indicators and trends from harvested data. The selection of indicators should be done in close collaboration with all actors involved.
- Maintain an overview of biodiversity monitoring status (per theme or EBV) constantly updated. This will contribute to the gap analysis.
- Make publicly available in a user-friendly way other data-derived products (apart from indicators), such as species lists per country or region.
- If requested and not available within the national hubs, support the assessments to fulfil reporting obligations.

Analysis 4: Gap analysis, both on monitored data and on information

The EBOCC, through its data tasks and the connection with relevant monitoring networks, can support Member States and the EC in identifying priorities for expanding existing monitoring schemes and establishing new ones. An effective identification of these priorities requires assessing critical monitoring gaps and how these gaps may impact biodiversity status and trends assessments. This task could support the development of the IPBES "methodological assessment on monitoring biodiversity and nature's contributions to people" expected by 2026, which will feed the Kunming-Montreal Global Biodiversity Framework.

The EuropaBON project has conducted a first analysis of monitoring gaps based on a compiled list of monitoring initiatives coordinated at supranational and European levels, complemented with some national and subnational monitoring programs[24]. See Sections 3.1 and 3.2 for a summary of the findings.

The EBOCC should analyse current monitoring gaps at the European scale in collaboration with national and regional administrations. The gap analysis should differentiate gaps in monitoring data collection and gaps in information on biodiversity status and trends. As a result, the analysis should significantly expand the information currently available on existing data collection initiatives; how the data are being used; and what are the implications of the gaps for assessments of biodiversity status and trends. Important gaps that require a comprehensive analysis are:

- Spatial coverage gaps. Analysis of regional information deficits that typically result from insufficient geographic coverage of monitoring programs. Spatial gaps are not only defined by administrative boundaries but also biogeographic regions, current and future climate gradients, ecosystem types, nature protection networks, etc.
- Temporal coverage gaps. The time span and the frequency of repeated data collection, and their effects on the quality of the derived information on biodiversity trends at national and subnational levels.
- Thematic and taxonomic gaps. These refer to the collection of data required for monitoring different EBVs and to obtain comprehensive information across multiple biodiversity components. It involves the degree of coverage of different taxa, habitat types, and ecosystem functions relevant for policy assessments.
- Data-to-knowledge gaps. This involves assessing the extent to which data collected in multiple monitoring programs are made available and/or reused to maximise the production of information (and, ultimately, knowledge) that is comparable between different regions and with different purposes.
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Other gaps that can be analysed during the process are monitoring capacities and national/transnational coordination across administrations and sectors (Vihervaara *et al.* 2023a and b).

Analysis 6: FAIR principles and justice/transparency

The FAIR principles (Findability, Accessibility, Interoperability, and Reusability), justice and transparency should allow to maintain the scientific reproducibility and as well as all the authorships and responsibilities. This could be potentially applied in a general manner to all information flows involved in the coordination work of the EBOCC. However, because of the diverse nature of the monitoring and its particularities in every Member State, information can be mobilised in different ways depending on the topic and the existing information flows, and this could be also linked to the best possible approach to the implementation of these principles.

Thematic expert groups dealing with each of the EBVs or topics within the EBOCC would ideally develop the best procedure to ensure these principles are met. EBOCC should take care of these principles regardless of data features, from raw data collected in the field to structured data ready for its proper interpretation in science-policy. The concept of EBVs could be particularly useful because it identifies the final aim in which every thematic expert group could propose a FAIR/justice/transparency framework. Usually EBVs are not raw data but the result of a process of (among others) validation, integration, modelling and adoption. In this context, it is important to identify where each principle applies within the information flow, ensuring that all stakeholders involved in the process keep the proper responsibility for these principles (see examples below). It is of paramount importance that the EBOCC thematic expert groups identify the most reliable framework for each EBV.

Example 1: FAIR principles and justice/transparency in GBIF occurrence data (raw data level):

- FINDABLE: GBIF has requirements for metadata and datasets. All datasets are identified by Digital Object Identifiers (DOIs).
- ACCESSIBLE: The GBIF Portal API provides a machine-readable interface (REST + JSON) and use the Integrated Publishing Toolkit (IPT) as trusted data repository.
- INTEROPERABLE: GBIF recommends using Darwin Core for occurrence data.
- REUSABLE: GBIF requires creative common data licences (CC0, CC BY, or CC BY-NC). Provenance available from the GBIF portal.
- JUSTICE: organisations responsible for data are shown.
- TRANSPARENCY: Links to data provider allows to track all details on the data collection, curation and management.

24 https://monitoring.europabon.org/

Example2: FAIR principles and justice/transparency in distribution of terrestrial bird species25 (EBV data level):

- FINDABLE: agreement shows that the EBV data and metadata for each species would be findable for both humans and computers in a specific online database (ebba2.info) run by the EBCC.
- ACCESSIBLE: Once found, the data can be automatically accessed including authentication and, in case of non-open data (some EBVs), previous authorisation by EBCC (some EBVs) or national partners (raw data).
- INTEROPERABLE: EBBA2 data can be integrated with other data thanks to the use of EU standards (grids, species names, units, etc).
- REUSABLE: the reuse of data is described. Some have creative common data licences, while for sensible data the copyright is retained by EBCC. People responsible for the project are maintained for any consultancy even once the project is finished.
- JUSTICE: European and all the national partners (organisations, people responsible for data at national level) are shown, together with their role in data use.
- TRANSPARENCY: the website explains how the data was collected, who can access it, how it was used and how to interact with it.

25 The most reliable information on the distribution of birds at European level is the European Breeding Bird Atlas 2 (Keller et al. 2020). They ensure the FAIR/justice/transparency principles by developing a number of agreements among stakeholders.

5.3 Prioritisation of topics for piloting EBOCC

The EuropaBON project established a comprehensive identification process of EBVs to measure Europe's biodiversity change across multiple dimensions in space and time (Junker *et al.* 2023). The final list with 84 EBVs prioritises the most important variables to address issues such as the policy and scientific relevance, and the feasibility of the monitoring[26]. Even if this is a short list for all the existing biodiversity monitoring obligations, it is already too long to be accomplished in a relatively short and small test phase of the EBOCC (the preparatory action fostered by the European Parliament plans a budget of EUR 5M for up to 3 years). Thus, we reanalysed EuropaBON's list of proposed EBVs and elaborated for this proposal a policy relevant mechanism to select them.

It must be noted that EBVs are only one approach to structuring the EU biodiversity monitoring challenge and they do not represent the entire biodiversity monitoring required by policy-makers and managers. Those policy requirements still need a massive investment on direct biodiversity observations. Focusing on a few EBVs is just a pragmatic initial choice, while biodiversity monitoring in support of legal obligations would require much larger tasks.

EuropaBON's advice is to focus an eventual EBOCC pilot on a maximum of 5 commonly agreed EBVs; a pool of 10 is proposed in Table 5. These EBVs were selected because they allow the EBOCC to tackle the challenging task of coordinating the mobilisation, integration and sharing of monitoring data collected by Member States and other institutions (e.g. NGOs, research organisations). The selected EBVs represent all three realms (freshwater, marine, terrestrial) and are highly relevant for the reporting to the main EU environmental directives, the EU Biodiversity Strategy for 2030, including the Nature Restoration Law, and the Kunming-Montreal Global Biodiversity Framework. The selected EBVs cover a wide range of taxonomic groups and habitats (see column 'Taxonomic or habitat focus' in Table 6) and rely on structured monitoring schemes, but with the potential to integrate other monitoring methods in the future (see column 'Monitoring methods' in Table 6). The five criteria for selecting these EBVs are provided in Table 6. A detailed description of the workflows of these EBVs was extracted from the EuropaBON virtual workshop on EBV workflows of February 2023 (Lumbierres and Kissling 2023).

26 https://github.com/EuropaBON/EBV-Descriptions/wiki

Table 5: Priority list of EBVs for piloting the coordination tasks of EBOCC. The selected EBVs encourage the interaction between the EBOCC, Member States and other institutions (e.g. NGOs, research organisations), especially in the context of reporting to the main EU directives on biodiversity (see column policy relevance). Abbreviations: BD = Birds Directive; CFP = Common Fisheries Policy; EVA = European Vegetation Archive; HD = Habitats Directive; MS = Member State bodies; MSFD = Marine Strategy Framework Directive; NRL = Nature Restoration Law; WFD = Water Framework Directive; WISE = Water Information System for Europe.

EBVs	Realm	Policy relevance	Feasibility & immaturity	Taxonomic or habitat focus	Monitoring methods
Ecosystem distribution of terrestrialhabitats[27]	Terrestrial	HD, NRL, ecosystem accounting	Massive in-situ data collection by MS for HD (Natura2000) and by research organisations (e.g. EVA), but data are not integrated and raw data from regulatory monitoring are not available	Select a subset of terrestrial habitat types from those listed in Annex I of the NRL (i.e. grasslands and other pastoral habitats, forests, steppe, heath and scrub habitats, and rocky and dune habitats) plus focus on the extent of green urban areas for NRL and ecosystem accounting	In-situ mapping and monitoring (from vegetation surveys), can be used as calibration and validation data for satellite remote sensing products, potential to integrate drone imagery and LiDAR
Community composition of benthic invertebrates[28]	Fresh-water	HD, WFD, NRL	Massive data collection by MS for the WFD reporting with aggregated indices (EQRs) being shared to the EEA through WISE portal, but species-level raw data not available at EU level	Select a group of invertebrate species that is relevant for the WFD (e.g. Ephemera, Plecoptera, Trichoptera, Gastropoda, Oligochaeta, Diptera)	Regulatory in-situ monitoring in lakes and rivers, could be complemented with eDNA
Species distributions of marine mammals[29]	Marine[30]	NRL, MSFD, HD, CFP	Data collection by MS for HD and regional integration initiatives exist, but currently no EU-level integration initiatives and raw data from regulatory monitoring are not available	Marine mammals as listed in the Annexes II, IV and V of the HD and covered by the MSFD (seals, small toothed cetaceans, deep-diving toothed cetaceans, baleen whales)	Monitoring with ship and aircraft surveys, potential to combine with eDNA, acoustic sensors, and citizens science
Species distributions and abundances of wetland[31], marine[32] and terrestrial[33, 34] birds	All realms	BD, HD, MSFD, WFD, NRL	Massive data collection by NGOs with national monitoring schemes and sub-national, national and European integration nodes exist, but data sharing is restricted and, rare species are less monitored	Vertebrates (rare and priority birds listed in Annex 1 of BD, common farmland birds and common forest birds related to Annexes V & VI of the NRL)	Structured in-situ monitoring schemes (e.g. point counts, territory mapping, line transects), involvement of citizen science, new possibilities for monitoring with acoustic sensors
Genetic diversity of selected taxa (include terrestrial, freshwater[35] and marine[36] taxa)	All realms	GBF (target 4), MSFD (D3C3)	Recent studies have shown that monitoring genetic diversity is feasible and already ongoing in several countries, but it is very challenging and needs to be reinforced and coordinated.	Select a few (terrestrial, freshwater and marine) species categorized as threatened by the European Red List to demonstrate feasibility	Census data on the distribution and sizes of populations, DNA-based genetic monitoring,

27 https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Ecosystem-distribution-of-terrestrial-EUNIS-Habitats
28 https://github.com/EuropaBON/EBV-Descriptions/wiki/Freshwater-The-communities-of-benthic-invertebrates-in-European-lakes-and-rivers
29 https://github.com/EuropaBON/EBV-Descriptions/wiki/Marine-Species-distributions-of-marine-mammals
30 The marine research community tend to consider marine mammals data too challenging and prioritise instead the EBVs related to phytoplankton (relevant for WFD and MSFD) or seagrass (especially relevant for NRL, but also for HD, WFD and MSFD).
31 https://github.com/EuropaBON/EBV-Descriptions/wiki/freshwater-Species-abundances-of-wetland-birds
32 https://github.com/EuropaBON/EBV-Descriptions/wiki/Marine-Species-distributions-of-marine-birds
33 https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Species-distributions-of-terrestrial-birds
34 https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Species-abundances-of-terrestrial-birds
35 https://github.com/EuropaBON/EBV-Descriptions/wiki/Freshwater-Genetic-diversity-of-selected-freshwater-taxa
36 https://github.com/EuropaBON/EBV-Descriptions/wiki/marine-Genetic-diversity-of-selected-marine-taxa

Table 6: Proposed criteria for EBV selection. Abbreviations: BD = Birds Directive; CFP = Common Fisheries Policy; EVA = European Vegetation Archive; HD = Habitats Directive; MS = Member State bodies; MSFD = Marine Strategy Framework Directive; NRL = Nature Restoration Law; WFD = Water Framework Directive; WISE = Water Information System for Europe.

Criteria #	Criteria name	Criteria description
1	Realm representation	Select a combination of EBVs that represent all three realms (freshwater, marine, terrestrial)
2	Policy relevance	Select EBVs that are highly relevant for improving the reporting to the main EU directives on biodiversity (i.e. BD, HD, WFD, MSFD) and the EU Biodiversity Strategy for 2030, incl. the NRL
3	Feasibility & immaturity	Select EBVs that are feasible (i.e. data collection efforts are already ongoing in some/several member states of the EU), but still immature in terms of data accessibility and data integration at the EU level (i.e. raw data are not easily accessible at EU level and a centralised EBOCC coordination could strongly increase the transnational data integration across the EU)
4	Taxonomic or habitat focus	Select EBVs covering a breadth of taxonomic groups and habitats, e.g. vertebrates, invertebrates, plants, and different habitat types
5	Monitoring methods	Select EBVs that rely on structured in-situ monitoring, but with future integration potential of data from other monitoring methods that are currently not used for regulatory monitoring (e.g. citizen science observations, DNA, digital sensors, remote sensing)

In this report we propose to start the set-up of the EBOCC **focusing mainly on the coordination of biological variables (reflecting state, trends and functioning of species, habitats and ecosystems)**. For ecosystem processes, some abiotic variables are also needed. This can already represent a large work programme. However, at some point the EBOCC should cover or establish the necessary bridges to **assess the key stressors/pressures and eventual impacts** through the monitoring of co-variables. This would complicate the mandate of the EBOCC since the monitoring of stressors and human activities is spread over plenty of regulations and competent authorities. However, it is crucial to ensure that the measurement of pressures and the monitoring of biodiversity is spatially and temporally aligned. Some of these tasks are being covered by the European Topic Centres working for the EEA, but the work needs strengthening to get more curated/harmonised data products based on observations (rather than assessments or interpretations), and to do thorough analyses of pressures and impacts.

5.4 The policy mandate

As the analysis of the biodiversity monitoring in Europe indicated, there is a diversity of research initiatives, schemes, programmes, projects, institutes, agencies, and infrastructures that share some elements of EBOCC's vision and mission. Compared with existing ERICs, the EBOCC is not driven by scientific goals but by **policy goals**. Its assignment should be to cater to the policy-making, decision-making and biodiversity management communities, integrating and making accessible the EU monitoring information. Depending on the different legal acts, this assignment is partially shared with the EEA (with its European Topic Centres and Eionet network), the JRC (including the Knowledge Centre for Biodiversity[37]) and some Commission expert groups (all of them with the active participation of Member States), thus coordination and integration with these organisations are crucial and could be facilitated by integrating the EBOCC secretariat in one of these institutions (as reflected in the governance model, where we advocate for the EEA option). Actually, EBOCC should facilitate and strengthen the existing policy structures and processes, while the creation of new ones should be limited to gaps on data collection or on data integration. EBOCC should ensure that policy-oriented biodiversity information is more accessible on a permanent basis, always looking to reach the efficiency objective of "**measuring once, use many times**".

The vision and mission of the EBOCC have a strong operational element, similar to Eurostat/LUCAS, the EEA, JRC, PECBMS, or the European GOOS. Thus, the proposed EBOCC should be an **operational infrastructure** that is (Alleaume *et al.* 2018; Portillo-Quintero *et al.* 2022; Révelard *et al.* 2022):

- Mission oriented
- Driven by a well-defined operational purpose (technically feasible, including time series and the implementation of user-friendly tools)
- Have well-defined governance system and strong leadership
- Public and political interest (e.g. support strategic plans and assessments towards achieving policy requirements)
- Secure and sustainable funding

37 https://knowledge4policy.ec.europa.eu/biodiversity_en

The key **opportunity** for the EBOCC is to act as a catalyser and enable systematic and long-term routine measurements of biodiversity, and their rapid interpretation and dissemination.

The major **challenge** for the EBOCC would be to turn a fragmented landscape of different monitoring approaches, dispersed monitoring schemes and varied data standards into one shared biodiversity monitoring framework that can serve the needs of Europe, from the EU to local environmental managers and businesses. That requires an inclusive stakeholders and partners' architecture.

One of the major **risks** of the EBOCC is to become an "aggregate of researchers" where the designers of monitoring systems (responsible authorities or scientists) will establish a system that suits their professional interests or diminishes problems and costs, not necessarily aligning with operational objectives (Watson and Novelly 2004).

Policy-driven requirements for biodiversity monitoring are increasing at international, EU and, consequently, national scales. EBOCC's proposal fits with the observations by Tanhua *et al.* (2019) 'the rapidly increasing requirements, the growing landscape of actors and activities in biodiversity monitoring, and the constrained resources, require that some form of improved ocean observing governance evolve that can effectively and efficiently address the growing needs of the many stakeholders.'

EBOCC's policy goals should be very specific and align with the following legal acts. The present **EU policy framework** driving the development of biodiversity monitoring and assessments, and fostering management measures for the conservation and sustainable use of EU ecosystems, includes:

- The EU Biodiversity Strategy for 2030 (EC, 2020a) boosts all the high-level ambitions of the EU (through more than 100 actions) and offers as a tracking system of its implementation a dashboard with headline indicators linked to its 16 targets. Those indicators have different sources and do not necessarily depend on official reporting obligations of the Member States.
- The Habitats Directive (EC, 1992) and Birds Directive (EC, 2009) require the Member States to monitor and report on the conservation status of species and habitats of community interest and of all wild bird species both within and beyond protected areas. This includes notably the assessment of habitat extent and condition and of the population size, trends and distribution of the species protected under the nature directives. The corresponding Commission services also support the European Red Lists of Threatened Species, developed independently by the IUCN, to provide an overview of the conservation status of species.
- Under the Regulation on Invasive Alien Species (EC, 2014), EU countries have set up a surveillance system which collects and records data on the occurrence of invasive alien species in the environment.
- The Pollinators Initiative (EC, 2023a) had initiated the development and testing of an EU-wide pollinator monitoring sampling scheme that includes bees, butterflies and hoverflies while also increasing taxonomic capacity and expertise in countries.
- The Water Framework Directive (EC, 2000) requires Member States to monitor and report on the ecological and chemical status of water bodies, including a wide range of biological quality elements.
- The Marine Strategy Framework Directive (EC, 2008) requires Member States to monitor and report on the environmental status of all marine EU waters, including biodiversity criteria that cover all species groups and broad habitat types.
- The Common Agricultural Policy (CAP) and the Common Fisheries Policy (CFP) also deploy wide monitoring frameworks targeting selected species and habitats (by Member States or by centralised EU systems). For instance, farmland birds are reported as an indicator under the monitoring and evaluation framework of the CAP and the population sizes of various marine fish stocks are monitored under the CFP.
- The National Emission Ceilings Directive (EC, 2001) establishes the emission reduction commitments for the Member States' anthropogenic atmospheric emissions. Under this directive, EU countries need to measure in situ the impact of air pollution on terrestrial and freshwater ecosystems.
- The Land Use Land Use Cover and Forestry (LULUCF) Regulation (EC, 2023b) aims to remove annually by 2030 310 million tonnes CO2 equivalent from the atmosphere. This also requires the monitoring of carbon stocks in managed forests, croplands, grasslands and wetlands. Such ecosystem-based carbon monitoring will also be relevant to support the proposed framework on carbon removal certification.

In addition, the EC is currently preparing a series of new policy initiatives that will further extend the existing monitoring framework. The proposal for a Nature Restoration Law (EC 2022a) but also the proposal for a Regulation on Ecosystem Accounting (EC 2022b) will make the monitor-

ing of specific biodiversity and ecosystem indicators mandatory. Moreover, the EC has published legal proposals for the monitoring and management of soils (EC, 2023c) and for forest monitoring (EC, 2023d). If these proposals are implemented, their competent authorities and their requirements should be integrated in the EBOCC objectives. In addition, the EU Green Deal initiatives and the requirements of the EU Taxonomy for Sustainable Activities (EC 2020b and subsequent delegated acts) have increased exponentially the need of biodiversity data from the private sector.

At the global level under the Convention for Biological Diversity, the recent Kunming-Montreal Global Biodiversity Framework, together with a further COP15 Decision, includes 23 action-oriented targets to be measured and tracked through an effective and transparent framework for monitoring, reporting and review of progress. These targets have to be underpinned by science and have explicit outcomes. A list of 27 headline indicators has been already adopted, but future *ad hoc* meetings will have to agree on a longer list of indicators and to advise on the further operationalization. Parties are to align their national biodiversity strategies and action plans, including national targets, by COP16. National targets should be specified in accordance with an agreed template. To support the Parties implementing the framework, strengthening and standardising the knowledge base to support implementation, it has been proposed to set up a Global Knowledge Support Service for Biodiversity. The EC's Knowledge Centre for Biodiversity can help the future EBOCC to make the appropriate links both with the EU policies and with the Global Biodiversity Framework.

As we explained in the Introduction, the **immediate policy action is boosted by a request from the European Parliament that will start in 2024** (Preparatory action 09 24 01 in [38]). The Parliament calls for piloting the EU Biodiversity Observation Centre with the goal to ensure effective tracking of the progress towards the goals and targets of biodiversity policies, which should be based on the regular and frequent provision of high quality data and information, underpinned by a systematic field observation of biodiversity over a long time frame. The action will focus on the operationalisation of a set of biodiversity variables with a direct application in policy and decision-making. Specifically, the preparatory action will support the following activities:

- Piloting and testing an EU biodiversity observation service, featuring key functions and services as proposed under the EuropaBON project, by building on, connecting and reenforcing existing institutions, and thereby contributing to the development of the Global Knowledge Support Service for Biodiversity adopted at the CBD COP15;
- Implementing workflows that deliver harmonised EU-wide biodiversity data necessary to build policy-relevant indicators;
- Providing technical assistance to Member States regarding the implementation of the biodiversity observation network proposed by the EuropaBON project and contributing to the Global Knowledge Support Service for Biodiversity;
- Building capacity for biodiversity observation by providing trainings for taxonomic experts and strengthening citizen science networks.

5.5 Governance structure and functions

Preferred option: the hybrid "hub and spokes" model

Overtly centralised or decentralised arrangements were excluded from consideration as they do not fulfil the EBOCC needs identified by the consortium (e.g. inclusion and integration of all knowledge, strong policy mandate).

The **governance architecture** most favoured by the consortium and stakeholders usually goes by the term "hub and spokes". An EU body hosts the central part of the EBOCC (the "hub") covering a coordination and connector role. Each of the "spokes" (e.g. national biodiversity hubs) usually act as "hubs" at another level, channelling the numerous monitoring efforts (Figure 5). The model is supported by strong EU presence, mandate and funding, with direct membership status for Member States' hubs, and indirect membership status for diverse organisations from the NGO, citizen science, business, research and education worlds. In terms of investment from the EU, the hybrid model is larger than the decentralised model (which is close to zero in direct funding) although much smaller than the centralised approach. There is core funding associated with ensuring long-term sustainability and the necessary structures and commitments to develop the tasks (it could be a core team of *ca.* 10 employees and external temporary support when necessary), but Member States and other organisations contribute significantly to maintaining biodiversity observations.

EBOCC would be based on a general secretariat developing the tasks described in the Section 5.2. This work would build and depend on the national biodiversity hubs that develop similar roles at the national level. National and subnational public entities perform nowadays most of the data collection tasks, even if they can outsource it to competent organisations. Both EBOCC and the national hubs face the challenge to align the approaches of multiple sectors and organisations with different objectives and structures. This would help clarifying the EU monitoring landscape and the mandate/contribution of different actors. Ideally each country should have a national biodiversity monitoring hub, or as a minimum requirement, one identified focal point, to allow efficient connection with the EBOCC. Both EU and national levels should prioritise the work together.

A close link in the executive and strategic roles with EU institutions and agencies (notably, but not limited to, the EC and the EEA) would ensure the policy orientation of the

38 https://data.consilium.europa.eu/doc/document/ST-15238-2023-ADD-5/en/pdf

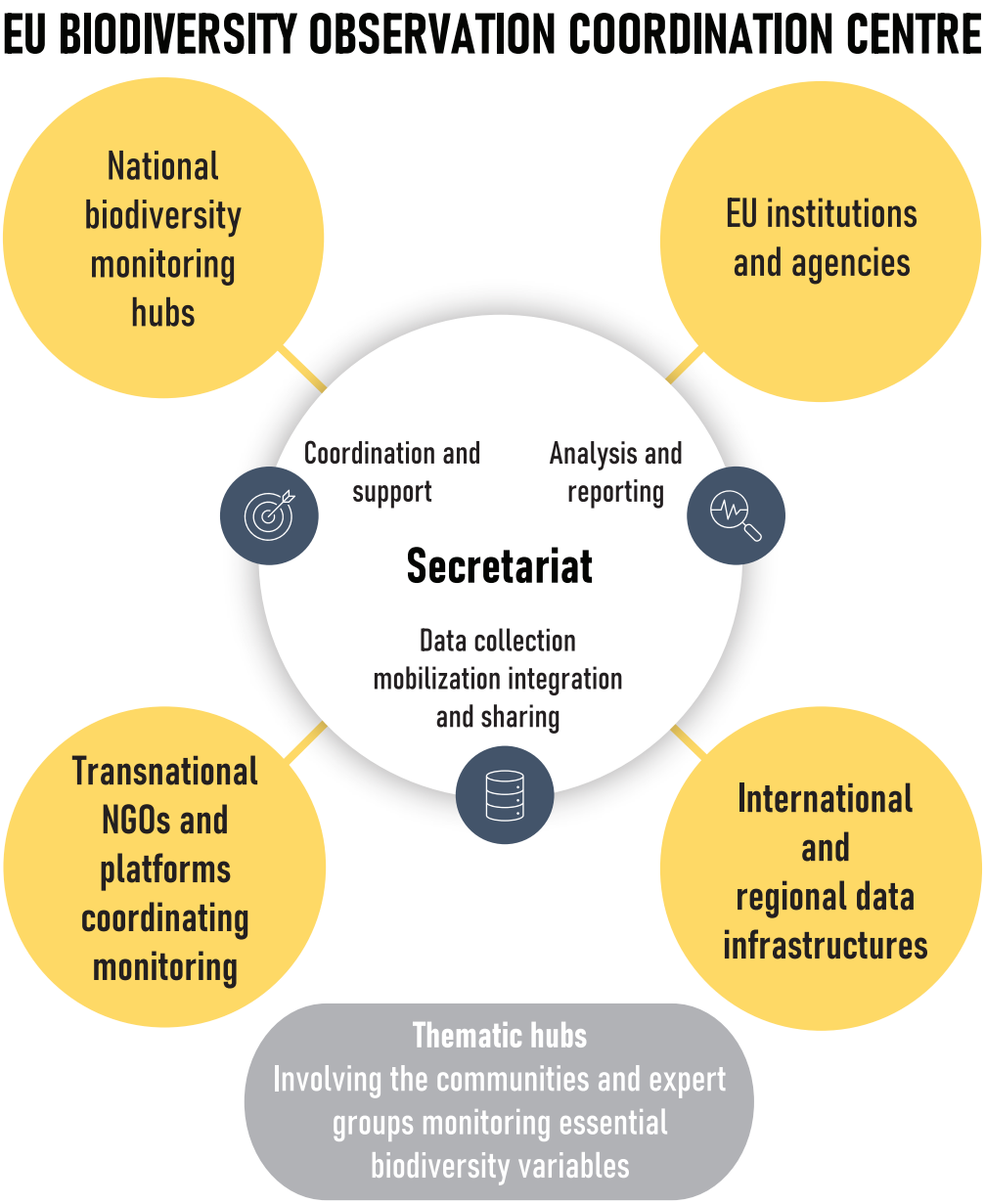

Figure 5. Representation of the proposed EBOCC external structure based on a "hub and spokes" model.

centre. In fact, we propose the EEA as the possible host for the EBOCC secretariat. EEA already has a role as collector and distributor of environmental information for policy purposes, involving a wide range of thematic areas, actors and end users. Still, the mandate and the level of detail of the information received by the EEA (presently being assessments rather than observations) do not cover the role of EBOCC. The EC's Joint Research Centre and, in particular, the Knowledge Centre for Biodiversity can provide links the tracking of certain EU policy targets and to some to EC-steered biodiversity monitoring schemes.

But EBOCC would go beyond established policy frameworks and bridge also with transnational organisations, citizen science initiatives, conventions or agreements that perform and coordinate data collection (e.g. EBCC, BCE, Regional Sea Conventions, ACCOBAMS, biodiversity workings groups from EuroGOOS/EOOS). These organisations usually mobilise the communities of experts around single biodiversity variables and, as such, would be essential for the thematic hubs[39]. Specific subnational, national and EU expert groups or public entities monitoring biodiversity variables (mostly linked to policy mandates) would be part of the thematic hubs. EBOCC do not need to duplicate these fora, but to screen them looking for gaps in the monitoring workflows, to support them with their technical needs, and to consult them with the best available options (i.e. to provide a common framework for existing groups). This would help both EBOCC and the national hubs to recognize mandates and responsibilities that would lead to recommendations for future funding. Hence, the thematic hubs would be the backbone of the technical and operational level of EBOCC and would be focused on individual biodiversity variables.

The fourth pillar of this organisation is to establish a close link

39 For instance, the EBCC is proposing to act as a reference organisation for the EU regarding knowledge on bird monitoring in Europe, including the connection with other relevant international organisations that sit in their Board.

with transnational data infrastructures like GBIF, EMODnet, OBIS, EASIN, eLTER, etc. As explained in the previous section, they would be key contributors to EBOCC's data tasks, possibly also as part of the secretariat. EBOCC should identify the contribution of the existing data infrastructures to individual biodiversity variables and streamline the support along the entire data flow (from data collection to policy indicators).

The online consultation of this deliverable showed that *governance* is not identified as a conflicting point, although the structure and involvement of stakeholders should be very clear from the start. Regarding the *role of non-governmental knowledge providers*, most participants (70%) support their involvement in the working groups (70%) but not so much in the central structure with voting rights (21%); they should be consulted (59%) and/or get financial support for their monitoring activities (53%).

Regarding the **internal structure**, the bodies that would form the EBOCC are:

- General assembly (or governance board): the main decision-making body. It is formed by representatives of the Member State hubs (i.e. the relevant national Ministry or agency) and of the relevant EU institutions and agencies. The assembly meets regularly and decide on the strategic orientation and agenda setting, with a strong focus on EU laws and commitments.
- Technical and stakeholders advisory board: it is composed of leading researchers, heads of large-scale monitoring programmes (e.g. PECBMS) and infrastructures (e.g. eLTER; LifeWatch). It advises the general assembly on the topics to be addressed (e.g. knowledge, capacity and data gaps; funding needs; development of protocols, new schemes and guidelines; curricula on biodiversity monitoring). It can also oversee the scientific capacity of the outputs produced by EBOCC and by the thematic hubs.
- General secretariat: a new small size body (*ca.* 10 core members with possible external collaborators) that implements the tactical and operational roles mandated by the general assembly. It ensures that the tasks are implemented with the coordination and collaboration of all members. Its members should have the competences to coordinate and/or cover all the assigned tasks and, at least on a temporal basis, the selected biodiversity variables/indicators. The chair of the secretariat could be an appointed person from the hosting institutions.
- Thematic hubs: these are a combination of existing working groups in areas underpinning the strategic agenda (i.e. focused on a selection of biodiversity variables or indicators). In some cases, in the absence of relevant EU networks, EBOCC could promote the development of missing working groups. The members of the thematic hubs come from relevant and competent (sub-)national and international institutions (e.g. EIONET, Commission expert groups, JRC, GBIF, OBIS), scientific experts and large-scale monitoring schemes (e.g. Atlases, PECBMS, etc.). Naturally, these groups are the implementers and often hold the operational role to collect and integrate biodiversity observations. EBOCC should minimise the workload of these groups and rather support them with the identification and filling of structural and capacity issues for the delivery of evidence-based biodiversity indicators.
- Data governance and ethical committee: it is a small group of selected members from the extended partnership (full members and associated members) that can be appointed every few years. It should be a self-regulated committee that develops, promotes and update a common code of conduct and data management plans; track the FAIR and CARE principles; reviews and liaises on granting data requests.

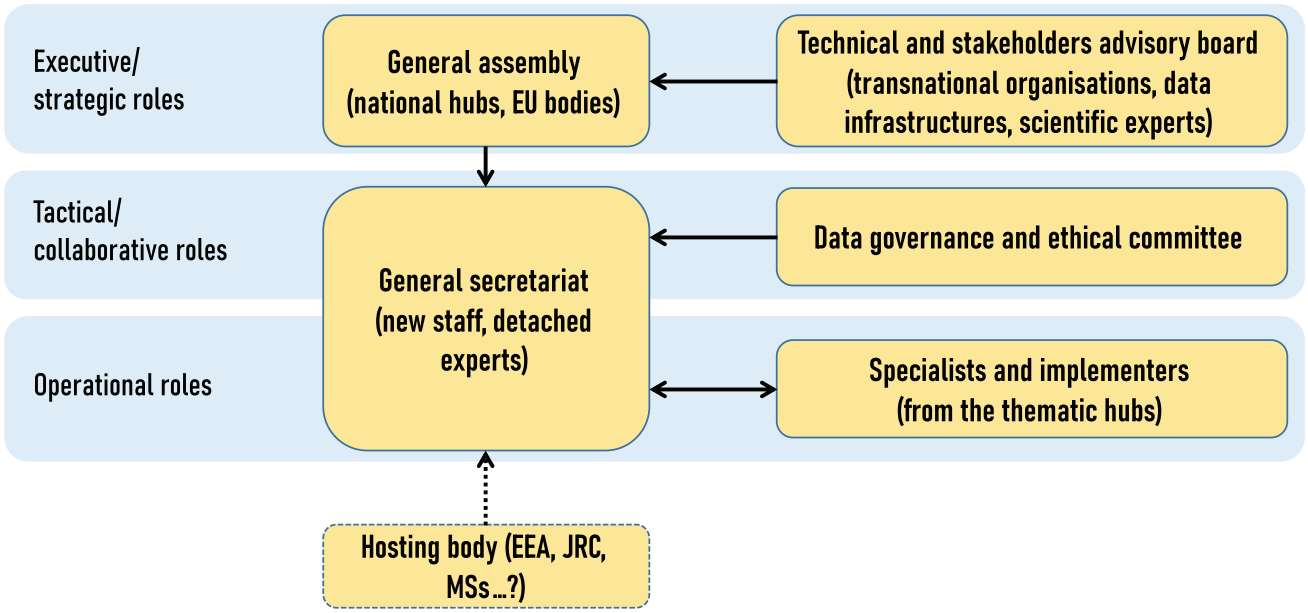

Figure 6. Proposed internal organisational structure.

The hosting institution in this instance would have a 'subsidiary function' (Tanhua *et al.* 2014), performing tasks that cannot be performed locally. However, since the central organisation would be nimble, it would be able to outsource actions, activities, and tasks to organisations that are able to perform them, including universities, the private sector, NGOs, etc. These organisations would sign service agreements of memoranda of understanding, each case-tailored, to be able to provide their services to the EBOCC.

An important consideration is that a centre like EBOCC cannot be operational immediately. A starting phase would be focused on planning, networking and scoping tasks (Figure 7). An intermediate construction phase would start establishing the centre. A pre-operational phase would focus on the delivery and long-term sustainability. The duration and ambition of these phases, especially related to the number of topics covered, depend on the mandate and resources allocated to the centre. The initial implementation phases of the centre may rely on an interim type of organisation; while the pre-operational phase should be organised and established over the definite principles and governance structures.

Overcoming the challenges of centralised and decentralised governance

The most appropriate approach to biodiversity monitoring will depend on the specific goals and context of the monitoring effort. Decentralised systems can provide a more comprehensive and representative view of biodiversity, but may be more difficult to ensure the quality and consistency of the data. Centralised systems can provide a more consistent and standardised approach, but may be more expensive and less representative of the broader ecosystem. A hybrid approach can provide a balance of both benefits and limitations, but may be more complex to implement and coordinate. Section 4 and Supplementary Material 3 provide more details on how the centralised and decentralised models could look like.

For the purposes of the EBOCC, as envisioned by the majority of stakeholders and the EuropaBON and Biodiversa+ partnerships, there are some identified challenges that the EBOCC should overcome (Table 7). The preliminary risk analysis below justifies the **(widely agreed) preference for a hybrid system in these terms of reference**.

Minimum requirements for the governance structure for the EBOCC

The EBOCC should be a strong international organisation with **adequate funding** to direct, coordinate, integrate and assess biodiversity observations, data and products across the EU, if necessary helping competent authorities and communities to design or improve data collection. It should be able to provide and coordinate capacity building for non-government actors, Member States and other stakeholders in need of it. It should have a **central role in linking policy requirements** to (1) monitoring schemes and data collection, and (2) indicators/EBVs or other assessments in order to support the entire policy cycle. Other EU and international organisations and other sectors producing, handling or needing biodiversity information would be incentivized to coordinate their needs and efforts with the EBOCC.

Considering that the EBOCC should, at the very least, work on tasks related to coordination, data handling and integration, support to multiple actors and analysis, and based on stakeholder consultations, we arrived at the following basic principles.

1. **Every Member State should have a national biodiversity monitoring hub responsible for national coordination** (e.g. data sharing, data formatting, coordinating national observation networks) and for co-designing monitoring schemes with other Member States and data holders, collating raw observations in common international standards. Based on Member States and Biodiversa+ feedback, establishing a network of coordinated national and subnational biodiversity coordination centres would be important if harmonisation of monitoring activities is to be achieved across different countries. This national hub would coordinate its monitoring efforts with the EBOCC and establish close collaboration with Eionet, GBIF national nodes and any relevant national/transitional hubs. Already some of the Biodiversa+ par-

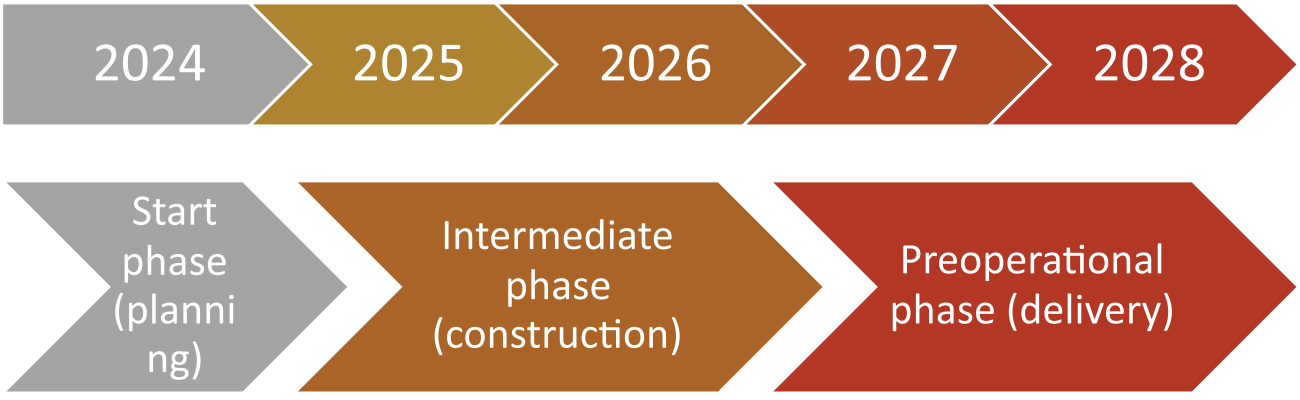

Figure 7. Indicative phases for the development of an operational EBOCC.

Table 7: Preliminary risk assessment for the EBOCC. The major risks actually correspond to the main challenges linked to the establishment of either a decentralised or a centralised governance model. The proposed actions for mitigating the risks should be embraced in the establishment of a hybrid model.

Major risks	Identified mitigation actions
National bodies and other knowledge holders do not cooperate with the EU body or among themselves	- Interconnected structure at different levels, with the EU level providing coordination - Support at European level but implementation decisions nationally - Federalise - central structures at EU level and decentralise knowledge and data holders - A centralized but nimble coordination body is necessary - Reach more harmonisation by gradually gaining acceptance - Support co-development and solidarity among Member States
Do not reach common, flexible and easy workflows	- Set common standards to be fulfilled for sampling but freedom to nationally adapt - Create standards on how to gather and, if possible, share information - Avoid duplications & simplify the processes - Demonstrate and exploit the cost-effectiveness of shared transnational approaches
Do not get enough funding	- Explore and plan not only EU funds, but also national sources, including blue & green investments, recovery funds, etc. - Join forces to mainstream the need of accurate biodiversity information and inform about the benefits - Clarify possible funding mechanisms for the levels where the information is collected - Work for specific funding calls and technical support at the EU and national scales - Identify monitoring gaps and provide advice on how to improve funding to fill them
Miss a clear vision and mandate	- Anchor the work with a strong policy mandate, including binding policies at EU level, international commitments and outstanding synergies - Negotiate the short and long term vision - Get support and contribution from EU bodies and Member States
Do not ensure transparency and accountability	- Revise the EBOCC governance structure and performance regularly - Ensure an open strategic vision of EBOCC by Member States and EU bodies and the advisory role by all stakeholders - Rely on an ethical committee and a transparent system of decision-making and funding - Engage with all stakeholders early in the process - Make methods community driven
Lack legitimacy and inclusion	- Respect EU's founding principles to enhance cohesion but respect diversity among countries - Ensure stakeholder engagement & communication - Set the level of engagement on legal and ethical terms from all the members - Good communication and diverse contact points, where even local specificities should be heard - A wide board with institutional, citizen science, research & user representatives ensures accountability & stakeholder buy-in

ticipating countries and sub-national regions have a national biodiversity monitoring hub in place.

National authorities are presently under a lot of pressure to serve various data users such as EU directives, municipalities, environmental impact assessments (EIAs), private companies, land use sector, civil society, etc. This creates a real need to improve national scale coordination and empower national biodiversity monitoring centres. It is crucial to see synergies with the national developments and align them with EU level development.

Some transboundary, regional or biome monitoring efforts already have clear common governance architectures; EBOCC would need to coordinate with them and perform a holistic gap analysis. EBOCC should build on what already works, reinforcing seamless integration, encompassing national (and, if possible, sub-national) level(s), as well as existing pan-European cooperation structures.

2. **An entity with an EU mandate would host the EBOCC**, provide leadership and a policy-linked mandate, and employ a Secretariat. It would mobilise technical groups with expertise on certain taxa, biodiversity topics or monitoring techniques. Special attention will be devoted to integrating (and avoiding duplication with) existing policy implementation structures (e.g. EC ex-

pert groups, national authorities, EIONET, technical groups from multilateral agreements). The overarching goal for the EBOCC is to bring these actors together and ensure coordination, harmonisation and access to data and information. Citizen and local participation at the national and sub-national would be promoted and enhanced, to ensure engagement, relevance, legitimacy, and justice of the overall structure.

3. **Inclusion and integration of knowledge**. All other knowledge holders should be part of EBOCC, at least as members of stakeholder and scientific committees, while some of them could provide services (e.g. existing data infrastructures, particular Earth Observation techniques, capacity building, Research Infrastructures). All members should agree on the creation of a code of practice and ethics principles, in charge of promoting FAIR and CARE principles and resolving issues.

5.6 EBOCC Stakeholders

In broad terms, EBOCC stakeholders consist of organisations with an interest or with some influence on the EBOCC and its services. Key stakeholders include Member States' environmental bodies, existing monitoring schemes and their networks, citizen science data platforms, technical experts, policy makers, EU agencies and programmes, research and education institutions, EU/international research and data infrastructures and private companies.

We have identified three principles that can influence EBOCC stakeholders and the governance arrangements that will bind them together in an organisational structure:

1. **EBOCC should not and cannot replicate biodiversity monitoring and data aggregation efforts already in place**. Thus, the EBOCC should partner with and/or involve and support existing international, national, regional and local schemes to achieve its mandate. This means that existing international and national monitoring programmes third-sector large-scale schemes (e.g. PECBMS), citizen science data platforms and organisations, universities and research institutions, existing data infrastructures, and private companies that hold data or can offer services should be invited to take part of the EBOCC.
2. **National participation and coordination are key for efficient EU monitoring**. Government agencies or facilities for biodiversity monitoring and data aggregation acting as national hubs will form the core partners of the EBOCC. Member States' participation in coordination greatly enhances the legitimacy, accountability, transparency and acceptance of the EBOCC.
3. **EBOCC's organisation and governance should be inclusive, accountable and transparent.** The EBOCC should represent all Member States equally, and in case of differences in capacity, funding or power, it should strive for enhancing capacities and cohesion. Differences in monitoring cultures and approaches should be acknowledged, respected, and if changes or additions are recommended, consensual decision-making approaches should be taken.

Here below, we provide an overview of the key stakeholder groups and how they could interact with EBOCC. Table 8 summarises the responsibilities, contributions, actions and derived benefits of all the stakeholders groups.

Member States' government bodies are key data and knowledge providers for national information. They coordinate national monitoring efforts and cooperation in international programmes. They provide funding and support to monitoring schemes. They can act as representatives to the EBOCC. They can use and build upon EBOCC indicators and help develop data standards. In return, they can receive support from the EBOCC and the EU (e.g. the funding model of Biodiversa+ where partners valorise their in-kind contributions to monitoring and they receive back a 30 % top-up). Member States provide and will also benefit from specific data and policy coordination (e.g. more accessible and comparable evidence to evaluate the need of national or subnational programmes of measures), as well as strategic input and help in local policy development. The EBOCC can support Member States on the implementation of EU legislation and facilitate an easier, more efficient reporting system. As a first step, every country should map and coordinate their monitoring and data aggregation networks and identify or set up **national biodiversity monitoring hubs** recognized and mandated by the ministries of the environment or similar national authorities. This process is ongoing, supported by Biodiversa+. At the end of this section, we provide two examples of detailed stakeholders' mapping (at EU level) that should be replicated at national and EU levels per each EBV or topic at stake.

The main benefit that **European agencies and the EC** would enjoy is evidence and quantitative decision-making abilities regarding biodiversity indicators and targets. This can help assess policy effectiveness and gathering

standardised and comparable data across the EU. Importantly, EBOCC should achieve this by investing, coordinating, and enhancing the monitoring infrastructures that are currently in place, rather than building a new monitoring infrastructure. In particular, the **EEA**, in its role as collector and distributor of environmental information, has developed broad networks and knowledge to coordinate and host complex data flows, involving a wide range of thematic areas and actors, as required for setting up an EBOCC. The EC's Joint Research Centre, together with EC policy services, is playing a central role developing and implementing tracking systems for different Green Deal initiatives of relevance for EBOCC.

NGOs and other not-for-profit organisations can also be key stakeholders of the EBOCC. Aside from their roles in the coordination of monitoring schemes, data provision, data processing and analysis, they also play a crucial role in public engagement. Particularly important are the training and dissemination activities put in place by NGOs. As envisioned in this report, NGOs will see their funding increase if they are to take on additional roles and responsibilities. Apart from funding, NGOs and other not-for-profit organisations will benefit from having their role acknowledged in raising awareness about biodiversity and enhancing evidence-based decision making. The EBOCC can also provide training to help them improve their capacities for e.g. data management and analysis where needed or desired. On return, well-established citizen science platforms around certain taxa (e.g. birds, butterflies) can share their experience and know-how with eventual new initiatives.

Research and education institutions (universities, research institutes and infrastructures, natural history museums, etc.) are also key stakeholders with distinctive roles and some salient benefits. Research and education institutions can align research, knowledge provision and education practices with activities of the EBOCC. In many cases, research projects could support or develop some of the activities of the EBOCC, with positive consequences on visibility, policy impact and networking. The EBOCC can highlight and try to fill the needs, e.g. for taxonomic expertise or certain monitoring techniques. Furthermore, considering that these institutions typically collect and analyse data, they can also act as data providers and technical advisors to analysts of the EBOCC. Research and education institutions will also benefit from leadership positions which can translate into collaboration opportunities, increased funding and more engagement with society and/or policy.

Businesses also have a role to play in the current EU monitoring framework, but their contribution is less clear as the data they produce are often not shared (e.g. environmental impact assessments). The EBOCC aims to change that, looking for structural changes to mobilise those valuable data (e.g. by offering businesses the role of data providers with some remuneration). The EBOCC can collaborate with businesses in terms of building partnerships for research and innovation. The business sector can assist the EBOCC by providing targeted funding or services and tools, and they can be assisted by making use of EBOCC data and in fulfilling compliance mandates.

In our online consultation, we asked participants for the potential contribution that their organisation or project could give to the EBOCC. *(Field) data collection/mobilisation* (74%), *Biodiversity data analysis/integration* (68%) and *Knowledge exchange/collaboration with stakeholders* (68%) were the main contributions envisioned by the respondents. Many participants were willing to analyse, share and channel data to the EBOCC. Some were willing to support knowledge sharing or to mobilise stake- and right-holders across realms, although the lack of temporal and financial capacity was mentioned as an obstacle to provide data.

In a question about the kind of support expected from EBOCC, participants ranked as the most desired supporting mechanisms: *Network support/communication on European level/national level* (64%), *Financial support* (62%) and *Access to data/processed data* (54%). The respondents indicated that regular updates on the status of the EBOCC, transparency and clear objectives were crucial for stakeholders to stay or become engaged. Participants saw engagement with the EBOCC as a great opportunity to effectively contribute to policy decisions.

Example of stakeholder's mapping

A general stakeholders' mapping will not be enough to avoid duplication of efforts and facilitate exchange between existing monitoring activities. Hence, the future EBOCC work should begin with a detailed mapping of actors monitoring each EBV at different levels. Here we provide two initial examples at EU level which would be further elaborated by the EBOCC, one for marine mammals and one for wetland, marine and terrestrial birds.

Table 8: EBOCC stakeholder categories, description, potential responsibilities and benefits.

STAKEHOLDER CATEGORIES	EXAMPLES	KEY RESPONSIBILITIES	KEY BENEFITS
EU institutions and agencies	JRC, DG ENV, DG AGRI, DG MARE, DG CLIMA, Eurostat, EEA, ETC-BE, EIONET, ESA, Commission expert groups and platforms	- Provide funding and support - Host an eventual EBOCC - Provide policy framework for monitoring, mandate, overarching vision - Bundle and disseminate data and information - Coordination, standardisation and harmonisation of data and methods	- Get evidence / data-based decision making abilities - Get insight into the state of European biodiversity - Assess policy effectiveness - Gather information and data for establishing & updating policies - Get standardised & comparable data for monitoring biodiversity - Early warning of risks and threats
EU / international research or data infrastructures	EU Open Science Cloud, EU research infrastructures (e.g. eLTER), GBIF and its member nodes, UNEP-WCMC	- Methodological support - Analysis and IT development - Data collection & provision (monitoring)	- Additional funding - Enhanced infrastructure - Avoid duplication, further research and policy responses through cumulative evidence by integration of monitoring data, e.g. through GBIF.
Member States' governments and bodies	Conservation & monitoring authorities, such as environmental agencies and ministries, Representatives from national hubs, Nationally-funded monitoring schemes	- Coordinate existing and future monitoring schemes - Provide material support to existing and enhanced monitoring networks - Act as representatives in EBOCC governance structure - Use data and indicators to inform environmental policy and practice - Provide data (raw data or aggregated) from national and sub-national monitoring schemes	- Get training support - Get EU money for monitoring - Build national strategies supported by the EBOCC - Meet target goals - Facilitation for local policy strategy and decision-making - Comparison of national data due to harmonised standards may reveal interaction structures - Would get an easier and standardised reporting system - Get their data for monitoring and compliance purposes
Member State technical experts	Sampling statisticians, Technical experts & specialists	- Methodological support (sampling design, analysis) - Local and specialised knowledge provision	- Get EU money for monitoring - Local knowledge feeding into EU monitoring
Non-governmental monitoring schemes	Networks of representatives from existing schemes, NGO networks working on biodiversity monitoring at local, regional or national scale	- Coordinate existing and future monitoring schemes - Share knowledge and capacity building - Provide data - Organise publicity, citizens & volunteers - Process and analyse data	- Receive funding so they don't rely on selling their data - Receive funding for the monitoring they perform - Receive funding for training volunteers - Their observations contributing to society awareness of status and trends in biodiversity - Observations leading to evidence-based decisions by local, regional and national government (e.g., permission for new industrial development) - Use the information to control EU and national governments
Non-governmental local stakeholders	Local and regional stakeholders (e.g. farmer communities, value chain partners, protected areas, fishers' associations)	- Data provision - Use data and indicators to inform management practice - Local validation of data and indicators	- Inform and influence national governments and EU policy - Get data and indicators from neighbouring regions - Compare findings with national measures

STAKEHOLDER CATEGORIES	EXAMPLES	KEY RESPONSIBILITIES	KEY BENEFITS
Research and academic institutions	Scientific societies and museums, Research institutes and universities, EU-funded research projects	- Research - Knowledge provision - Education - Data provision & collection (monitoring) - Data use & analysis	- Leadership and collaboration - Enhanced international profile - Increased impactful research publications - Leading Regional Biodiversity Portals Connect with monitoring organisations in order to stimulate projects - Receive funding for the monitoring that they perform - Receive funding to analyse and report data to the database - Receive funding to support EBOCC to analyse data
Citizen science platforms	iNaturalist, ECSA, Citizen science organisations, natural history societies	- Citizen engagement and literacy - Data provision - Code of Practice and Ethics review	- Enhanced engagement with society - Recognition & visibility - Data standards & infrastructure
Business sector / Private entities / SMEs	Private industries (e.g. agriculture, renewable energy), Consultancy firms, EIA experts	- Provide funding and support - Participate and collaborate - Provide & promote open data	- Get EBOCC data for adaptation and mitigation measures - Quantify the impacts of their activities in biodiversity/ environment - Compliance activities
Multilateral agreements with commitments for EU monitoring	EU representatives in CBD working groups, Regional Seas Conventions, UNEP-WCMC	- Provide link to global initiatives - Ensure EBOCC is meeting international norms and standards	- One single entry point for EU biodiversity data - Harmonised EU-wide standardised data

For the EBVs 'Species distributions of marine mammals' (Table 9) and 'Species distributions and abundances of wetland, marine and terrestrial birds' (Table 10), the EBOCC should bring together or consult the following knowledge holders (who actively monitor or collect information on distributions of marine mammals) and knowledge users (for national and EU level decision-making). Potential actions may include, among others, coordinating meetings, technical exchange, infrastructure development, and more.

5.7 Cost and long-term sustainability considerations

This section provides a conservative (minimum) estimate of the activity costs of a reduced EBOCC pilot limited to six EBVs and to the urgent tasks outlined in Table 4 during an initial period of 5 years (Table 11). **Biodiversity data collection is not part of this cost estimation** and is not included among the tasks proposed for the EBOCC as it is the mandate of national and sub-national authorities (with or without the support of NGOs and contractors). Data collection costs and the maintenance of EBVs' workflows will be included in the upcoming EuropaBON deliverable about a modern and efficient European biodiversity observation network (D4.3). Preliminary results show that implementing the proposal for the EuropaBON biodiversity observation network, including coordinating the monitoring of EBVs, data collection, maintenance and analysis of the data, will require approximately €501M of initial investment and €465M of annual costs (Kissling *et al*. 2024).

The full exploitation of biodiversity data must include in the planning stage costs of organisation, data processing, management and archiving, curation, analysis, governance or communication. Important considerations are (1) investment costs (until the achieving of an operational status) are considerably higher than annual maintenance costs, and (2) the benefits of a harmonised system of data collection and analysis lag years behind the costs. For example, the estimated annual cost of maintaining three global knowledge products/platforms (the IUCN Red List of Threatened Species, Protected Planet, and the World Database of Key Biodiversity Areas) is US$6.5 million. However, reaching pre-defined baselines of data coverage would cost an additional US$114 million and, once achieved, annual maintenance costs will be approximately US$12 million (Juffe-Bignoli *et al.* 2016).

In its first phase, the EBOCC would lead on open discussion and comparisons of monitoring schemes per EBV to allow the identification of opportunities where EU-coordinated approaches would bring the maximum benefits at low costs (e.g. centralised Earth Observation products, coordinated surveys).

Table 9: Key actors and associated main responsibilities within the EBOCC for the EBV 'Species distributions of marine mammals'.

Major risks	Identified mitigation actions	Key roles on the measurement of this EBV
Member States	Member States biodiversity hubs, Nominated national authorities	They may provide access or point to (sub) national databases, as well as coordinate the national contri40utors
Commission expert groups[40] and technical groups	- WG on Good Environmental Status of the MSFD - Marine Expert Group of the HD - Group of experts on D1 Biodiversity Mammals of the MSFD (managed by the JRC) - Relevant fisheries advisory boards, STECF	They organise the data flows, assessments and reporting feeding the Marine and Habitats Directives. There are interlinks with fisheries measures, action plans and requirements from the Common Fisheries Policy.
Regional Sea Conventions	- HELCOM Expert Group on Marine Mammals (EG MaMa) - OSPAR Intersessional Correspondence Groups on Coordination of Biodiversity Assessment and Monitoring (ICG COBAM) and on Protection & Conservation of Species and Habitats (ICG POSH) - Mediterranean Specially Protected Areas Regional Activity Centre (SPA/RAC) - Advisory Group to the Black Sea Commission on the Conservation of Biological Diversity (CBD)	They coordinate and collect national data to build common regional indicators/ assessments
EEA	Eionet Biodiversity and Ecosystems 1 Group or National Focal Points	They gather and develop data, knowledge and advice to policy makers
Organisations with long-term and large scale scope (e.g. NGOs)	ACCOBAMS, ASCOBAMS, PEW, Oceana, etc.	They can collect observations to build indicators/assessments, not necessarily uptaken in policy processes
Research initiatives with long-term and large scale scope	- ICES Working Group on Marine Mammal Ecology - Working Group on the Joint Cetacean Data Programme - EMODnet with its Biology portal - Selected Research Infrastructures and research projects	They can collect observations to build indicators/assessments, not necessarily uptaken in policy processes. They can collect, integrate, harmonise and disseminate data

40 The Commission expert groups are responsible for the implementation of EU legislation or EU initiatives. They are composed by the relevant Member States authorities, the relevant Commission services and organised observers interested on the topic (NGOs, professional associations, platforms, etc).

In the second phase of implementing the EBOCC, it would begin coordinating and channelling funds for EU-level data collection - similar to the LUCAS run by Eurostat, and funded by other Commission services such as DG Agriculture. For the time being, due to the lack of an environmental or biodiversity fund in the EU and to the national competences on environmental monitoring, this task cannot be proposed.

Here, we break down the costs of the most urgent EBOCC functions in terms of initial investment and annual maintenance costs for six EBVs (Table 11), and identify any associated costs to be borne by Member States or other organisations (Table 12). It is important that such activities which would fall to Member States should be appropriately funded at that level to avoid deterioration in the quality of existing data collection efforts, as has been observed in some existing scheme (Breeze *et al.* 2023) and to highlight the activities that EU candidate states may need to consider.

All costs are based on the previous efforts to generate similar functions, either though biodiversity monitoring activities or through the INSPIRE programme. These costs are indicative and only apply to the six initial EBVs. These costs also do not include any costs relating to data collection.

A detailed breakdown of all cost estimates is provided in Supplementary Material 5. All staff costs include a 25% overhead rate. We also include an estimate of the total costs including inflation, using 1.98%/year (average 5 year annual Labour cost index for Denmark, 2018-2022, Eurostat 2023).

Table 10: Key actors and associated main responsibilities within the EBOCC for the EBV 'Species distributions and abundances of wetland, marine and terrestrial birds'.

Categories of actors	Examples of actors	Key roles on the measurement of this EBV
Member States	National biodiversity hubs, National Ministries, agencies and, in some countries, subnational governments	They have the legal responsibility on bird conservation and management. They ultimately coordinate data compilation and storage through different strategies (i.e. Birds directive, or the Marine strategy framework directive (MSFD). They report data and knowledge to the EU Commission.
Commission and Council expert groups and technical groups	Expert groups on Bird conservation	These groups (like the Commission expert group on the Birds and Habitats Directives, the Group of Experts of the Council of Europe or the one on the Bern Convention) monitors the compliance of Parties with the provisions related to bird conservation, including migratory birds, and informs the responsible bodies on the progress in the implementation of the species action plans so far endorsed. It further identifies other species requiring specific action plans and proposes measures that may be appropriate for the conservation of threatened birds. Among its priorities, the different expert groups are leading European work against the illegal killing, trapping and trade of wild birds.
Bird related international conventions	Convention on Biological Diversity, Europe's Convention on the Conservation of European Wildlife and Natural Habitats, The Convention on Wetlands, Convention on the Conservation of Migratory Species of Wild Animals	Convention on Biological Diversity is dedicated to promoting sustainable development. The Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats (1979), or Bern Convention, was the first international treaty to protect both species and habitats and to bring countries together to decide how to act on nature conservation (see - Commission expert groups) The Convention on Wetlands (adopted in Ramsar in 1971) is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. As an environmental treaty of the United Nations, CMS provides a global platform for the conservation and sustainable use of migratory animals and their habitats.
EEA	Eionet Biodiversity and Ecosystems 1 Group or National Focal Points	They gather and assess data, knowledge and advice related to EU nature directives and related legislation.
Organisations with long-term and large scale scope (e.g. NGOs)	European Bird Census Council (EBCC), Wetlands International, EURING, BirdLife International	The EBCC coordinates national organisations (NGO; universities, museums, governmental departments) to compile data and produce breeding bird population trends (PECBMS, Pan European Common Bird Monitoring Scheme), distribution (EBBA, European Breeding Bird Atlas), as well as all-year around species occurrence (EBP, EuroBirdPortal). Wetlands International compiles the information on wintering wetland birds. EURING is the coordinating organisation for European bird ringing schemes. Key actor for EBVs on species mobility (migration). BirdLife International is the official scientific source of information on birds for the IUCN Red List. It reports bird conservation status in EU.
Research initiatives with long-term and large scale scope	eLTER, MoveBank, Living Planet Index, GBIF, Census of Marine Life	The eLTER Advanced Community Project (eLTER PLUS) tests the performance and further develops the services of the emerging eLTER Research Infrastructure (eLTER RI). Occurrence data on birds, mainly valued for integration at ecosystem level. Movebank is an online database of animal tracking data. Movebank is a free, online community database of animal tracking data hosted by the Max Planck institute of Animal Behavior. The LPI is based on trends of thousands of population time series collected from monitored sites around the world. GBIF—the Global Biodiversity Information Facility—is an international network and data infrastructure funded by the world's governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth. Census of Marine Life is an international effort undertaken to assess the diversity (how many different kinds), distribution (where they live), and abundance (how many) of marine life.

Core Staff

At its core the EBOCC will require a number of staff to oversee and maintain its activities and a budget for expert liaison each year. For this proposal, these staff are based in Denmark. Based on discussions with stakeholders throughout the development of the EBOCC proposal, we estimate that, for an initial pilot centre to manage six EBVs, two senior scientific co-ordinators (€156,797 per year each) to oversee scientific co-ordination and reporting, two software engineer/research assistants (€110,225 per year each) to oversee the technical aspects of the centre and six project officers (€116,485 per year each) would be required to establish and maintain these activities. Several of EBOCC activities fall under these core costs. Finally, we also include two FTE posts of consultant grade staff to support analysis and reporting, and co-ordination of workflow maintenance and development activities. This staff load is approximately equivalent to the EEA State of Nature reporting (EEA 2023 pers. comm.).

Thus, **the costs for an EBOCC pilot limited the urgent tasks related to six EBVs over the first 5 years sum up €12M**. However, such reduced pilot centre only represents a fraction of the coordination of an entire EU biodiversity observation network entailing, based on EuropaBON's proposals, around 84 EBVs. Scaling up this estimate gives an **approximate cost of€68M of initial investment and €54M of annual costs to run the coordination of the full EU biodiversity observation network**.

At a Member State level, national expertise is essential to engage with the EBOCC in an effective manner. This should be an adequately paid, long-term position to ensure that knowledge and skills can be retained between years and not lost to inadequate job security (Breeze *et al.* 2023). These staff should ideally be based at a research institution, university or museum to retain access to materials and allow opportunities for research on the data they collect. Based on European butterfly monitoring, it is recommended that this effort should be equivalent to at least two full time staff, but divided among different people to support different specialised activities such as volunteer coordination (e.g. five people at 40% FTE each). Where there is already a suitable liaison for the EBOCC, it is recommended that their role be adjusted to reflect this as the number of EBVs grows, ideally by at least 0.1FTE to begin with.

Where data collection is to be led by volunteers (e.g. EBCC, eBMS), this can require additional coordination effort, which we estimate at ~0.1FTE per 10 sites monitored (eBMS 2024 pers. comm.). This extra expense is important to support volunteer engagement and retention, producing more financially sustainable and cost-effective data collection (Breeze *et al.* 2023). Additional funding should also be considered to support engagement events, like annual meetings that bring together volunteers, researchers, policy, and, where applicable, private actors.

Funding sources

Substantial extra funding will be necessary to cover many of the proposed tasks of the EBOCC, and to better coordinate the rather scattered biodiversity monitoring across the EU. Potential sources of finance are:

- European Research Infrastructures or similar set-up (normally long-term sustainability by R&I funds).
- Delegation agreements similar to Copernicus service funding.
- New budget line/activity by the EU (including the new commitments under the Green Deal), including statistical (rather than research) programmes.
- Direct & indirect funding from EC's programmes.
- Member States' budget.
- Partly financed by fees from the private sector for example:
    - Sustainable finance instruments.
    - Auditing system similar to the one in USA for EIAs.
    - Providing independent quality control and validation centre for private genetic monitoring companies.

In the short term, one of the most effective mechanisms for supporting EBOCC activities could be EU COST actions, which support research groups to collectively address a specific challenge, such as method development, power analyses, data mobilisation tools, etc. For example the COST Action Bottoms-Up (CA18207) developed materials for standardising forest biodiversity monitoring across several taxa (e.g. Burrascano *et al.* 2022) and COST action G-Bike has developed standardised protocols for collecting, analysiing and reporting on species genetic diversity monitoring (O'Brien *et al.* 2022). A tranche of such projects, aligned with the EBOCC objectives and administered in direct collaboration with the EBOCC could not only reduce or eliminate the need for many expert groups included in the costs above, but can foster engagement between actors and may lead to wider research advances. However, this approach may be slower to deliver than a targeted expert group for some tasks.

EU Marie Curie Fellowships and Doctoral Research Networks may also present an opportunity to support capacity building in member states where this is lacking for a particular EBV, by providing dedicated training opportunities.

Engagement with private actors may require further investment in ethical considerations and legal administration. When engaging with these actors, it will be crucial for the EBOCC to maintain independence to retain relationships with monitoring organisations.

Regarding long-term sustainability, several studies highlight that, aside from stable funding (Tanhua *et al.* 2019), long-term institutional survival means that EBOCC would meet both its own and the objectives of other organisations (Watson and Novelly 2004, Wright *et al.* 2020), not necessarily with the same objectives (e.g. different Directorates of the EC, private sector). Furthermore, while several studies highlight the importance of influential champions

Table 11: Summary of activity costs for an EBOCC pilot limited the urgent tasks related to six EBVs over the first 5 years (conservative estimate).*

Category	Task	Investment	Subtotal	Maintenance (per year)	Subtotal (4 years)
Coordination and support functions	Coordination 1: Support coordination between Member States and institutions	Expert group to establish co-ordination (€11,000 per EBV, €66,000 total)*	€66,000	Maintaining expert groups (core costs) Total: €0	
	Coordination 2: Collaborate and engage with external knowledge holders	0.25 years of researcher time to generate the initial database (€27,556)	€27,556	Database maintenance (core costs) 70 expert days for specialist thematic groups (€35,000) plus €10,000 expenses Total €45,000/year	€41,500/year
	Capacity building 1: Support data exchange, analysis and standardisation	75 Expert days to establish workflow standards (€33,750 per EBV, €202,500 total) Software Engineers - 0.5 Years to create metadatabase (€55,112) - 1 year of software developer time for Portal (€110,225) - 0.5 years per EBV to set up automated pipelines (€55,112 per EBV, €330,675 total) - 0.3 Years for IT procurement and set up (€33,067). €100,000 for materials (e.g. software) 24 days of expert time, plus €15,000 travel expenses included for training in data collection standards (€25,800 per EBV, €154,800 total).	€986,376	Technical staff - 0.3 years for IT maintenance (€28,467) - 0.25 years to quality control workflows (€23,722) - 0.4 years to maintain platform (€37,955) - 0.3 years to maintain metadatabase functions (€28,467) - 0.4 years to update and check metadatabase (€37,955) €30,000 for material expenses 0.5 years of software developer time to update the geoportal (€55,112) 10 days of expert time plus expenses for annual training workshops (€8,250 per EBV) **Total:** €41,500/year	€188,631/ year
Data collection, mobilisation, integration and sharing	Data 1: Data mobilisation, integration and harmonisation	75 days of expert time for establishing workflow standards (€33,750 per EBV, €202,500 total)	€202,500	50 expert days for training in data management and standards (€22,500)	€22,500/year
	Data 2: Improved sampling designs and standardisation of field data collection	135 Expert days plus €20,000 expenses per EBV included to undertake power analysis* (€80,750 per EBV, €484,500 total) 20 expert days per EBV to develop guidance (€9,000 per EBV, €54,000 total) €420,000 for developing field guides for difficult taxa (we assume just one is required)	€958,500		

* For these items, higher investments may be required for EBVs that are not already well established. These are discussed in Supplementary Material 5.

Category	Task	Investment	Subtotal	Maintenance (per year)	Subtotal (4 years)
Data collection, mobilisation, integration and sharing	Data 3: Data infrastructure and tools	25 expert days per EBV to outline data infrastructure needs (€11,250 per EBV). Software Developers - 1 year per tool developed (e.g. apps) for two tools (€110,225 per tool) - 0.2 years to develop an API (€22,045) €10,000 for materials	€319,995		
	Data 4: Develop data access and data sharing policies	2 years of researcher time per EBV to develop and test harmonisation and interoperability (€220,450 per EBV, €1,322,700 total) €20,000 per EBV for materials (€120,000 total)	€1,442,700	1 year of researcher time to update interoperability, harmonisation and quality control and address technical issues. (€110,225) 0.4 years of technical staff time to maintain interoperability (€36,455) €10,000 for materials (e.g. license updates) Data storage (average €39,600) **Total:** €196,281/year	€196,280/ year
Analysis and reporting to support stakeholders	Analysis 4: Gap analysis, both on monitored data and on knowledge	0.5 years of researcher time to update, check and corroborate EuropaBON Gaps and Bottlenecks analysis for the focal EBVs (€55,112)	€55,112	Annual update of gaps and bottlenecks (included in core costs).	
	Analysis 6: FAIR principles and justice/ transparency	36 expert days to establish and prepare an initial Ethical committee and deliver FAIR principle guidelines (€16,200)	€16,200	18 expert days to maintain the expert ethical committee (€8,100) **Total:** €55,112	€8,100/year
Core staff		1 senior researcher per 3 EBVs (€156,797 each) 1 software engineer/research assistant grade staff per 3 EBVs (€110,225 each) 1 project officer per EBV (€116,485 each)	**€1,232,954**	1 senior researcher per 3 EBVs (€156,797 each) 1 software engineer/research assistant grade staff per 3 EBVs (€110,225 each) 1 project officer per EBV (€116,485 each)	**€1,232,954/ year**
Total			€5,307,893		€1,689,995/ year
Total EBOCC costs €12,067,753 (5 years) (€12,555,192; including inflation at 1.98%)					

Table 12: Summary of the corresponding Member State activity costs over the first 5 years.*

Core staff	2FTE staff per taxonomic group if monitoring is not well established. Where monitoring is well established, an additional 0.1-0.2FTE to existing staff to participate in EBOCC activities. 0.1FTE per 10 sites managed by volunteers.		
Category	**Topic**	**Investment**	**Maintenance (per year)**
Coordination and support functions	Coordination 1: Support coordination between Member States and institutions		Additional core staff time may be required to engage across highly devolved member states
	Coordination 2: Collaborate and engage with external knowledge holders	*Early engagement with data providers to understand likely changes	
	Capacity building 1: Support data exchange, analysis and standardisation		0.25-0.5 years per EBV to adopt new pipeline
Data collection, mobilisation, integration and sharing	Data 1: Data mobilisation, integration and harmonisation	1 year to develop a national biodiversity portal (where one is not present). 0.5yrs implementation of data pipelines	0.25 person years to maintain a biodiversity portal 0.25 years for quality control of workflows Host data quality workshops if required (important for highly devolved countries)
	Data 2: Improved sampling designs and standardisation of field data collection	Variable costs for adopting new sampling methods or designs or increasing sampling points. 10-20 days of training workshops with national data providers is required (administered by data collection organisations) Taxonomic guidance, developed for key taxa (€30,000-€48,000) Translation of guidelines produced by EBOCC	Regular annual data collection training workshops to facilitate volunteer and new professional engagement
	Data 3: Data infrastructure and tools	*Early engagement with current data providers to understand the scale of support required for data mobilisation (expected to be 3-12 months per EBV) Develop or collaborate with technology companies to develop tools as required. One or more 5 day data management workshops (if required).	
Data collection, mobilisation, integration and sharing	Data 4: Develop data access and data sharing policies	2-12 months per data provider to facilitate the harmonisation and interoperability of data	0.25FTE for data interoperability and harmonisation updates and checks. Costs of cloud storage for national biodiversity data, depending on the size of data deposited
Analysis and reporting to support stakeholders	Analysis 4: Gap analysis, both on monitored data and on knowledge	A member state specific gap analysis	
	Analysis 6: FAIR principles and justice/transparency	Consultation about data providers compatibility with principles during other engagements.	

* This step should ideally be undertaken very early into the EBOCC's operations and does not rely upon EBOCC activities to inform it.

and leaders (Watson and Novelly 2004, Vořišek *et al.* 2008, Wright *et al.* 2020), especially in the beginning, they also note that "reliance on individual initiative" must be superseded by organised solution in the pre-operational and operational phases. The early phases of the initiative are crucial, before real monitoring time-series data are available, as that is when stakeholders place their "expectation value" on the programme. Maintaining support means that reporting should start as soon as he first data are available.

Benefits

Assessing the economic value of the EBOCC's coordination is challenging as benefits of monitoring are often less overt than costs in general. Yet, EuropaBON's Deliverable 4.4 (Breeze et al. 2024) predicts these benefits to exceed €252 billion over ten years, highlighting the significant financial opportunities from centralised, high-quality, open-access, harmonised biodiversity data provided by an EBOCC, in response to the growing interest in biodiversity data by public and private organisations.

Cost saving for external actors: Centralising and opening access to data can have tremendous cost-saving implications for other organisations. An in-depth analysis of GBIF, including a survey of its users, highlighted the platform saved 845,000 hours, worth approximately €35M in researcher time in 2021 alone (Deloitte Access Economics 2023). This value is likely to grow considerably as the demand for biodiversity data continues to grow, for example under the EU Sustainable Financial Disclosure rules, as businesses from across sectors become more accountable for the environmental impacts of their supply chains (EC 2019).

Environmental Impact Assessments (EIAs): Sustainable business: A lack of baseline biodiversity data and high-quality monitoring standards are major bottlenecks for businesses - slowing the process of Environmental impact assessments and creating difficulties in trust building for green financial instruments. This can result in greater pressures on biodiversity monitoring organisations at the expense of their main activities (Breeze et al., 2023). EBOCC has the potential to meet these business needs by providing data, standards, decision support tools (e.g. Olsson et al., 2023) and consultation for the private sector and acting as a hub for engagement with local experts.

Improving modelling of biodiversity and natural capital: Lacking baseline data, EIAs and other commercial methods for assessing biodiversity, often use modelling approaches that are not validated for all relevant species, which can lead to erroneous conclusions about the impacts of the project and ultimately, greater impacts on the species affected (Horswill *et al.* 2022; Croll *et al.* 2022). Similarly, public natural capital accounts[41], meant to track changes in the supply demand and value of biodiversity across Europe, also utilize models that are not widely validated against field data and which do not actively incorporate other datasets to address pressures on these assets and thus highlight risks. By creating benchmark data standards and collecting harmonised, open access data that is interoperable with other datasets, EBOCC can support validation and further innovation of these modelling approaches. Increasing confidence in EIAs for the private sector and can offer opportunities to valorise ecosystem services to a greater extent through targeted restoration action (e.g. restoring pollinators in areas of known deficits to enhance access to nutrition – Smith *et al.* 2022).

Innovation: Innovations in biodiversity data collection (e.g. digital sensors, eDNA), modelling (e.g. Satellite remote sensing) and processing (e.g. machine learning) require significant amounts of data to develop, train, test and validate. EBOCC can not only provide an open access source of data, reducing the initial investment in data collection required by these innovation actors, but by setting and maintaining various standards, can act as a source of quality control for these innovations, possibly on a commercial basis. For example, acting as an independent laboratory to test the accuracy of eDNA sampling or providing certifications for new modelling apps to attest their compatibility with EBV requirements.

Opportunity savings: EBOCC represents the culmination of a number of needs identified by stakeholders, particularly around data that is already widely collected but which requires dedicated efforts to harmonise and adequately address policy priorities. Many of EBOCCs activities require a significant upfront investment of specialised staff time that will only increase in cost in the future due rising employment costs. Based on the average 5 year (2018-2022) labour cost index for Denmark (1.98% - Eurostat 2023), the costs projected would increase by ~€1.06M if EBOCC were to be implemented in 5 years.

Risks

Although the EBOCC has a number of substantial benefits, there are long- and short-term risks inherent in its implementation.

Funding risks: The EBOCC is a publicly funded body and will be sensitive to changes in available central funding. Inadequate and inconsistent funding is a major challenge for European Biodiversity more broadly, and can compromise the capacity of organisations to undertake certain activities or retain skilled staff (Breeze *et al.* 2023). As the EBOCCs remit expands, it will need to develop new standards for new EBVs and may need to support a greater number of Member States or citizen science effort. If funding for these activities is not adequate, the EBOCC may have to compromise on other activities, or may become a bottleneck in the development and implementation of monitoring within Member States. This will be exacerbated where an EBV requires multiple taxa to be monitored consistently. This can be mitigated by ring-fencing funding for the EBOCCs core activities on a regular basis and providing support e.g. through interaction with EU Research and Innovation projects, for adopting cost-savings (e.g. improved data workflows, collaborations with Horizon projects to undertake activities) as they arise.

41 See the INCA Platform developed by the JRC: https://ecosystem-accounts.jrc.ec.europa.eu/

Choice of EBVs: Unless funding is greatly enlarged, the EBOCC will not be able to support all key EBVs and have to choose which to support. If a highly sensitive EBV is not included within the remit of EBOCC, especially where the EBV is not monitored by all Member States or where data needs significant harmonisation, there is a risk that biodiversity losses of key biodiversity may continue unabated. EBV selection should therefore be driven by a clear rationale aimed at maximising biodiversity conservation, priority taxa that are functionally important or which are indicators of wider ecosystem health, rather than trying to maximise the number of EBVs monitored within a given budget.

Expert engagement: The EBOCCs activities rely upon significant input from often very specialised experts. Failure to properly engage these experts will limit the effectiveness and timeliness of EBOCCs outputs, with cascading impacts on member states and reporting. Expert engagement could be incentivised by including opportunities for participants to valorise their inputs into e.g. academic publications, policy briefs or dedicated research project funding streams (e.g. funding for projects to test the proposed workflows, in collaboration with Horizon Europe) that are consistent with their day-to-day activities.

Member States' engagement: The EBOCC fundamentally aims to support EU level EBV generation through setting standards, databases' interoperability and other cross-border activities. However, its recommendations may clash with Member States' priorities or simply receive little uptake in local decision making, especially where an EBV is not currently monitored. This can be mitigated by instigating direct collaboration between EBOCC and Member States from the beginning of each policy cycle – including a review of policies and priorities by each Member State to highlighting links with EBOCC activities. Member States will also have opportunities to regularly feed back to the EBOCC, suggest future needs or modes of engagement.

Citizen science's engagement: Although the EBOCC will aspire to the highest standards of data ethics and transparency, as an EU organisation, public scepticism may create reluctance of citizen science monitoring efforts to engage with it, especially if the standards set are not compatible with the monitoring efforts provided. EBOCC's expert groups will help forewarn of this but efforts should be made to highlight the benefits that citizen science organisations have found in working with EBOCC throughout its lifespan.

Opportunities

In addition to the direct benefits of accessible, standardised biodiversity monitoring data, EBOCC's activities can also generate long-term opportunities for data utilisation and more transformative change in society.

Capacity building: A significant challenge in much biodiversity monitoring is the lack of relevant expertise around specific taxa in many countries, particularly insects where taxonomists of many taxa are rare, ageing, and often not engaged with biodiversity research (Hochkrich *et al.* 2022). By developing standards and offering harmonised and standardised training courses, links through expert groups and support for data management, EBOCC represents an opportunity to (re)build this capacity across Europe to meet the growing needs for specialists and preserve local expertise.

Tool development: Through harmonisation and interoperability activities, EBOCC also represents an opportunity to develop software and other specialised tools to facilitate data management, a key challenge facing many national monitoring schemes that have limited time for these activities (Breeze *et al.* 2023).

Knowledge exchange: As a hub for sharing experiences across member states, schemes and even taxa, EBOCC also represents an opportunity for learning between different actors. This is especially important for developing citizen science and engagement activities where volunteer networks represent tremendous added value to monitoring (Breeze *et al.* 2023), but require substantial upfront effort to build and maintain and can fail where co-ordinators are inexperienced or are unable to connect with would-be volunteers (eBMS 2024, Pers Comm). Such engagement with monitoring activities has itself been linked with transformative changes among participants, promoting nature consciousness and greater engagement in wider environmental issues.

Consistency: As political priorities change, new EBVs may become more important to different national and European policymakers – EBOCC therefore represents a central hub to rapidly and efficiently develop the necessary tools, standards and training for new EBVs and provide tailored support for Member States which lack certain capacities. As an extension of this, EBOCC's remit could, in the future, be expanded to provide support to applicant States in aligning with EU monitoring requirements to ease their transition into full Member States.

6 CONCLUDING REMARKS

Biodiversity monitoring is the process of determining both the state and changes in living organisms and the ecological complexes of which they are a part. The EU has a long tradition of biodiversity monitoring developed to understand species trends and monitor the success of conservation programs. Currently, the landscape of biodiversity observations and data aggregation in Europe comprises many different schemes, programmes, agencies and infrastructures.

The main challenges for biodiversity monitoring in Europe include lack of long-term secured funding for monitoring networks, biased spatial coverage and taxa representation, and limited human and technical capacities. The key bottlenecks to produce evidence-based assessments of biodiversity are data access and data integration (e.g. among realms, across borders, between in situ and remote sensing data, etc.). The need for better coordination, harmonisation, digitalization, increased funding, and capacity building is emphasized to address these challenges. Also, there is a massive need for standardisation (of data collection methods, metadata, etc.) to enable data integration.

In this context, EuropaBON experts have identified five basic solutions to improve biodiversity monitoring in Europe: (1) enhance coordination and synchronisation of monitoring efforts, (2) enhance data gathering, sharing and standardisation, (3) take advantage of digitalization and novel technologies, (4) increase technical capacities and stakeholders engagement, and (5) increase the coordination and access to long-term funding while improving the efficiency of monitoring.

In this deliverable, EuropaBON proposes an EU Biodiversity Observation Centre (EBOCC) focused on implementing these solutions and being a catalyser for knowledge exchange, despite the significant challenge of actually increasing funding available for biodiversity observations. EBOCC should be driven by policy goals rather than scientific goals, and cater biodiversity information for managers and policy-makers implementing legal acts like the EU Biodiversity Strategy, Habitats and Birds Directives, Water Framework Directive, Marine Strategy Framework Directive, and others. In this vision, EBOCC could serve policy implementation (via a soft, non-regulatory approach) by deepening the policy perspective from assessments down to information, to ensure coherence across sectors and efficiency in the data collection and re-use.

Most of the key messages collected in this proposal (coming from experts, stakeholders and the literature) converged into a narrow set of options and an astonishing broad agreement around the mission, vision and governance for EBOCC. The EBOCC depicted in this deliverable has a clear mission to help coordinate biodiversity-related

monitoring efforts in Europe and establish a shared European biodiversity monitoring framework. To this aim, the following actions are necessary:

- Support coordination between Member States and organisations involved in monitoring, and assist them to maintain, enhance and align existing monitoring schemes. This may include developing standards, designing new monitoring schemes where gaps exist, improving sampling designs, developing novel techniques, etc. The engagement of diverse knowledge holders not commonly involved in policy processes is one of the key milestones for EBOCC. Another important role is offering capacity building to improve the monitoring and data skills of all stakeholders. The training topics should be decided on demand; apart from monitoring techniques, there is interest on topics such as taxonomy, funding sources or citizens science.
- Boost the biodiversity data collection, mobilisation, integration and sharing. Integrating the results of the monitoring schemes in a meaningful way requires improving data access, harmonisation or at least interoperability of EU, national and local biodiversity data. An integrated data infrastructure (with adequate tools) is needed for the collection, storage, management and analysis of information. But in many cases such structures already exist and may be just promoted or integrated in a distributed infrastructure. Access to high-quality spatial data is still a matter of concern and debate. EBOCC should be able to develop data policies compliant with the FAIR principles and to explore innovative and widely acceptable approaches to data sharing.
- Analyse and disseminate the information in ways

that serve policy needs. This may include quality control, modelling, gap analysis, identification of priorities, etc. Once the workflows and data flows are clarified, the added value of the EBOCC should be demonstrated by deriving some policy-relevant indicators in close collaboration with experts of the thematic groups. All the information flows passing through EBOCC should follow a FAIR/justice/transparency framework developed together with each topical community or thematic expert group.

This initiative is not the first one going in this direction. Many biodiversity communities and research infrastructures have been working for years on these issues. EBOCC should not replicate existing biodiversity monitoring and data integration efforts, but rather leverage existing leadership and coordination networks, and build upon them to complete the workflows where necessary.

Key lessons learned from previous experiences (that should be taken into account for establishing an effective EBOCC) include the need for strong political mandate, leadership, coordination, transparent governance, broad stakeholder participation, and a focus on legitimacy, accountability, and justice. These lessons highlight the importance of integrating various stakeholders and addressing social aspects.

A hybrid "hub and spokes" governance model is proposed for EBOCC, with an EU body hosting the general secretariat and Member States acting as spokes, coordinating national efforts. A close link in the executive and strategic roles with EU institutions and agencies (notably the EC and the EEA) would ensure the policy orientation of the centre. EBOCC should also mobilise the communities of experts that perform and coordinate data collection (e.g. non-governmental transnational organisations, citizen science initiatives, multilateral agreements) and transnational data infrastructures. Again, EBOCC will operate with the principle of not replicating existing efforts but partnering with and supporting ongoing initiatives. EBOCC's internal governance structure includes a general assembly, a secretariat, technical and stakeholder advisory board, thematic hubs, and a data governance and ethical committee.

EBOCC will require an initial investment and annual maintenance costs, to be covered by EU funding. A conservative estimate of EBOCC activity costs to initiate the most urgent tasks related to just six EBVs brings a total of €12M over the first 5 years, along with associated costs to be borne by Member States. Biodiversity data collection is not part of this cost estimation.

In practice, the implementation of EBOCC can:

- address the urgent need for coordination, integration, harmonisation and strengthening of biodiversity data collection and analysis;
- operationalise of a set of biodiversity variables with a direct application in policy and decision-making;
- contribute to the development of the entire data-to-knowledge chain based on direct observations, transparent scientific approaches, and improved access to biodiversity data;
- serve a more robust implementation and impact assessment of public policies.

Overall, this deliverable provides insights into the challenges, landscape, future needs, and lessons learned in biodiversity monitoring in Europe, emphasizing the need for coordinated efforts, improved data integration and interoperability, and support for monitoring networks to establish an effective EU-wide biodiversity observation network.

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ANNEX I: GLOSSARY

Aggregator (of data): A data repository is a virtual entity designed for the storage, retrieval, search, and distribution of data. It serves as a centralised hub where various types of data can be securely stored and easily accessed. Data repositories often play a dual role as data aggregators, collecting and organising data from diverse sources for efficient management and dissemination (Hackett *et al.* 2019).

Application Programming Interface (API): A set of clearly defined methods of communication between various software components (GBIF 2021[42]).

Biodiversity data: Biodiversity data refers to factual information devoid of contextual relationships (BID-REX 2019). Typically, a raw biodiversity data record corresponds to an observation of a living organism in a specific time and place, at the minimum sampling and time unit resolutions, ideally with GPS coordinates (Calas *et al.* 2020). Data encompasses a wide range of elements, including species inventories, distributions, multimedia content, ecological interactions, behavioural data, dataset descriptions, as well as analyses and interpretations. Primary biodiversity data can manifest in various forms, such as numerical, categorical (e.g., species or place names), images, or sounds (Costello *et al.* 2013).

Biodiversity indicator: Biodiversity indicators are one or more measures that condense complex data into simplified, standardised, and easily communicable figures (Wentworth and Henly 2021). Such measures of biodiversity help scientists, managers and politicians understand the condition of biodiversity and the factors that affect it[43]. These indicators can be used to monitor specific biodiversity aspects (e.g. forest area) or to evaluate the overall state of biodiversity (Wentworth and Henly 2021). Biodiversity indicators may also involve the use of a single species or a taxonomic group as a surrogate for less-known taxonomic groups (Noon *et al.* 2009). According to the OECD[44] , these indicators and valuation methods enable quantifiable assessments and comparisons of biodiversity across different spatial and temporal scales, which are essential for effective policy development and implementation.

Cleaning (of data): Data cleaning is the process of correcting or removing dirty data caused by contradictions, disparities, data-entry mistakes, missing bits, and more. It also includes the changes made, and may require normalisation (GBIF 2021).

Collation (of data): Gathering independent datasets to one repository (Schulman *et al.* 2021).

Curator (of data): Person or organisation that organises, analyses, and disseminates data into information (Hackett *et al.* 2019).

Darwin Core: A biodiversity data standard, maintained by Biodiversity Information Standards[45] widely used within the GBIF community and partners. It is a set of standardised terms (vocabulary, or field names) and their definitions, which are used to share biodiversity information (GBIF 2021).

Data flow: The movement of data from one part of the system to another, usually through a system comprised of software, hardware or a combination of both

Data infrastructure: It refers to the various components (including hardware, software, networking, services, policies, and more) that enable data consumption, storage, and sharing.

Essential Biodiversity Variables: A minimum set of spatial and temporal measurements of the state of biodiversity, complementary to one another, that can capture major dimensions of biodiversity change. EBVs are organised in six classes (genetic composition, species populations, species traits, community composition, ecosystem functioning, ecosystem structure) and cover the three realms (marine/coastal, terrestrial and freshwater)[46]. EBVs are measurements required for study, reporting, and management of biodiversity change (Pereira *et al.* 2013). The EuropaBON project has proposed a list[47] of Essential Biodiversity Variables for operationalisation in Europe.

Essential Ecosystem Services Variables: A minimum set of measurements, complementary to one another, that can capture major dimensions of ecosystem services change[48]. They can provide comprehensive pictures of how links between nature and people are changing (Balvanera *et al.* 2022).

Harmonisation (of data): Data harmonisation aims to integrate diverse data types, levels, and sources in a manner that makes them compatible and comparable, thereby enhancing their utility for decision-making. Unlike standardisation, which imposes a singular methodology or norm, harmonisation seeks to integrate information collected through different methods to achieve a coherent outcome. The primary focus is to find practical means of blending and integrating datasets collected for varying purposes, under distinct collection procedures, and using different standards and methodologies. This approach avoids the task of converting all data into a single standard and instead emphasises usability at a higher level of aggregation or generalisation. Methods for achieving harmonisation may include applying conversion factors, altering map projections for spatial datasets, and estab-

42 https://docs.gbif.org/course-data-mobilization/en/glossary.html
43 https://www.bipindicators.net/
44 https://www.oecd.org/environment/resources/biodiversity-indicators-valuation-and-assessments.htm
45 https://www.tdwg.org/
46 https://geobon.org/ebvs
47 https://europabon.org/?p=2993
48 https://geobon.org/ebvs/ecosystem-services/

lishing correspondences between different classification systems or terminology sets. In the context of biological species data, harmonisation seeks to reconcile descriptions of taxa without delving into intricate taxonomic details (Global Terrestrial Observing System 1998[49]).

Information: Information is the result of imparting meaning to data through its contextual relationships with other elements. Information extends beyond raw data, as it involves the interpretation and organisation of data points to create a coherent narrative or knowledge. Biodiversity data, for instance, encompasses vast sets of singular recordings, which, when aggregated, form valuable repositories for ecological research, knowledge production and decision-making (BID-REX 2019).

Integration (of data): Making separate datasets an interoperable data mass (Schulman *et al.* 2021), or the activity of combining data from different sources (Gadelha et al 2021). Crucially, data integration has to bridge not only multiple spatial and temporal resolutions but also domains (e.g. eDNA with Earth Observation and species occurrence, see König *et al.* 2019).

Interoperability: 'The ability of data or tools from non-cooperating resources to integrate or work together with minimal effort' (Wilkinson *et al.* 2016). This encompasses syntactic interoperability, in which two or more systems adopt identical data formats and communication protocols. It also involves semantic interoperability, ensuring that data transfer conveys meaningful information, enabling the recipient system to accurately comprehend and utilise the exchanged data. In the context of Essential Biodiversity Variables, cross-domain interoperability gains significance, denoting the alignment of multiple organisations around shared policies, principles, and procedures (Hardisti *et al.* 2019). In the EU INSPIRE Directive (Directive 2007/2/EC), interoperability is defined as 'The possibility for spatial data sets to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent and the added value of the data sets and services is enhanced'.

Mobilisation (of data): The implementation of data curation solutions that improve openness and re-use of data (Diack *et al.* 2022). For example, in the context of species occurrence data, data mobilisation describes the process and workflow for moving your database from being an internal-to-your-institution dataset to being ready50and formatted for external use[50]. In some cases, it can include some basic data manipulations like parsing data into separate fields, normalising names or putting dates into ISO format. This term, though not precisely defined, conveys the understanding that to facilitate reproducible and replicable science the sharing of data and repeatable methods are of critical importance (Diack *et al.* 2022).

Monitoring (of biodiversity): Monitoring is the practice of intermittently conducting surveillance to assess the degree of compliance with predefined standards or deviations from expected norms. Typically, biodiversity monitoring involves the examination of the distribution and abundance of organisms, such as species, genera, and families, along with their interactions with the physical environment. The primary objective of biodiversity monitoring is to provide valuable guidance for landscape management, with a dual focus on resource production for the human population and the preservation of biological diversity. Achieving these objectives involves conducting monitoring activities across various ecological scales and employing diverse techniques. These techniques include surveys, cataloguing, quantification, and mapping of entities such as genes, individuals, populations, species, habitats, and ecosystems, with subsequent synthesis of the gathered information (Niemelä 2000 and references therein).

Monitoring scheme: Systematic/standardised monitoring scheme where a field protocol is followed, and able to provide quantitative data on biodiversity for a give

49 https://www.fao.org/3/X0587E/x0587e09.htm
50 https://www.idigbio.org/wiki/index.php/Category:Data_mobilization

www.europabon.org