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D4.4 Business model for a European biodiversity observation network based on the outcomes of the cost-benefit analysis of different monitoring scheme options

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D4.4 Business model for a European biodiversity observation network based on the outcomes of the cost-benefit analysis of different monitoring scheme options

07/05/24

Lead beneficiary: UREAD

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EU Horizon 2020 Coordination and Support Action

Project acronym:	**EuropaBON**
Project full title:	**EUROPA BIODIVERSITY OBSERVATION NETWORK: INTEGRATING DATA STREAMS TO SUPPORT POLICY**
Start of the project:	01.12.2020
Duration:	36 months
Project coordinator:	Prof. Henrique Pereira Martin-Luther Universität Halle-Wittenberg (MLU) www.europabon.org

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

Deliverable title	**A Business Case for European Biodiversity Monitoring**
Deliverable number	**D4.4**
Contractual date of delivery	**31.03.2024**
Actual date of delivery	**07.05.2024**
Type of deliverable	**Report**
Dissemination level	**CO**
Work package number	**WP4**
Institution leading work package	**UvA**
Task number	**T4.4.**
Institution leading task	**UREAD**
Author(s)	**Tom D. Breeze, W. Daniel Kissling, Maria Lumberries, Joana Santana, Alejandra Morán-Ordóñez, Roy van Grunsven, Tim Hirsch, Tree Robinson, Simon Potts, Ian McCallum, Pavel Stoev, Ute Jandt, César Capinha, Jessica Junker, Camino Liquete, Henrique M. Pereira**
EC project officer	**Laura Palomo-Rios**
Deliverable description	The project will assess the full costs and benefits of schemes developed in T4.3 for different survey intensities/site distributions. Costs will be appraised using data from existing monitoring schemes, local research organizations and adjusted for cost differences between countries, allowing different site distributions to be incorporated. Monetary benefits, in terms of research costs saved by the monitoring scheme, will be evaluated using a Delphi panel approach: i) a list of crucial policy relevant questions relating to the taxa monitored will be

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	derived from suggestions submitted by national biodiversity organizations. ii) Using online surveys, expert opinion will be collected on the design of research networks (number of sites, years of sampling, samples per year) to answer these questions at a European level (considering EU legislation, e.g., the Habitats Directive) to an applicable minimum, moderate or ideal standard. iii) Summarized survey results will be shared with the respondents, giving them an opportunity to discuss and re-evaluate their responses until consensus is reached. iv) Respondents will be asked to evaluate schemes from T4.3, comment on the projected cost-benefits and identify opportunities for improving research and wider public engagement for each. Benefits will be evaluated as the sum costs of running all the relevant research networks (using the same costs data used to cost the network itself) that fit within the scheme size and structure. Information from T2.4 will also be used to measure the human capital value added by the scheme, in terms of training and educational value added
Keywords	Costs, benefits, biodiversity monitoring, ecosystem services, natural capital, sustainable finance, sustainable business, hazards

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Contents

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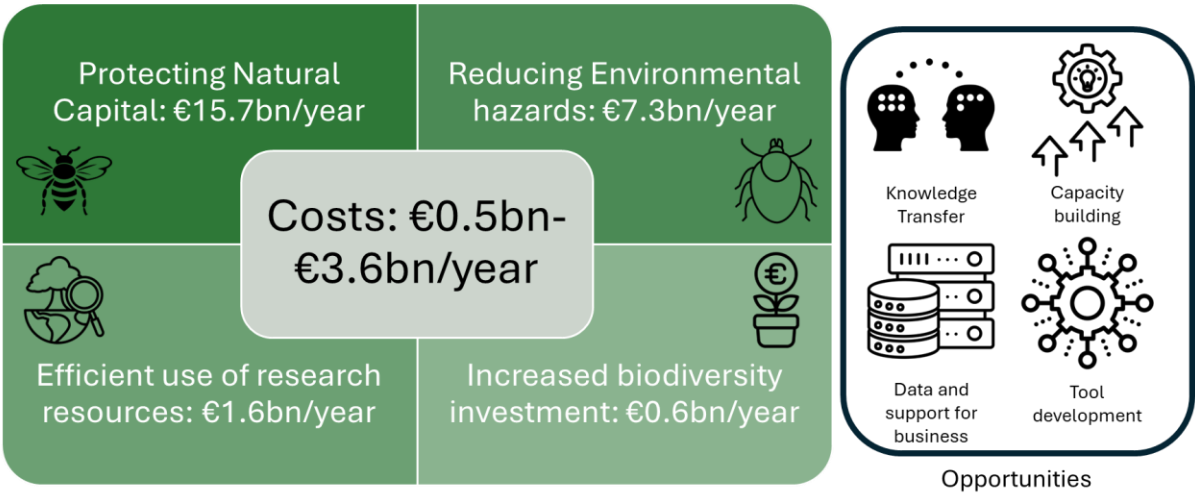
Graphical abstract

Although biodiversity monitoring costs are widely cited as a constraint, there have been very few assessments of these costs and even fewer studies have assessed the potential benefits of this monitoring. Here, we synthesise available evidence, alongside a comprehensive assessment of the costs of proposed biodiversity monitoring to explore the relative costs, benefits risks and opportunities in biodiversity monitoring. We find that the costs of biodiversity monitoring, €0.5bn-€3.6bn/year, are greatly outweighed by the combined economic benefits and opportunities arising from the availability of co-ordinated, high-quality data, which are estimated to be >€25.2bn/year.



Key messages

1. **Monitoring biodiversity through a series of cost-effective, integrated networks is estimated to be €0.5bn-3.6bn/year (€5.7bn-€38bn over a 10-year time frame)**. Approximately 10% of these costs are for upfront material purchases. Due to incomplete information, we cannot estimate how much is already spent through existing monitoring efforts by governments, NGOs and research organizations.
2. **Costs can be further reduced through a combination of novel technologies, co-location of sites to measure multiple variables and engagement with citizen scientists.** These options will each require additional investment in technological roll out, harmonization of methods and co-ordination of citizen scientists.
3. **The overall network, if properly co-ordinated, could have economic benefits of at least €25.2bn/year (€252bn/decade).** These benefits include, but are not limited to, Natural Capital protection (€15.7bn/yr), Hazard reduction (€7.3bn/yr), researcher costs saved (€0.1bn/yr), research funding saved (€1.5bn/yr), and increased biodiversity investment (€0.6bn/yr). There are also likely to be indirect and less apparent benefits.
4. **Biodiversity monitoring is essential to supporting the mainstreaming of biodiversity and our dependence on natural ecosystems into business and finance**. Biodiversity restoration will require>€48bn/year from a mix of public and private sources. Current sustainable financial instruments for supporting biodiversity are severely limited by available data and expertise, both of which could be addressed with a coherent biodiversity monitoring network.
5. **A unified biodiversity monitoring network presents significant opportunities to add long-term value to biodiversity research and mainstreaming.** In addition to producing high-quality data, a co-ordinated biodiversity monitoring network would facilitate knowledge

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exchange, capacity building and the development of data collection, workflow and tracking tools, and could be a significant leverage point for transformative change in society.

6. **Failing to implement effective long-term biodiversity monitoring in the near future creates economic, financial, environmental and policy risks.** Implementing monitoring after the current EU Biodiversity Strategy in 2030 would increase the annual cost of the network by at least €38M-€0.25bn due to monetary inflation alone, and risks the loss of existing research collaborations.
7. **The longevity of biodiversity monitoring is threatened by high turnover of staff and volunteers, and shifting research and policy priorities and funds**. A unified, long-term supported network would make monitoring efforts much more resilient to political change through knowledge exchange, central support and collaborative networks within and between countries.
8. **Funding for the network can come from a range of public and private sources**. The proposed network is less costly than many EU research infrastructures and could be recipient of redirected subsidies, but could also generate funding through providing consultation, training and quality control.
9. **Overall, the annual maintenance costs of monitoring are between 2% and 13% of the annual benefits of improved biodiversity conservation.** These estimates are very simplistic and can be greatly improved upon but are likely to be underestimated given the very limited data on ecosystem service benefits at an EU scale.

1. Introduction

Since the Millennium Ecosystem Assessment in 2005, there has been a substantial, increase in the evidence base around both the decline of biodiversity and the role of biodiversity in human wellbeing (IPBES, 2022). However, despite decades of initiatives and actions at all levels of policy to support biodiversity, these declines are continuing and, in many cases, may be accelerating (Diaz et al., 2019). A major driver in these inefficiencies has been the lack of measurable targets and active monitoring of biodiversity, making it difficult to understand the relative importance and interactions of drivers of decline, or the efficacy of restoration measures (Kleijn and Sutherland, 2003; Cuadros-Casanova et al., 2023).

Biodiversity monitoring has been widespread across the European Union since the implementation of the Habitats Directive in 1992 (EC, 1992), later reinforced by other environmental directives, and member states all have their own Biodiversity Action Plans with quantitative targets. However, much of biodiversity monitoring relies heavily upon data collection from individual research projects, discontinued dedicated research stations, or incomparable approaches. The development of Essential Biodiversity Variables (EBVs) has emerged in response to a need for more simplified and effective metrics of biodiversity that can be understood across realms and actors (Geijzendorffer et al., 2016). However, EBVs are strongly reliant on the existence of high-quality and harmonized monitoring data.

With the growing recognition of the dependences of society and economy on biodiversity, the Convention on Biological Diversity's Global Biodiversity Framework (CBD, 2022) calls upon governments to ensure that businesses monitor and mitigate their impacts on biodiversity and contribute to its restoration. This will be implemented throughout the EU via policies such as the Corporate Sustainability Reporting Directive (EC, 2022a) to create a legal framework for biodiversity credits and trading markets similar to carbon market structures (Waterford et al., 2023; Kedward et

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al., 2023). Consequently, many businesses are now investing in developing biodiversity strategies alongside (or as part of) their existing climate strategies (zu Ermgassen et al., 2022).

Collectively, these factors have driven an unprecedented demand for biodiversity data. However, funding is a persistent limiting factor for long-term monitoring efforts, resulting in significant gaps in data and bottlenecks in the development of data products and indicators (EC, 2019a; Moersberger et al., 2022; Santana et al., 2023). At the same time, the demand for biodiversity monitoring data from the private sector is increasingly greater than organizations are able to effectively handle within their current resources (Breeze et al. 2023). Expanding biodiversity monitoring efforts to address the taxonomic, spatial, temporal and workflow gaps will require additional funding and coordination.

Although often discussed, the costs of implementing biodiversity monitoring are seldom measured (Hyvärinen et al., 2021). A previous study by Nesbit et al (2022) estimated that €104M per year would be required to support European biodiversity monitoring but it is not clear what biodiversity this refers to or what activities are incorporated within this.

The majority of studies examining the costs of biodiversity monitoring are entirely contextualised around improving cost-efficiency by reducing the costs of monitoring targeted indicators (e.g. Griffiths et al., 2016; Elmiger et al., 2023) or through new, more efficient data collection techniques (e.g. Larrieu et al., 2018). Although useful, these studies tend to frame their arguments around the need to reduce the costs of monitoring overall, often with a view to reinvest funds in targeted conservation action (Tepedino and Portman, 2021). Some studies quantify this through "Value of Information" analyses where costs are constated with the relative benefits of additional data in achieving the overall goals of conservation (e.g. Nygard et al., 2016; Bolan et al., 2019). However, this remains focused solely on the goal of biodiversity conservation and does not account for the potential benefits of monitoring in itself on wider society. Very few studies have focused on the benefits of biodiversity monitoring as a public good in itself. Those which have, demonstrate the significant excess in benefits over costs through the protection of ecosystem services and costs saved, or value added to research (The Nature Conservancy, 2022; Breeze et al., 2021; Tyllianakis et al. 2019).

Here, we estimate the costs of a European Biodiversity Observation Network that would monitor a diverse array of EBVs (Kissling et al., 2024) and contrast this with a comprehensive overview of the social, scientific and economic benefits such a network could provide. We also examine the societal and economic risks of maintaining the current status quo and explore the opportunities to leverage monitoring data into wider, more transformative benefits to benefits to society.

This deliverable was developed throughout the EuropaBON project process, building upon the stakeholder engagement sessions in 2022 (Moersberger et al., 2022 – EuropaBON Deliverable 2.2.), the analysis of gaps (Santana et al., 2023 - EuropaBON Deliverable 3.2) and bottlenecks(Morán-Ordóñez et al. 2023 - EuropaBON Deliverable 3.3), surveys of the costs of biodiversity monitoring experienced by different organizations (Breeze et al., 2023), information from the workflows workshop (Kissling et al., 2024a) and a specific workshop session in November 2023 were participants identified the key benefits, risks and opportunities associated with biodiversity monitoring.

2. Estimating the costs of monitoring biodiversity

2.1. Costing approach

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We estimated the costs of monitoring 84 Essential Biodiversity Variables (EBVs; Geijzendorffer et al., 2016a) that were defined by the EuropaBON project (Junker et al., 2023; Kissling et al., 2024a). This network would be responsible for: 1) collecting, 2) integrating and harmonizing data that can be used to 3) model the EBVs at an EU scale and 4) co-ordinating the running of the network and its engagement with external actors.

Based on a series of workshops, we identified protocols for data collection for each EBV and used existing literature and discussions with relevant researchers to identify the material and staff requirements of these protocols and their associated workflows, or suitable proxies where this was not possible. For many EBVs, these costs are poorly recorded and many current monitoring efforts lack the funds to invest in or maintain more effective tools and methods (Breeze et al., 2023).

Once methods were established, EBVs were grouped into 18 Sampling Networks that share different methodological or taxonomic focuses. We then estimated costs using data on local salaries gathered from statistical agencies and from a survey of partners involved in the EU Pollinator Monitoring Scheme pilot project SPRING. Material costs for data collection and workflow materials (e.g. computing time and data storage), were estimated using commercial sources and fuel costs were taken from the salary cost survey. We also factored in other "hidden" costs such as workflow maintenance, travel to and from sites, administration and site selection through general assumptions. The full details of these costs are outlined in Kissling et al (2024a – EuropaBON Deliverable 4.3.) but are surmised in Figure 1.

Site numbers: A major factor affecting costs is the number of sites involved. Ideally, this should be determined by use of power analyses, statistical models which estimate the number of sites which should be sampled to capture a proportionate scale of change in a particular population variable (e.g. Potts et al., 2021). However, we were not able to identify any suitable EU scale power analyses for any of the EBVs in the proposed network. As such, we use generalised site numbers, following the rationale of the Land Use/Cover Area frame Statistical Survey (LUCAS) network – here total EU land area is divided into 2km2 cells and 40% of these (~400,000) are surveyed (Zachariadis, 2018). We apply this same principle to terrestrial and cross-realm site networks. For freshwater systems, we use the number of rivers and lakes in the European catchments and rivers network system (Ecrins, 2012). For Marine systems, we use the total Exclusive Economic Zone for mainland EU member states and the overseas territories of the Canary Islands, Madeira, and the Azores as the basis for a 10 km2 grid network.

From these areas, we derived two scales (lower and higher site numbers to bound our cost estimates: 2,000-20,000 lakes (~3%-~28% of ECRINS lakes), 10,000-100,000 rivers (~1%-~7% of ECRINS rivers), 550-5,500 marine sites (1%-10% of 10km2 EEZ cells) 10,000-100,000 terrestrial or mainland (terrestrial and freshwater) sites (~1%-10% of LUCAS terrestrial grid points), or 1 site per 500km2 or 50km2 of a country for certain technologies used to validate spatial models. Within the 18 sampling networks, we assumed that all data collection methods for each network are applied to every site in order to increase cost-effectiveness (Breeze et al., 2023) and eliminate redundancies in data collection for different EBVs which could draw on the same data.

Lacking precise information on the proportion of data collection that can be covered by existing networks, we assumed that new and existing data collection is required for EBVs already monitored. As such, we assume that 50% of data collection for EBVs focusing on birds and 25% for EBVs focusing on priority insects such as butterflies, dragonflies and pollinators is by volunteers, although these are likely to be very conservative. A citizen scientist is assumed to monitor one site only.

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European Biodiversity Observation Co-ordination Centre: In addition to the monitoring activities of member states, we also estimate the costs of biodiversity monitoring integration through the European Biodiversity Observation Co-ordination Centre (EBOCC), both through the EBOCC itself and through the activities of member states that would be necessary to integrate member state and EBOCC efforts (Liquete et al., 2024 – EuropaBON Deliverable 2.3.).

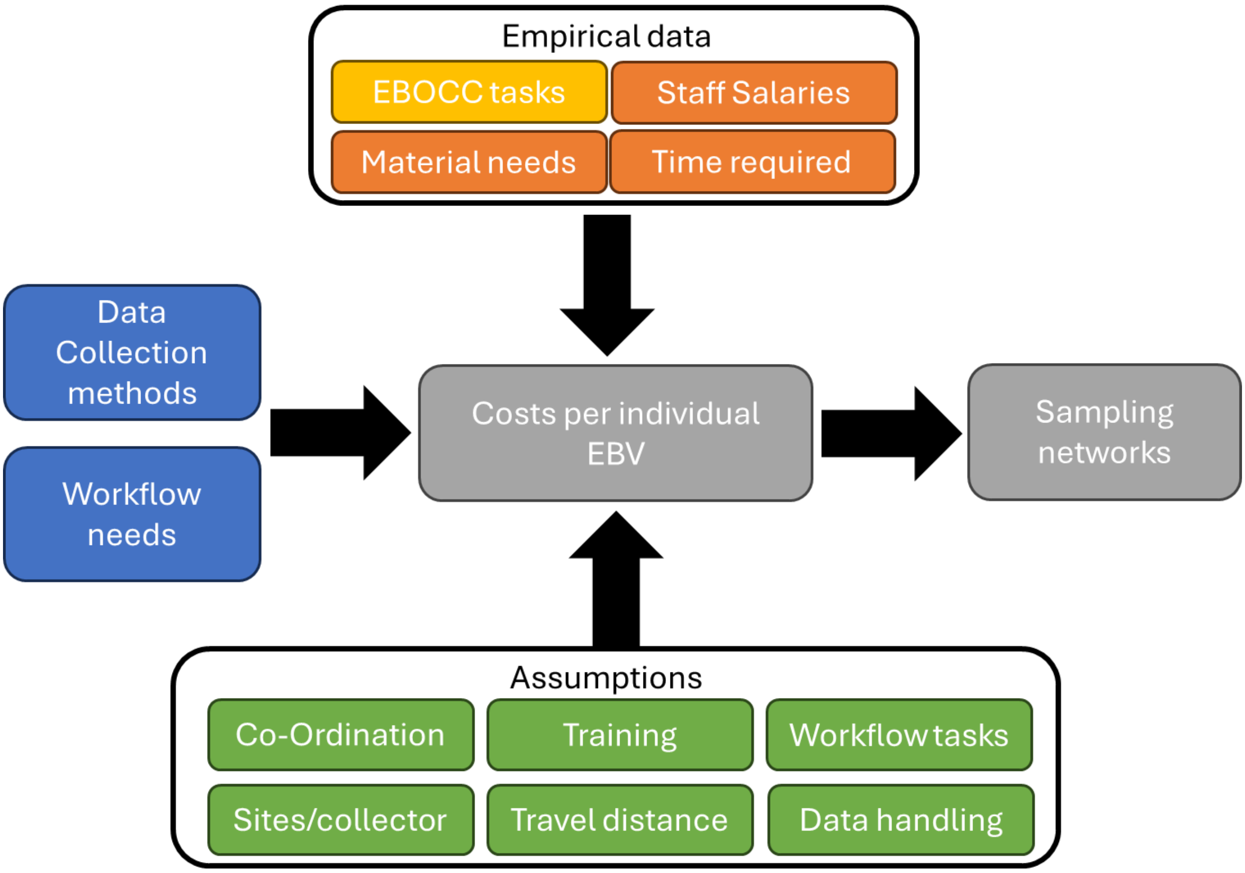

Figure 1: Process for estimating the costs of biodiversity monitoring in Europe.

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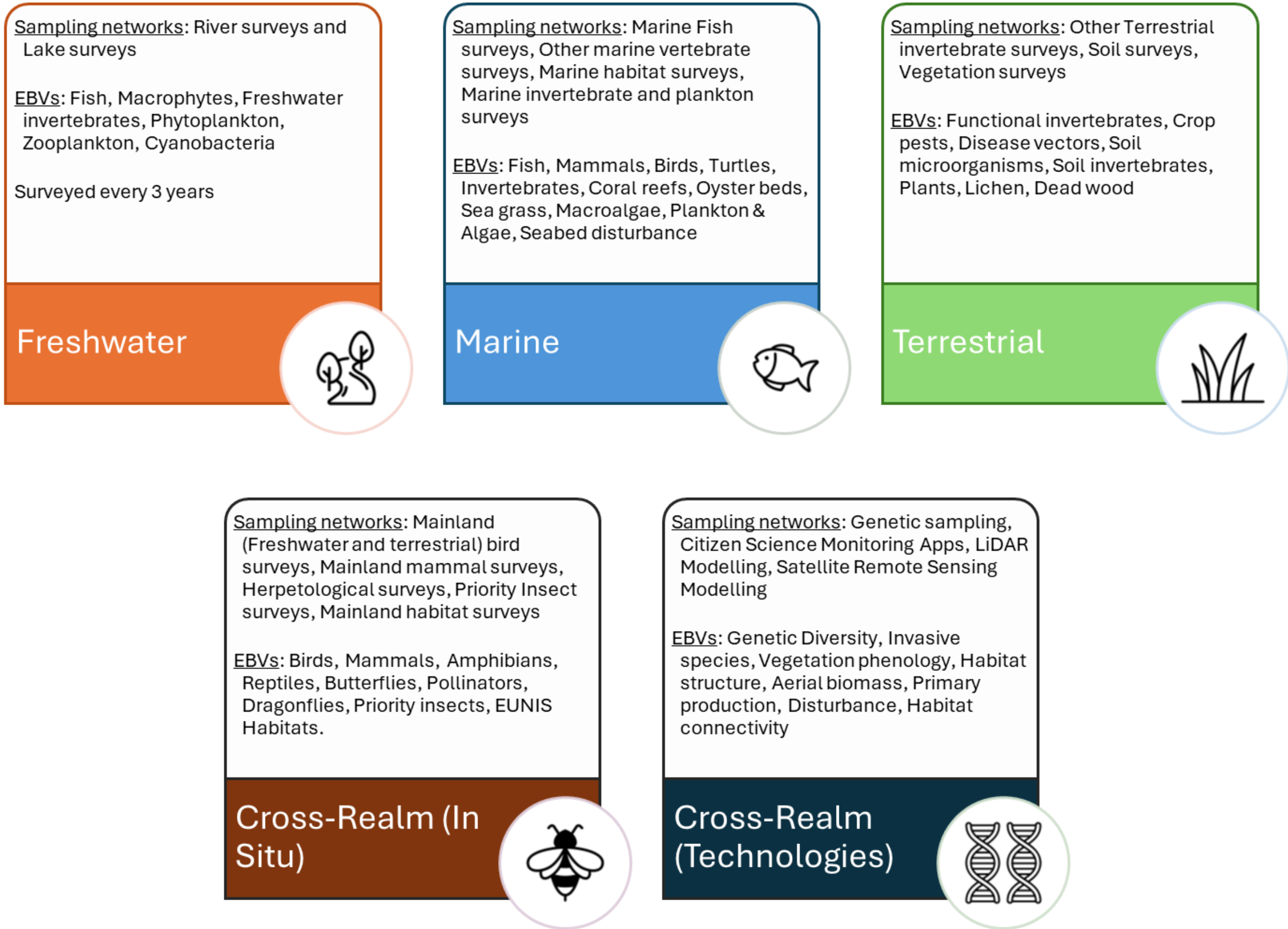

Figure 2: Overview of Sampling networks and their EBVs by Realm

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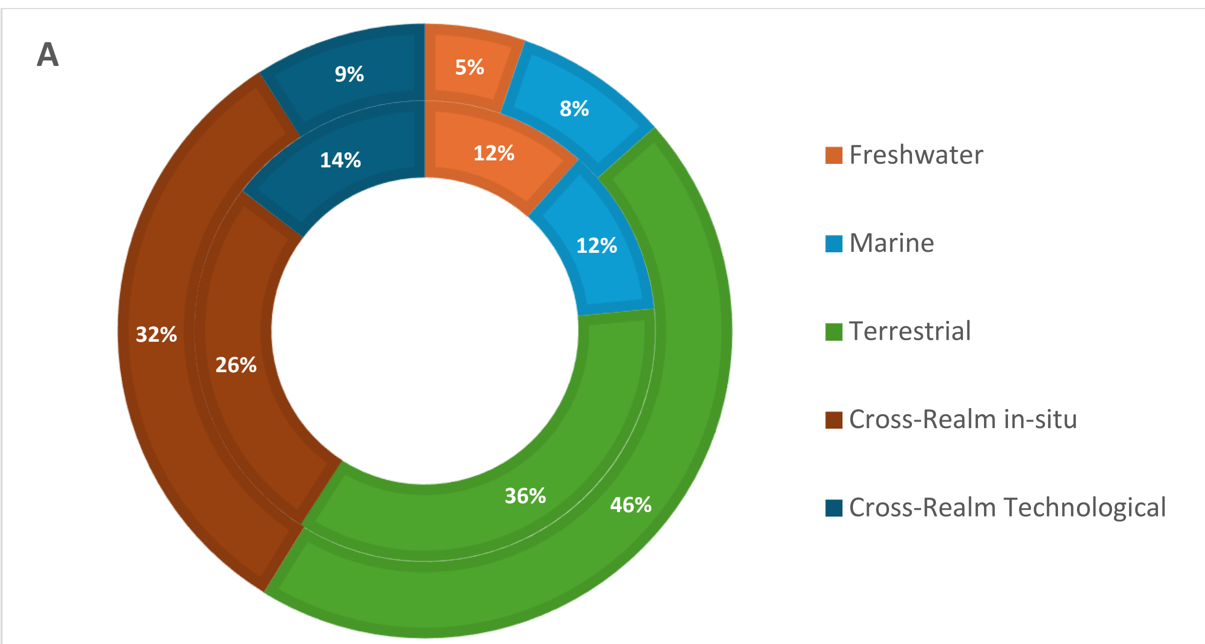
Disclaimer: These costs do not necessarily cover all of the costs of monitoring as an EBV may require specific costs in certain countries (e.g. site rent) and there may be further costs associated with publishing scientific outputs (article fees) and employee licensing (e.g. insurance) that we are not able to fully capture.

Furthermore, the number of sites used is a generalised proxy and may over- or under-estimate the total number of sampling points required for certain EBVs, particularly those for rare and threatened species. Power analyses for each EBV should be conducted to determine total site numbers at a member state level.

2.2. Costs of the proposed Monitoring Network

In total, monitoring all 84 EBVs using a well co-ordinated and co-located sampling design would cost €5.7bn-€39.6bn over 10 years. The costs are higher than the estimates of costs (€7M-€433M) for farmland biodiversity indicators in Geijzendorffer et al. (2016b), but cover a far broader suite of species, habitats and systems, do not include time-consuming farmer surveys and centralise the data analysis effort. The costs for this total network are equivalent to 40%-264% of the seven-year budget (€14.8bn) of the Copernicus Programme (EC, 2021a); 5-34% of the overall seven-year NextGenerationEU budget to support Biodiversity, which combines spending from across Common Agricultural Policy, Horizon Europe, European Space Agency and other initiatives (EC, 2023a); and 3-20% of the target €20bn/year spent on biodiversity in the EU Biodiversity strategy (EC, 2021b).

In total, ~10% (€529M-€2.8bn) of the costs of monitoring are initial up-front costs for equipment, training and workflow set ups. Once established the costs of running the network will be €464M-€3.6bn/year. The greatest expenses projected are from the very intensive field data collection required for many terrestrial and cross-realm EBVs. The costs of Marine and Freshwater monitoring are mitigated by their lower number of sites (Marine) and low frequency of sampling (Freshwater), but they are generally more expensive on a per-site basis.



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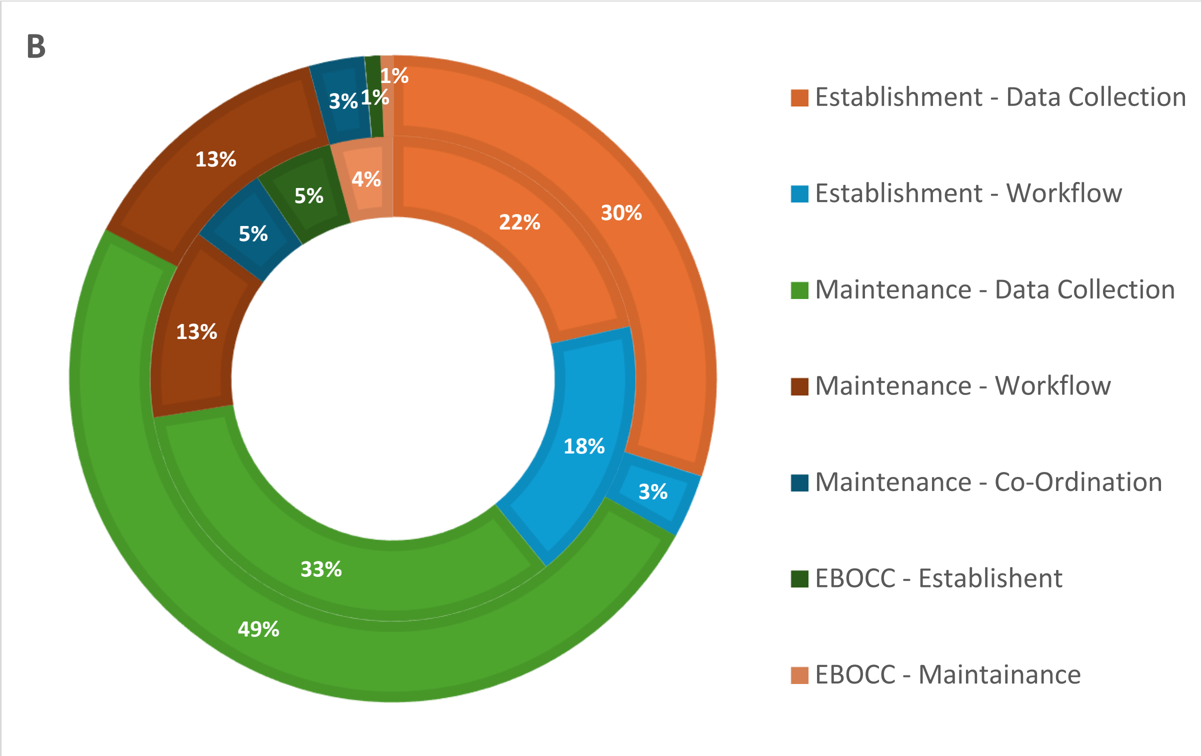

Figure 3 – Overview of the different costs of biodiversity monitoring A) by realm, and B) by stage. Inner rings relate to lower site numbers, outer rings relate to higher site numbers.

The most expensive sampling networks are those concerning mammals and invertebrates. Currently, there is no structured, EU-wide scheme to monitor mammals, although there is some co-ordination through initiatives such as Eurobats, some member states have large, active monitoring networks that build on citizen science, and projects such as EnetWild have developed effective protocols (EOW, 2023). Invertebrate monitoring is largely focused on butterflies, although there is a significant effort to expand pollinator monitoring across member states (Potts et al., 2021). Besides these priority insects, other invertebrates have very little active monitoring, even among member states. Current protocols largely focus on large networks of malaise and other lethal trapping methods.

The costs of the European Biodiversity Observation Coordination Centre (EBOCC) do not vary by site numbers and remain consistent at €610M[1] over 10 years for all 84 EBVs in total. EBOCC would represent a significant investment in biodiversity infrastructure. Presently, spending on biodiversity-related infrastructure is relatively limited and only five (Lifewatch ERIC, ESMO ERIC, AnaEE, EMBRC ERIC, MIRRI) of the 41 current EU infrastructure landmarks support biodiversity data collection, accounting for only ~2.2% (€493M) of the total expenditure on infrastructure landmarks (€21.9bn) between 2006 and 2021 (ESFRI, 2021).

2.3. Methods to increase cost efficiency

[1] Note that this is higher than the figure presented in Liquete et al (2024) because of the greater number of EBVs and activities in this report.

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The estimated costs for the proposed EuropaBON network are based on existing data collection protocols and methods but a number of factors could increase the cost-efficiency of the network, either by reducing costs overall or by generating more data for the same costs.

Novel technologies: Data collection is the main driver of costs for most of our sample network estimates. A number of novel technologies have the potential to greatly reduce the costs of data generation, either by reducing the time requirements for species detection (e.g. identifying marine fish from eDNA – Fu et al., 2021), identification (e.g. DNA metabarcoding to identify insect species - Buchner et al., 2023), or by reducing the need for in-situ visitation (e.g. automated camera traps - Kissling et al., 2024b). Of the different methods in the cost analysis, methods which make the greatest use of novel technologies (Satellite remote sensing and LiDAR) tended to be the lowest cost per year overall, despite a more significant upfront investment in time and materials to establish models and workflows.

However, this initial investment, and hiring the specialist staff to support it can be hindered by low and unstable budgets (Breeze et al., 2023). Furthermore, there will often need to be significant initial data collection to support the development of these technologies at a member state level – e.g. generating DNA or sound databases – which will require the participation of specialists. Similarly, if some member states adopt the technology but not all, significant investment in harmonization and/or interoperability may be required (Snowden et al., 2019; Kissling et al., 2024a). Thus, the true upfront costs of these technologies should be considered at an EU level as part of central co-ordination.

Citizen Science: Staff costs were the most significant expense in most countries and could be greatly reduced through voluntary data collection by citizen science (e.g. Estes-Zumpf et al., 2018; Targetti et al., 2016). Our previous research has estimated the value of volunteer efforts for just 21 monitoring efforts at over €10M (Breeze et al., 2023). This is likely to be a small fraction of the total costs as nearly 80,000 citizen scientists contribute to annual data collection for the Habitats and Birds Directives alone (EEA, 2020) and many thousands more participate in wider monitoring activities through organizations (Juffe-Bignoli et al., 2016). In our cost estimations, we assume most monitoring efforts are undertaken by professionals, but citizen scientists have been effectively involved in a wide variety of monitoring, including mammals, amphibians and reptiles but also less accessible types of biodiversity such as river barriers (AMBER, 2023), marine fish (Fairclough et al., 2014), and standing and lying deadwood (TVC, 2019). Although these citizen scientists will require a greater long-term investment quality control (Fraisl et al., 2022) and co-ordination to maintain engagement (Mason and Ahri, 2019; Breeze et al., 2023), the costs are likely to be much lower than the benefits of additional labour from citizen scientists. Mobile apps built around a common architecture would further increase accessibility at, according to our cost analysis, a relatively low cost while also enhancing engagement more broadly.

Co-location: The site networks used in the cost calculation are co-located in the sense that all methods are undertaken at all sites within that network. However, these networks are quite simple and based on common methods and taxa – in reality it may be possible and practical to further overlap data collection such as collecting vegetation surveys at sites where mammal and invertebrate surveys also take place. Doing so would not only reduce the costs of fuel and consumables but would allow teams of recorders to support and learn from one another. Previous analysis by EuropaBON indicates that monitoring organizations that collect data for multiple taxa are among the most cost-efficient in terms of data generated (Breeze et al., 2023). The value of co-location is especially promising for digital sensors where site visits are short and focused on device maintenance, meaning that once set up, multiple real time data could be collected for minimal (Kissling et al., 2024b; Williams et al., 2018).

3. Benefits of biodiversity monitoring

Studies into the benefits of biodiversity monitoring in itself are very rare and typically focus on the benefits to ecosystem services and as a research tool. Drawing on the discussions and workshops, we identified a series of environmental, social, and economic benefits from biodiversity monitoring and how they relate to current and upcoming EU Policy. For each, we reviewed available EU academic and grey literature from after 2008 and provide a summary of available quantitative and qualitative evidence of these benefits and monetary estimates of their value.

3.1. Protecting natural capital

The loss of natural capital that benefits society and the economy has been a major argument for biodiversity conservation for nearly 30 years (Costanza et al., 1997; IPBES, 2019) and global biodiversity loss is thought to be pushing many ecosystem services to tipping points (Chaplin-Kramer et al., 2019), but the extent and likelihood of these risks remains largely unknown (IPBES, 2022). Natural Capital accounting frameworks, such as the UN SEEA (UN SEEA, 2022) and Eurostat's Integrated Natural Capital Accounts (INCA) programme (Vysna et al., 2021), attempt to bring ecosystem services into national accounts for decision making. However, such systems are often very simplified and use unvalidated models that may neglect the diversity of systems supporting these services. For example, the same crop pest may have multiple predators across different systems, each of which may be vulnerable to different pressures (Haan et al., 2019). As such, we cannot be sure how effectively Natural Capital Accounts predict the real trends in services or the impacts of restoration measures.

Although natural capital is preserved and restored through conservation activities, biodiversity monitoring can play a key role in bridging the gaps between accounting and practice:

1) **Short-term (1-3 years)**: In the initial years of any scheme, monitoring will generate useful baseline data for ecosystem service provision, allowing us to identify areas that may already be suffering deficits in supply relative to demand.
2) **Medium-term (3-6 years)**: By generating diverse, high-quality data, the proposed network will augment and validate existing spatially explicit natural capital models (INCA, 2024) to better estimate trends and target preventative and restorative measures most effectively.
3) **Long-term (>6 years)**: Long-term primary data is extremely valuable for identifying the drivers of change in functional biodiversity, allowing for management designed to reduce the risks of ecosystem service collapse.

Many of the proposed EuropaBON EBVs relate to such functionally important biodiversity data, such as pollination, recreation and water quality. Unlike conservation actions, monitoring does not fundamentally alter the stocks of natural capital or the flows of benefits and is instead valuable through the information it provides. As such, we explore the ecosystem services associated with the EuropaBON EBVs and provide an overview of the quantitative and qualitative benefits they provide and assume that a portion of the value potentially lost will be attributable to the data deficiencies in the absence of monitoring.

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Value of Natural Capital protected: To quantify the potential benefits from biodiversity monitoring, we linked EBVs to different aspects of natural capital and compiled relevant EU-wide estimates of the value of the benefits from ecosystem services that flow from them (Table 1). It is likely that there would be some delay between monitoring commencing and effective action being implemented. Additional details for the valuation methods are presented in Appendix A.

Table 1: EU-Wide Economic Valuations of Natural Capital

Ecosystem Service	Value/year (2023 €)	Source	EBVs
Freshwater			
Recreational angling (freshwater)	€3.14bn	Arlinghaus et al (2021); Carlén et al., (2021)	SP_dis_fish_FW; CC_com_fish_FW; ST_phe_fish_FW
Water purification	€74.44bn	Vysna et al., (2021)	SP_dis_inve_FW; SP_dis_mphy_FW CC_com_ppla_FW; CC_com_mphy_FW CC_com_pben_FW
Marine			
Fish and seafood[2]	€3.94bn	Prellezo et al (2022)	SP_dis_fish_MA; SP_abn_fish_MA; SP_dis_inve_MA; CC_abn_inve_MA; ES_dis_oyst_MA
Nature based recreation	€31.11bn	Czajkowski et al (2015 – extrapolated)	SP_dis_fish_MA; SP_abn_fish_MA; ES_dis_cora_MA; ES_dis_malg_MA
Carbon Sequestration (Marine)	€14.41bn	Alarcon Blazquez et al., (2023 - extrapolated)	SP_dis_bird_MA; SP_abn_bird_MA; SP_dis_mamm_MA; SP_dis_rept_MA; CC_com_micr_MA; ES_dis_cora_MA; ES_dis_malg_MA; ES_dis_plan_MA; EF_pro_habi_MA
Terrestrial			
Habitat and species maintenance	€36.51bn	La Notte et al. (2021)	ES_dis_habi_FW; ES_dis_habi_TER
Crop pollination	€5.88bn	Vysna et al., (2021)	SP_dis_inve_TER; CC_abn_inse_TER
Carbon sequestration (terrestrial)	€15.96bn	Vysna et al., (2021)	SP_dis_plan_TER; ES_dis_habi_TER
Soil Retention (from water-borne losses, cropland only)	€9.96bn	La Notte et al. (2021)	SP_dis_plan_TER; ES_dis_habi_TER; CC_bio_micr_TER; CC_com_micr_TER
Cross-Realm			
Flood Control	€21.68bn	Vysna et al., (2021)	ES_con_habi_FW; ES_dis_habi_TER
Wild Game	€0.57bn	Schulp et al (2014)	SP_abn_bird_FW; SP_abn_bird_TER; SP_abn_mamm_TER
Nature Based recreation (non-marine)	€96.55bn	Vysna et al., (2021)	SP_abn_bird_FW; SP_dis_inse_FW; ES_dis_habi_FW; SP_dis_bird_TER; SP_abn_bird_TER; SP_abn_mamm_TER; SP_abn_inse_TER; SP_dis_mamm_TER; ES_con_habi_TER; ES_dis_habi_TER

[2] This covers both fish and shellfish (benthic invertebrates).

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Total: €314bn/year

If the information generated by the EuropaBON network is able to increase the maintenance of natural capital value by 5% per year, the total benefits would be **~€15.7bn/year**.

While we have used the best available EU scale data to estimate benefits, for many taxa within the proposed EuropaBON network, no economic valuation exists, such as for amphibians and reptiles (Hocking and Babbit, 2013; Valencia-Aguilar et al., 2013) or freshwater invertebrates (Macadam and Stockan, 2015; Vaughn, 2018). As such, not only are our conservative estimates likely to be substantially lower than the true value of these ecosystem services, but they underline that, despite two decades of economic valuation, much of Europe's biodiversity remains outside of economic valuation.

Non-Economic Values: Although economic assessments of natural capital are useful to contrast with the costs of monitoring, they are only one aspect of human values of biodiversity (IPBES, 2022). Many of the EuropaBON EBVs represent aspects of biodiversity that have been demonstrated to have positive impacts on these other values. In particular, access to nature (Engermann et al., 2019), nature-based activities (e.g. Angling – Wheeler et al., 2020) and species diversity of plants and birds have been demonstrated to have significant positive effects on mental health (Methorst et al., 2021) and aesthetic values (Lindemann-Matthies et al., 2010). Not only would the proposed EuropaBON EBVs support the preservation and management of these benefits, but they can also play a critical role in understanding these links. For example, Methorst et al. (2021) used monitoring data on species richness of birds and plants with mental health across Germany at a NUTS3 scale.

3.2. Reducing the risks of environmental hazards

In addition to the direct benefits of ecosystem services, many EBVs are indicators of wider environmental hazards and disbenefits. For example, the costs of controlling a growing number of biological invasions by alien species, which may be a threat to ecological or human health, are often in the billions of Euros and can rise considerably if detection is late (Soto et al., 2022). Many of these hazards are likely to become more frequent and severe due to climate change (Deutsch et al., 2021; Voyiatzaki et al., 2021; IPBES, 2023). By providing real-time information and a stronger basis of hazard modelling, biodiversity monitoring can better capture the occurrence (e.g. harmful marine algal blooms; Hallegraeff et al., 2021), risk factors (e.g. European Alien Species Information Network (EASIN); Polce et al., 2023) and impacts (EASIN - Magliozzi et al., 2023) of these factors, and allow member states to respond more flexibly and reactively to these hazards, minimising impacts.

There is a relatively EU scale estimation of the monetary impacts of biodiversity-related hazards, although many are widely acknowledged. We linked each of the EuropaBON EBVs with a series of key environmental hazards and reviewed the literature to determine the economic costs of these hazards. In total, these hazards were estimated to cost Europe €145bn/year (Table 2). If effective monitoring is capable of reducing these costs by 5%, this would equate to **€7.3bn**/year. These values do not represent the only measures of impact that these hazards can have, for example through reduced years of good health caused by chronic illness transmitted by ticks (van den Wijngaard et al., 2015).

Table 2 – Total costs of biodiversity related hazards relevant to EuropaBON EBVs.

Environmental Hazard	Value (per year)	Source	EBVs
Invasive Alien Species	€139.2bn (projected)	Haubrock et al., 2021	SP_dis_alie_FW; SP_dis_alie_MA; SP_dis_alie_TER
Harmful algal Blooms (Freshwater)	€0.87bn	See Appendix B	EF_phe_ppla_FW
Harmful Algal Blooms (Marine)	€1.1bn	Hoagland & Scatasta (2006)	EF_phe_habi_MA
Crop and forest damage by mammals	€0.11bn	Apollonio et al., 2010	SP_abn_mamm_TER; SP_dis_mamm_TER
Crop damage by Aphids	€3.17bn	Deutsch et al., 2021	SP_abn_pest_TER
Tick-Borne Diseases (direct costs)	€0.77bn	See Appendix B	SP_abn_dise_TER
Total: €145bn/year			

3.3. Benefits to European Research

Value of time saved: Although there has been a significant effort to increase the availability and re-use of data collected in European projects, researchers still face challenges in finding suitable data to assemble long-term and harmonized datasets. By making data available through targeted support to existing monitoring organizations, significant time can be saved for collecting and harmonizing data by researchers. For example, Durance et al. (2016) give an economic value of £8M/year for freshwater datasets in the UK in 2014, representing the costs saved in generating this dataset over 20 years. Similarly, Kuyer et al. (2021) estimate that the benefits of the UKs Marine Environmental Data and Information Network at €6M/year through time saved and simplified data management.

On an international scale, a survey of users of the Global Biodiversity Information Facility (GBIF) indicates that making data freely available and saving time in finding data saved users an estimated €48M/year (Deloitte, 2023). The number of citations of GBIF data has increased by an average of 31% per year between 2018-2023 (GBIF, 2024) – assuming that the value of time saved because of open data increases cumulatively by this amount annually, representing time saved from new users as well as the compounding value of time saved by existing users, over 10 years this would amount to a total value of €895M (average **€89.5M**/year).

However, there are still challenges for researchers using the GBIF platform due to taxonomic inconsistencies, incomplete datasets and issues with transparency around some data collection methods (Pfeiffenberger and Uhlir, 2020). Addressing these challenges after submission is a complex and demanding issue that will require a significant investment in time and resources (Zizka et al., 2020). As such, if harmonized, spatially explicit and European wide data used for EBV modelling were to be deposited on a regular basis, the use and value of GBIF (and other repositories such as the Ocean Biodiversity Information System (OBIS) would likely increase further still (Hochkirch et al., 2023).

Efficient use of research funding: In addition to the immediate value of time saved, a unified biodiversity monitoring effort centred on EBOCC could provide an invaluable data source for future research

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projects, saving researchers time in data collection, allowing for more data to be used in analysis than would be practical in standard research projects, and research funders on the costs of funding multiple projects. In particular, Breeze et al (2021) demonstrate that the costs of a UK-wide pollinator monitoring network were less than half the costs of undertaking separate research projects to address eight stakeholder-selected research questions.

To explore the potential costs saved for EU research funding, we estimate the equivalent costs of the network using standard Horizon projects to gather and generate the data required. Using the CORDIS database, we identified 98 Horizon 2020 and Horizon Europe projects on biodiversity monitoring, with a total value of €972M between 2015-2023. Taking a median cost per project[3] of €6.92M and a median duration of 4 years, this gives an effective total 10-year cost of €17.3M/project. However, many of these projects do not include significant data collection (e.g. projects that focus on expanding the uptake of Nature Based Solutions) and most of those projects that do are focused on testing specific research questions rather than collecting data for monitoring. Finally, the projects have a median of 21 partners from approximately 14 countries per project, meaning they will not have complete spatial coverage and, although we do not have information on site numbers, even those projects that do undertake data collection (e.g. Safeguarding European Pollinators), do not have the relative level of site replication assumed by the network we have estimated costs for.

Assuming only 50% of these costs are focused on biodiversity data collection and modelling, that at least twice the costs will be required for complete coverage of all member states and that costs must then be doubled again to ensure sufficient site numbers, this is equivalent to €138.3M/project, or €13.5bn over 10 years (**€1.35bn/year**).

3.4. Benefits to Business and Sustainable Finance

Supporting biodiversity reporting: The EU is seeing to increase private investment in biodiversity towards its target of €20bn/year invested in biodiversity (EC, 2021b). However, the true costs of restoration may be much higher, at ~€48bn/year (Nesbit et al., 2022). This will require a substantial acceleration in private investment to secure functional biodiversity in particular.

Business engagement with biodiversity has grown significantly in recent years following the Convention on Biological Diversity's Global Biodiversity Framework (CBD, 2022), which has raised awareness of the risks that business faces from biodiversity loss (de Carvalho et al., 2023), and the EU's Corporate Sustainability Reporting Directive (CSRD - EC, 2022a), which requires businesses to report on their targets towards and impacts on biodiversity. At the same time, the EU is seeking to increase private funding for biodiversity conservation measures as part of the 2030 Biodiversity Strategy (EC, 2021a), Sustainable Finance Disclosure Regulation (EC, 2019a) and EU Green Deal (EC, 2019b). Collectively, these actions have given rise to a growing number of biodiversity strategies (zu Ermgassen et al., 2022) and biodiversity based financial instruments (e.g. loans, green bonds, credits and trading schemes - IFC, 2023), both as new schemes (Waterford et al., 2023) and extensions to existing carbon trading schemes (You and Delerce, 2023). However, significant gaps in expertise and data are major bottlenecks to the

[3] We use a median cost as due to the high cost associated with the Biodiversa+ and EJP SOIL which greatly increases the average

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adoption of effective biodiversity strategies and financial instruments (zu Ermgassen et al., 2022; World Economic Forum, 2023a).

Both reporting under the CSRD and different green financial instruments will require robust baseline metrics and monitoring to measure their outcomes (Kedward et al., 2023). Such monitoring is unlikely to be directly compatible with scientifically robust cross-continental site networks such as those proposed by EuropaBON (Lindenmayer et al., 2023) and will have to be developed especially for those instruments. To date, monitoring measures are not publicly stated by more than half of available biodiversity credit schemes (Waterford et al., 2023), and many green loans have weak targets that do not add value to biodiversity (Kedward et al., 2023).

Although the EU is developing guidelines for monitoring biodiversity credits in certain sectors (e.g. forestry - EC, 2023b), by forming a critical mass of expertise across realms, taxa and member states, the proposed EuropaBON network, supported by member-state and EU level co-ordination (EBOCC) would be able to support these instruments in a number of ways:

- **Providing baseline data and models for setting targets**: This will significantly reduce the costs for the upfront development of these targets.
- **Developing protocols and advice for monitoring**: As an independent and open-source provider of this advice, the proposed network can improve confidence in corporate reporting and the effectiveness of green financial instruments.
- **Acting as a data repository and validation actor**: This will facilitate transparency by allowing data collected by corporations and schemes to be scrutinised and compared with independent data from the wider network.
- **Supporting connections with local experts**: This will enable accessibility, especially for small and medium enterprises that would not have the resources to engage with higher cost restoration activities and may benefit from connections with more local organizations (EEA, 2022).

Economic impacts of increased participation: The monetary benefits of business support are difficult to estimate. However, The World Economic Forum (2023b) explore three scenarios for one instrument - biodiversity credits. 1) Limited development, where only companies that have targets in 2023 have any participation in the market; 2) Effective development, where clear and credible guidelines support a more widespread adoption of biodiversity credits among large companies; and 3) Transformational development, where the Global Biodiversity Framework guidelines are implemented by almost all large companies. These scenarios result in market caps of €0.9bn, €1.8bn and €6.5bn by 2030 and €5.5bn, €64bn and €165bn by 2050, respectively.

If the network is able to support an increase in participation from the limited development scenario to the effective development scenario worth ~1% of the total change in value (€0.9bn and €58.5bn), this would equate to an initial increase in biodiversity investment of **€9M**/year up to 2030, rising substantially to **~€0.6bn**/year by 2050.

Improving environmental impact assessments: Although much attention has been paid to engaging the wide private sector with biodiversity, primary landowners typically bear much of the regulatory burden. For these actors, environmental impact assessments (EIAs) are often mandatory, particularly for large infrastructure projects such as wind and solar farms, housing development and high-speed railways (Lantieri et al., 2017). Delays in construction can lead to significant cost overruns (Molinari et al., 2021) of overall projects, although Environmental factors are not usually a major driver of these delays (Adam et al., 2017). EIAs can be very costly for projects, particularly where there is no easily accessible baseline data (Underwood et al., 2018), or where impact assessment criteria are not harmonized between member states (Manfra et al., 2020), often forcing them to rely on unvalidated modelling approaches to estimate the long-term impacts of monitoring. This can ultimately lead to erroneous conclusions about the impacts of the project (Horswill et al. 2022; Croll et al. 2022) and potentially risk reputation damage for the project (Church et al., 2022).

Similar to other aspects of business engagement with biodiversity, environmental impact assessments will benefit from robust and harmonized baseline data and, potentially, to properly validated models that can give an indication of the baseline state (Underwood et al., 2018; Lantieri et al., 2017). Not only will this potentially reduce the need for long or in-depth ecological surveys of the site, but it will also improve the effectiveness of EIAs in minimising harm. A review by Hatton et al (2020) in Australia indicated that if a project was deemed to not need a full environmental impact assessment because of available digital data, it could reduce data finding time by up to 1 year, saving ~AUS$1m/project and reduce construction time by 6-18 months, saving ~ AUS$18-$54 million/project. Furthermore, by simplifying compliance across multiple projects, this process could potentially save state regulators up to AUS$100m. Routine publication of survey data from EIAs through platforms such as GBIF will further reduce future costs, as well as improving the transparency and robustness of the assessments themselves.

4. Opportunities from a co-ordinated approach to biodiversity monitoring

Beyond the immediate benefits that effective biodiversity conservation can have on society, a biodiversity monitoring network also creates several other opportunities to meet EU and Member-State strategic priorities.

4.1. Knowledge exchange

Wider biodiversity monitoring has the potential to foster knowledge exchange activities and platforms at a local and EU scale (via EBOCC). Within the biodiversity monitoring sphere, this would allow organizations to exchange advise and effective practices on issues such as volunteer or business engagement, sampling design or data use. This is especially important for newer, citizen science led monitoring efforts that need to connect with older, better established data collection (eBMS, 2024 pers comm). More broadly, a sustained EU-scale biodiversity monitoring network can provide knowledge exchange to protected area managers to address challenges and adapt to new methods and data (Lundmark et al., 2019).

4.2. Capacity Building

Creating investment in rural communities: The proposed EuropaBON network would require the equivalent of 3,900-38,150 full-time jobs for professional data collection staff alone. Although positions will need to be based in institutions that already have sufficient supporting resources, they will also have to be dispersed throughout member states, and not concentrated in affluent areas, as current monitoring efforts tend to (Hobbs and White, 2012). As such, this creates an opportunity for developing

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high-skill employment in lower income and rural areas, adding value to targeted investment in infrastructure.

Generating key skills: Throughout Europe, biodiversity monitoring is struggling from declining ecological expertise, particularly among taxonomists (e.g. Hochkirch et al., 2022). Such skill shortages are a major barrier to private sector investment in biodiversity conservation more broadly (zu Ermgassen et al., 2022). An effective, co-ordinated biodiversity monitoring network will require significant development of these skills across all member states, including filling many key gaps in taxonomic expertise.

Support for Applicant member states: As EU biodiversity regulations become more comprehensive, they will present a greater barrier for harmonization with applicant member states (currently, 8 countries have candidate status). Between 2021-2027, the EU has already agreed a budget of over €14bn to support candidate states in aligning their laws and regulations with the EU (EC, 2022d), including €568M[4] for supporting biodiversity mainstreaming and policy alignment. The proposed monitoring network may significantly benefit these aspirant member states by providing ready access to standards, expertise, and knowledge exchange to support the expanded monitoring requirements. This is especially important in the western Balkan states, which have been identified as a European biodiversity hotspot and where monitoring efforts are already limited by funding and political pressures (Breeze et al., 2023).

4.3. Tool and model development

Facilitating technological development: Innovations in data science have led to significant growth in big data technologies such as machine learning and artificial intelligence. These technologies have a projected market cap of €443bn in 2024 (Economist Impacts, 2022) and are expected to grow further in the coming decade. Machine learning, in particular, requires significant baseline data with consistent metadata tags to develop and train. This can be achieved through data scraping from multiple sources, but this has proven controversial from a data protection perspective (Sharma et al., 2020). Through generating a repository of open access, annotated data, a European Biodiversity Observation Network could save businesses looking to develop machine learning models a significant amount of time in collecting appropriate data. For example, training an AI model to recognise a mammal species will require between 2,000 and 10,000 images which must each be labelled manually (Kissling et al 2024b). There can also be considerable amounts of unsuitable data in an un-curated dataset, requiring significant researcher effort to filter these out (Kissling et al., 2024b; Stowell et al., 2018). These costs are all in addition to primary data collection costs which may require multiple years of effort. A repository of tagged images, collected according to known protocols and spatial distribution can, therefore, considerably reduce these costs and allow developers to focus on model development and user accessibility.

Improving models of natural capital and nature-based solutions: Existing EU Natural Capital models are limited to a few well studied taxa and often have little or geographically limited validation (INCA, 2024). This limits both the information on natural capital we are able to utilize, and the capacity of these models to identify where and why deficits in natural capital occur. Consequently, our ability to deploy and evaluate "nature-based solutions" to restore degraded natural capital, build resilience or alter landscapes to allow supply to meet demands (Bulkeley, 2020). Long-term, spatially diverse data

[4] Figure as of 01/05/24 https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/programme-performance-statements/instrument-pre-accession-assistance-ipa-iii-performance_en

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generated by EU-scale biodiversity monitoring creates an opportunity both to develop and validate models of ecological processes which can form the basis of spatial planning tools (e.g. UKCEH's E-planner: https://e-planner.ceh.ac.uk/) or new management advice (e.g. indicators of pollination efficiency - Garibaldi et al., 2020) to undertake high-impact restoration. Such restoration activities and their economic benefits are a key objective of the proposed Nature Restoration Law (EC, 2022b).

Examples of the economic benefits of ecosystem restoration include:

- **Closing crop pollination gaps:** A meta-analysis by Garratt et al., (2021) identified a 16% deficit in apple production due to inadequate pollination across the UK, Germany, Sweden and the Netherlands. Assuming that these results are indicative of a general trend in apple production (total value €4.2bn in 2022) across Europe, this would indicate a total deficit of €600M. If biodiversity monitoring is able to add 5% to the effectiveness of restoration this would add **~€30M/year.** This only represents a single, high pollinator-dependent crop, but this is likely to be indicative of deficits in other high-value pollinator-dependent crops (Garibaldi et al., 2018).
- **Restoring water quality**: Freshwater bodies are highly dependent on biodiversity to process waste and maintain water chemistry at good levels to support ecosystem´s and human needs. An analysis of the costs from inadequate implementation of the Water Framework Directive (COWI and Eunomia, 2019) estimated the total costs of poor ecological status at between €3.2bn and €13bn/year. Taking a median of €8.1bn, if improved biodiversity monitoring and reporting were able to improve this restoration by 5%, this would add **€405M/year** of ecosystem service benefits.
- **Restoring Seagrass habitat**: Seagrass is a key primary producer in marine ecosystems and provides a wide range of ecosystem services (Tyllianakis et al., 2019). A review of the proposed EU Nature Restoration Law indicates that the value of restoring seagrass could be >€900/ha/year (EC, 2022), but that the costs of instigating this restoration may be quite high, meaning a significant long-term investment is needed for benefits to outweigh costs.

4.4. Encouraging Transformative Changes in Business and Society

EU Policy, including the 2030 biodiversity strategy (EC, 2021b), seeks to promote transformative changes in the way we relate to nature – mainstreaming biodiversity and the environment into planning and other everyday decision making. Such transformative change is difficult to achieve with policy alone as a much deeper level of engagement is required (Abson et al., 2017). Expanding biodiversity monitoring and the accessibility of data it provides, offers opportunities for this engagement at several levels.

Promoting societal engagement with biodiversity: Biodiversity monitoring is a significant opportunity for broadening interest in biodiversity and forming a leaver for more transformative societal change. Monitoring schemes with a citizen science component can foster greater public engagement in biodiversity more broadly (e.g. Gustaffson et al., 2017), in turn potentially leading to lasting change in behaviour (e.g. Deguines et al., 2020) and a stronger understanding of biodiversity conservation (Richter et al., 2012), which are already growing in some member states (Burivalova et al., 2018). However, our past research (Breeze et al., 2023) has suggested that there are strong cultural barriers towards engagement in biodiversity monitoring in some southern and eastern European countries. A co-

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ordinated monitoring network where member states are able to freely discuss and share ideas could provide a crucial opportunity to challenge these norms and build greater engagement in countries where expertise is most lacking.

Assessing the effectiveness of wider environmental policy Biodiversity protection is often cited as a driver in introducing new policies, such as the restrictions on neonicotinoid insecticides to protect pollinating insects (Auteri et al., 2017). Although based on robust empirical evidence (e.g. Rundlof et al., 2015), these derivations have proven controversial and it has been difficult to demonstrate their impacts due to a lack of pollinator monitoring (Nicholson et al., 2024). More widespread monitoring would not only allow earlier detection of such pressures but provide suitable baseline assessments to determine how effective they have been at supporting biodiversity.

Making History: Finally, biodiversity monitoring potentially has value as a historical record of the state of the world and the way in which we have engaged with and understood it. Historic data can give information on the baseline state of species or ecosystems in very different circumstances (Grace et al., 2019; Harkonen et al., 2014; Erostate et al., 2022) or the changing ways we engage with and value those ecosystems (Alleyway and Connel, 2015). Monitoring provides us with an opportunity to leave a data legacy for future generations, who may be able to use data in ways we cannot yet understand (as e.g. Gould et al., 2014) and re-examine our relationship with nature as we do so.

5. Risks to the network

Although the benefits of implementing a unified European biodiversity monitoring network are significant, declining political will may force delayed, underfunded and inadequate implementation of effective monitoring. Here, we examine the risks inherent that such under-funding, or maintaining the current status quo may have.

5.1. Delayed implementation

EU biodiversity policy is closely aligned with the Kunming-Montreal Biodiversity Targets and aims to ensure that species show no deterioration in conservation trends by 2030 (EC, 2021b). Although several indicators are under development, if monitoring is not implemented before this target date, it will be difficult to adequately assess the effectiveness of the last 10 years of EU biodiversity policy and spending, beyond a few common taxa. This could also have consequences for later implementation of the network.

Cost increases: If monitoring was implemented in 2030, wage inflation (at 3.75% per year, an average of the last 3 years; Eurostat 2024) will increase the costs of implementing this network by **€38M-€0.25bn** per year. This also risks missing out on several years of ecosystem service and hazard regulation benefits from the network due to the lag in responding to critical declines in functional biodiversity.

Loss of existing partnerships: In addition, delays in support for greater biodiversity monitoring may threaten well established integration efforts such as Euromammals (Urbano et al., 2021), where members have spent several years addressing harmonization and interoperability issues. Should this network cease due to lack of funds, it is likely that many of its activities would have to be repeated as e.g. new standards are not maintained, at a considerable expense. Similarly, the GloBAM project's data

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pipeline to generate models of bird biomass (EBV: CC_bio_bird_TER) is not being actively maintained due to lack of funding (workshop participation).

Obsolescence: A key bottleneck with harmonization in biodiversity monitoring is the regularity with which some member states are able to upgrade their systems. Even if they have access to new standards, lacking the technical support and access to newer software can lead to significant inefficiencies. For example, Bulgaria's National Biodiversity Monitoring System is ~15 years old and does not meet several basic standards and capabilities, such as being able to import or (fully) export data, incompatibility with common metadata standards (e.g. DarwinCore), a public interface, and being very complex, causing substantially more time to be spent on data entry and necessary. Without substantial local funding, there is a very real risk that this system will soon be rendered unusable. A new mobile app (SmartBirds) was tested in 2022 and was several times more efficient as a data entry portal than the exisiting software.

5.2. Staff Retention

Many biodiversity monitoring efforts have insecure and limited funds, resulting in high staff turnover. This can be a serious challenge in maintaining the necessary expertise for many monitoring efforts. Although our cost estimates do include assumptions about employee training every five years, with higher staff turnover this could rise to every three years, adding **€17M-€161M** in training costs alone under our assumptions (see Kissling et al., 2024b, Appendix A for details).

In addition to training, staff turnover can also affect the annual costs of data collection. For example, new insect recorders are likely to catch twice as many individuals for laboratory identification as a more experienced collector, resulting in greater costs for more expensive taxonomic staff, particularly in countries with diverse pollinator fauna (Potts et al., forthcoming). The forthcoming EU Pollinator Monitoring Scheme proposal estimates this initial learning phase would increase costs by up to €1.3M in the first 3 years across ~3500 sites. Upscaling this to the six monitoring networks used for cost estimation which include insect sampling, would increase costs by **€22M-€222M** every 5 years. Including the above costs for retraining staff, this would result in total retraining cost of **€39M-€383M** every 5 years.

Our cost estimations assume staff are working pro-rata (i.e. are paid by the hour), as is typical for a lot of biodiversity monitoring. Using an alternative calculation, where, instead of calculating the total hours and multiplying this by an hourly wage, we round up to the nearest number of full-time equivalent staff, the additional cost would be **€27.5M-€41M** per year.

5.3. Citizen Science engagement

A major challenge for citizen-science oriented monitoring efforts is the continual turnover of volunteers, which can not only increase the training effort required but slow the development of skills within volunteer recorders (Mason & Arathi, 2019). Citizen science engagement also tends to be concentrated in affluent areas (Hobbs and White, 2012) and focuses on areas where species are likely to be observed (Tulloch et al., 2013) and is much lower in eastern and southern European countries (Breeze et al., 2023). For cross-EU efforts, greater involvement of citizen scientists will also require a greater effort to maintain up-to-date translations of key materials. This is further complicated by the need for co-ordinators to be willing to engage with and build mutual trust with their citizen science partners (Grodzińska-Jurczak et al., 2018). As highlighted previously, knowledge exchange between co-ordinators, and from EBOCC, offers a potential solution to this challenge by being able to support new co-ordinators.

5.4. Biodiversity policy

Cross-regional governance: Even where biodiversity data can be harmonized, secondary data collection and regulations can vary substantially between different member states. For example, several member states (e.g. Poland and Germany) have legislation restricting the lethal trapping of invertebrate species, despite its necessity for identification with traditional or genetic methods. This is a particularly important consideration for biodiversity that spans multiple borders, notably marine EBVs but also larger mammals, birds and freshwater bodies. Co-ordination should account for this as much as possible and discuss the nuances of data collection and availability of secondary data sets across the network.

Political will: Changes in government may cause shifts in priorities, which can, in turn, lead to uncertainty about funds for monitoring or, where funds have already been approved, substantial delays in receiving payments. For example, a recent effort to conduct molecular monitoring of bear populations in Bulgaria was eventually cancelled after the collapse of the government in 2022 and the appointment of a new, provisional minister of the environment and waters in 2023 who changed priorities for spending away from biodiversity. Efforts should be made to secure long-term funding and internationally agreed priorities such as EBVs to maintain the stability of data collection through administrative changes.

5.5. Wider policy implementation

Member state policy and planning: Inadequate baseline biodiversity data and a lack of standardised monitoring and reporting make it difficult to evaluate the potential harm done by certain public subsidies (Deutz et al., 2020). New regulations introduced that rely on reducing environmental harm can also have costly and unforeseen issues if the underlying data is not available. For example, in 2019, many developments in the Netherlands were put on hold after permits issued under the country's Integrated Approach to Nitrogen were suspended following a European High Court ruling that the safeguards within the scheme were inadequate (Council of the State, 2019). Due to a lack of baseline biodiversity and abiotic data, it has proven very difficult for many of these projects to demonstrate that their environmental impacts were within acceptable limits, causing many to remain suspended.

Similarly, biodiversity policy often competes with other policy objectives to an unknown extent because of incomplete information on the synergies and trade-offs between different management (e.g. climate change policy in forestry; Blattert et al., 2018 or energy policy – Kati et al., 2021). Without adequate monitoring and reporting of these trade-offs, we risk creating perverse trade-offs that will require further investment in restoration measures to reverse.

Sustainable finance policy We have outlined the demand for an increase in sustainable finance instruments and the potential benefits that widespread monitoring can have for this sector. Considering the opposite perspective – if there is no co-ordinated source of independent advice or additional support for monitoring efforts, a number of risks to the success of these policies:

- Existing monitoring efforts are further compromised by growing demands for advice from the financial and development sectors, as has been observed by EuropaBON (Breeze et al. 2023).

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- Lacking full ecological baseline data, either real or through the use of validated, spatially explicit models, there are many perverse incentives for companies to engage in "Greenwashing", using easily achieved targets and limited transparency while claiming the benefits of e.g. cheap loans (Kedward et al., 2023).
- Private investment and support for biodiversity monitoring will be lowered, increasing the public burden for conservation targets.
- Lack of coordination and centralized funding support unintentionally promotes the duplication of efforts while not addressing data gaps, leading to inefficient, redundant, or poorly targeted analyses.

6. Funding the network

6.1. Current Funding

Existing Government funding: Given the significant investment required for effective monitoring, developing an equitable and sustainable funding structure will be key. The proposed EuropaBON Network is not intended as a replacement for existing biodiversity monitoring networks but as an illustration of the expenditure that is needed across actors. Current expenditure on monitoring the network is difficult to ascertain and seldom itemised. Drawing on data provided for the EuropaBON Co-Design (Moersberger et al., 2022) and from Biodiversa+ (Vihervaara et al., 2023), current budgets for biodiversity monitoring are €53.3M/year across 15 member states and three NUTS 2 regions, <5% of the costs projected for these countries. However, this data is very incomplete, missing budgets for many larger member states, and freshwater and marine monitoring spending is difficult to assess as biodiversity is intertwined with other data collection on water quality (Moersberger et al., 2022; Vihervaara et al., 2023).

A lack of consistent funding is the main issue facing many monitoring organizations, many of whom are largely supported by national or EU-level research programmes, such as Horizon, Biodiversa+ or LIFE, on a project-by-project basis. Although capable of generating high-quality data, these projects are of limited duration, must balance data collection and modelling with other research activities (particularly in highly interdisciplinary projects) and do not support regular employment, resulting in staff and skill turnover (Breeze et al., 2023). As such, the actual expenditure on data that can be used for monitoring is likely to be a small portion of the total expenditure on biodiversity research. Other expenditures from sources such as Cohesion funds and the European Social Fund are similarly hard to trace to monitoring specifically (Nesbit et al., 2022).

6.2. Generating additional funding

Funding of Core Activities: Expanding biodiversity monitoring to address the gaps and bottlenecks identified, would need to carefully balance expanding the capacity of existing networks and formally setting up new pan-European networks (Liquete et al., 2024). Leveraging additional funding could take a number of additional routes:

- <u>Collaborative funding agreements</u>: Funding core monitoring activities such as EBOCC could be achieved through funding models similar to existing European Research Infrastructure

Collaborations, with member states playing in part a flat fee, followed by GDP and/or GDP per capita based additional fees and agreeing to contribute in-kind time (E.g. EMBRC ERIC).
- Public Finance re-allocation: Additional revenue could be generated through the re-allocation of public environmentally harmful subsidies (EHS – subsidies that contribute to increased carbon footprint or slow transition towards net zero), towards supporting restoration (Kedward et al., 2023). Areas subsidised by EHS include fossil fuels, intensive agriculture and aquaculture or hard rock mining (Koplow and Steenblik, 2022). The EU is already committed to this action under the new Green Deal, and presently, each member state is in the process of reforming its own subsidies, mostly tax exemptions or direct subsidies. The total value of these subsidies is unknown, and different member states have made different degrees of progress on this (Porsch et al., 2022).
- Philanthropy: Philanthropic foundations have often been the main drivers of biodiversity data collection and early pioneers of conservation more generally (Juffe-Bignoli et al., 2016).
- Green financial instruments: Biodiversity monitoring activities could receive direct funding through green bonds or other financial instruments, with issuing organizations agreeing to provide finance via direct funding to public ministries to collectively support monitoring. This funding could be collectivised to ensure that taxa or habitats that are less often the focus of monitoring for these instruments are not neglected because they are less “popular”.

Commercialisation Although European biodiversity monitoring could be supported through member state funding, with the growing interest in biodiversity data from the private sector, workshop participants suggested a number of opportunities for commercialisation of monitoring activities at a member state or EU/EBOCC level. These activities would require a minor additional investment in staff but would both generate revenue for the network as a whole and contribute to capacity building and effective biodiversity management by private actors.

1. **Consultancy:** Biodiversity monitoring networks could provide cross-realm consultation for businesses and financers, providing independent advise on suitable and effective target setting. Being able to engage with multiple aspects of biodiversity simultaneously will be important to sectors where operations may cross realms (e.g. transport or manufacturing). By undertaking these activities for a fee, ideally one that scales with the size of the company, the network will be able to properly compensate experts for their time and re-invest funds back into monitoring.
2. **Training**: Monitoring networks also represent an opportunity to provide much-needed accredited training for consultancies, biodiversity financers, and education institutions (either through direct payments or co-funding of staff). This could have added value by providing trainees with a broad knowledge base across realms and biomes and can be combined with training field staff to increase cost-efficiency.
3. **Quality control**: environmental DNA (eDNA) is an increasingly popular tool in emerging biodiversity monitoring efforts and for monitoring financial instrument successes. However, such assessments require quality control through verification at an independent laboratory. The proposed network could allocate part of its resources, either at a member state or EU level, to providing this service thanks to the constant influx of genetic data it could receive from monitoring efforts.

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However, although private funding is a potential source of revenue, as highlighted above, some safeguards should be in place to maintain impartiality, ringfence core monitoring activities, retain intellectual property rights enforcement and continue to recognise biodiversity as a public good (Kedward et a., 2021).

7. Conclusions and Recommendations

7.1. Overall Appraisal

Cost:benefit ratio of the network: The economic benefits of a widespread and highly replicated EU Biodiversity monitoring network are hard to quantify, however, based on our conservative estimates, they amount to **~€25.2bn per year, between 7 and 54 times the total costs of the network**, while also providing critical data, skills and knowledge exchange to support mainstreaming of biodiversity into business, finance and wider public decision making. This benefit-to-cost ratio will only increase when existing biodiversity data collection by government and NGOs is taken into account.

Supporting biodiversity finance: After decades of EU and national efforts implementing environmental measures and fostering sustainable practices, biodiversity and ecosystem conditions are still in decline. During the last years, Europe has led the way to sustainable finance and financial regulations, placing a greater emphasis on reducing harmful subsidies. The EU is now seeking billions of € in investment for restoration activities to achieve its current biodiversity goals (EC, 2021). Much of the current funding has been poorly targeted (Hermoso et al., 2018). Monitoring not only allows for the development of new tools to restore biodiversity and its economically valuable ecosystem services but also promotes trust, transparency and confidence in the sustainable finance sector, as well as providing valuable skills and training across member states.

Risks are numerous but manageable: Although biodiversity monitoring networks are at risk from policy, public and staff changes, the most effective risk management tools are generally agreed to be collaboration, co-ordination and stable funding. These are all key features of the EuropaBON proposal, but in particular, the role of EBOCC should be to support these activities.

7.2. Limitations

Although we have endeavoured to be thorough, much of the information around the costs and benefits of biodiversity monitoring is limited and can have a significant impact on our estimations. Our assessments of costs and benefits are intended to be the first exploration of this topic but certainly not the definitive one. A broader range of natural capital valuations and a deeper, more precise exploration of the true costs of monitoring will be critical for truly understanding the full costs and benefits involved. However, this should not be a cause for inaction – implementing monitoring will only become more expensive with time and with it, the likely level of funding required to restore biodiversity.

Site numbers: The most significant issue with the estimates of costs has been the number of sites required to adequately address each EBV. Lacking power analyses, we are not able to estimate how many sites should be monitored and where and what proportion of this is undertaken by existing schemes. It is possible that existing data collection is entirely adequate at lower densities than those reported even in the lower site networks. However, a targeted, less random approach to site selection in

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order to better capture rare and threatened species may require much lower or greater site numbers than depicted here.

Standardised methods: We have endeavoured to follow the best available data collection protocols when estimating costs. Nonetheless the lack of standardised methods has forced a number of assumptions in the cost estimates. Furthermore, even where methods are standardised, there can be factors affecting costs between member states – for example, in the case of insect pollinators, the number of specimens caught will vary by the diversity of the local fauna and the availability of suitable taxonomic resources. We used a general average here but using more precise estimates per member state will result in much higher or lower costs as some member states will have to capture more individuals and spend longer identifying each individual due to limited expertise and resources (Hochkirch et al., 2022).

Limited cost data: The majority of studies discussing the costs of monitoring do not actually contain any cost data, certainly not enough to cover all the facets of data collection and, in particular workflows, where costs are very poorly documented. This not only makes budgeting difficult but will hold back our ability to judge the cost-effectiveness of new methods and identify avenues to reduce costs through different means.

Estimating benefits: the quantitative relationships between biodiversity monitoring and the value of ecosystem services are highly context dependent and there may be a substantial lag between data collection, management and realisation of benefits (e.g. Isaacs and Blaauw, 2014). Typically, value of information analyses is used to determine the specific value of monitoring data but these require either expert opinion or a substantial existing dataset in order to determine the realised benefits.

7.3. Recommendations

1. Researchers and implementers need to properly examine the real costs and benefits of biodiversity monitoring. Although the role of monitoring is widely analysed and promoted in scientific publications, the assessments of the costs of biodiversity monitoring are extremely limited. Many time-consuming activities within monitoring activities, such as travel between sites, processing data, managing workflows and modelling or co-ordinating the whole scheme are seldom discussed. As such, the true costs of monitoring are often under-stated, not only causing organizations to compromise on their activities (Breeze et al., 2023) but also limiting the focus of research into improved cost-efficiency largely to the realm of data collection (see Kissling et al., 2024b). Studies into new monitoring technologies and methods should not just claim that they are cost-effective but quantitatively demonstrate how, to what extent and over what time horizon and highlight challenges in using this technology across member states so that resources can be adequately distributed to support the transition.

At the same time, information on the benefits of monitoring in itself is even more limited and necessarily includes many assumptions and extrapolations we had to make through this report. Value of Information analyses is a useful tool to provide some links between monitoring and outcomes (Nygard et al., 2016), including potential economic benefits via ecosystem services. However, these models will remain largely hypothetical, expert opinion driven exercises until sufficient data has been generated to actually measure the influence of data on the effectiveness of management. In other words, we cannot afford to wait on analyses of benefits to enhance monitoring and make it suitable and sustainable in the long term for the present policy and business demands.

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2. Demonstrate the economic and social benefits of biodiversity across value chains to build business engagement. Much of the regulatory burden and costs of biodiversity conservation remain with initial producers such as agriculture, mining and utility companies or with public finance. Although the environmental benefits of these regulations can compensate these actors (e.g. Hanley and Black, 2009), in reality, the benefits of biodiversity are transmitted through value chains to third actors such as retailers, the service sector and transportation companies (Breeze et al., 2022). While investors are showing interest in biodiversity monitoring technologies such as eDNA and Machine Learning (World Economic Forum, 2023b), a major challenge in promoting engagement with biodiversity has been demonstrating the benefits to these larger companies. Expanded biodiversity monitoring data should, therefore, be linked with a renewed focus on in-field assessments of ecosystem services and how these values are transmitted across society. Although most companies currently take an anthropocentric view (Anthony and Morrison-Sunders, 2023), valuations do not have to be exclusively monetary - demonstrating the cultural or health benefits of biodiversity protected by proper monitoring may be as important to minimising an organization's reputational risk (Church et al., 2022).

3. Biodiversity monitoring needs to move away from research project funds and towards long-term funding models. Many monitoring organizations are reliant upon project funding to gather data but this is very inefficient and forces them into difficult trade-offs in data quality (Breeze et al., 2023). Funding through research programmes is also highly cost-inefficient and would need to more than double to achieve the proposed network due. The resultant staff turnover is thought to be driving a gradual decline in many key skills in biodiversity research (e.g., Hochkirch et al., 2022) and places a significant cost on either retraining staff or hiring consultants to undertake work that could be done at a lower cost by in-house staff. Public biodiversity funding is a major stream for monitoring; however, we have identified a number of possible alternative revenue streams from both public and private sources that should be explored in the short term. However, it should be stressed that branching into commercialisation must not come at the expense of the impartiality and core function of the network or there is a risk that trust and engagement potential will be lost

4. Implementing co-ordination and interoperability is a critical step to implementing effective monitoring. Effective national and central (EBOCC) co-ordination is a key factor in reducing the risks to long-term monitoring and maximising the opportunities. In particular EBOCC will have a key role to play in ensuring parity of support and expertise is available to all member states, formulating connections between member state co-ordinators and facilitating wider availability, interoperability, engagement with and use of data. The EBOCC and national costs for coordination and harmonisation are relatively small in proportion to the overall monitoring costs and the potential savings coordination brings. Similarly, member state co-ordination will need ample and sustained funding to support data collection, especially if citizen scientists are involved.

5. Biodiversity monitoring should be factored into governments' sustainable finance planning, including making the private sector aware of opportunities to utilise freely available data. The major barriers for investment in biodiversity are expertise and data availability. The proposed EuropaBON network will directly address these issues across multiple realms, while also facilitating knowledge transfer with private enterprises, empowering them to properly understand and factor in their impacts on biodiversity beyond their obligations. Considering what data is available and what can be produced in the short term should influence member states' standards for biodiversity financing, and it should be an

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EU priority to produce and regularly update models that are suitable for business decision making, as well as scientific research.

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Appendix A. Overview of sampling networks into which Essential Biodiversity Variables (EBVs) were grouped.

The following is reproduced from Kissling et al (2024a). Readers are recommended to consult Appendix A of that deliverable for full details of the cost analyses. Here we use the EuropaBON EBV coding system, available on GitHub https://github.com/EuropaBON/EBV-Descriptions/wiki

Network name	Description	Methods	Sites (low and high scenario)	EBVs
Freshwater				
River surveys[5]	Monitoring of rivers at a catchment scale using methods employed in biodiversity sampling for the Water Framework Directive (e.g. WISE-2), with additional surveys to capture bivalves and river barriers.	Electrofishing, macrophyte transects, diatom sampling, kick sampling, pump/core sampling, bivalve transects, barrier mapping.	10,000 or 100,000 river sections, proportionally divided among Member States based on the number of rivers as given by Lyche Solheim *et al.* (2019).	SP_dis_fish_FW, SP_dis_inve_FW, CC_com_mphy_FW, CC_com_pben_FW, CC_com_inve_FW, CC_com_fish_FW, CC_com_fung_FW, ST_phe_fish_FW
Lake surveys	Monitoring of large lakes (> 25 ha), using methods employed in biodiversity sampling for the Water Framework Directive.	Dip sampling (phytoplankton, cyanobacteria and zooplankton), pump/core sampling, macrophyte sampling, gillnetting.	2,000 or 20,000 lakes, divided proportionally among member states based on the number of lakes as given by Lyche Solheim *et al.* (2019).	SP_dis_fish_FW, SP_dis_inve_FW, SP_dis_mphy_FW, CC_com_mphy_FW, CC_com_ppla_FW, CC_com_zoop_FW, CC_com_inve_FW, CC_com_fish_FW, EF_phe_ppla_FW
Marine				
Marine fish surveys	Active and passive monitoring of marine fish, e.g. as implemented by the European Tracking Network (ETN) or for the Marine Strategy Framework Directive.	Trawling surveys, acoustic sensors.	550 or 5,500 ocean cells of 10 km^2 size, representing 1% and 10% of the total Exclusive Economic Zone (EEZ) of EU member states around continental Europe. These are divided among member states based on the relative size of their EEZ. We include the	SP_dis_fish_MA, SP_abn_fish_MA, ST_phe_fish_MA
Marine vertebrate surveys	In-situ monitoring of marine bird colonies, mammals and turtles, e.g. as implemented for the Helsinki Commission (HELCOM), Oslo and Paris Conventions	Ship transects, aerial transects.		SP_dis_bird_MA, SP_abn_bird_MA, SP_dis_mamm_MA, SP_dis_rept_MA, ST_phe_bird_MA, ST_phe_mamm_MA

[5] Following the Water Framework Directive, we assume that each site in this network is sampled once every 6 years

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	(OSPAR), and the Italian Institute for Environmental Protection and Research (ISPRA).		overseas territories of Medina, the Azores and the Canary Islands.	
Marine habitat surveys[6]	Monitoring of marine habitat distribution (Oyster and coral reefs, macroalgae and seagrass forests).	Marine habitat surveys, sediment core sampling.		ES_dis_cora_MA, ES_dis_malg_MA, ES_dis_plan_MA, ES_dis_oyst_MA, EF_dtb_habi_MA
Marine invertebrates & plankton surveys	Monitoring of marine invertebrates and plankton.	Plankton trawling, Autonomous Reef Monitoring Structure (ARMS) and Artificial Substrate Unit (ASU) sampling with genetic metabarcoding, Marine video transects.		SP_dis_inve_MA, CC_com_micr_MA, CC_abn_inve_MA
		Terrestrial		
Terrestrial invertebrate surveys	Monitoring of insects, also including some pollinators and other important terrestrial invertebrates (e.g. European Food Safety Authority guidelines)	Malaise traps, pitfall traps, sticky traps, light traps, tick cloth drags.	10,000 or 100,000 sites, representing 1% and 10% of the 2 × 2 km grid cells used as the basis for Land Use / Cover Area frame Survey (LUCAS) sampling. These are divided proportionally among member states based on their total land area.	SP_abn_dise_TER, SP_abn_pest_TER, CC_bio_inve_TER
Vegetation surveys	Monitoring of trees, plants, lichen and dead wood (e.g. European vegetation Archive (EVA)	Vegetation plots, tree transects, lichen sampling, dead wood transects.		SP_dis_plan_TER, SP_dis_lich_TER, ES_bio_habi_TER
Soil surveys[7]	Monitoring of soil biodiversity, including invertebrates as e.g. suggested for the Land Use / Cover Area frame Survey (LUCAS).	Soil metagenomics, soil invertebrate sampling.		CC_bio_micr_TER, CC_com_micr_TER
		Cross-Realm (In-Situ)		
Mainland bird surveys	Monitoring of terrestrial and wetland birds, e.g. as implemented by Birdlife International,	Point counts, constant effort ringing, bird transects	10,000 or 100,000 sites, representing 1% and 10% of the 2 × 2 km grid cells used as the basis	SP_abn_bird_FW, SP_dis_bird_TER, SP_abn_bird_TER, ST_phe_bird_TER, ST_phe_bird_FW

[6] Following existing schemes, we assume that each site in this network is sampled every 5 years
[7] Following LUCAS, we assume each site in this network is sampled once every 6 years

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	the European Breeding Bird Atlas (EBBA), Wetlands international, European bird ringing schemes (EURING).		for Land Use / Cover Area frame Survey (LUCAS) sampling. These are divided proportionally among Member States based on their total land area. It is assumed that these sites will be distributed between freshwater and terrestrial sites, but the methods used are the same. For mainland birds, we assume 50% of sites are monitored by volunteers, and for Priority insects, we assume 25% of sites are monitored by volunteers.	
Mainland mammal surveys	Monitoring of terrestrial and freshwater mammals, amphibians and reptiles, e.g. as suggested by the European Observatory of Wildlife (EOW), Amphibian and Reptile Conservation Trust (ARC), European Mammal Foundation (EMF) and Eurobats.	Camera traps, passive acoustic sampling, live-capture with genetic barcoding, mammal transects.		SP_dis_mamm_FW, SP_abn_mamm_TER, SP_dis_mamm_TER
Mainland herpetology surveys	Monitoring of terrestrial and freshwater reptiles and amphibians.	Amphibian transects, reptile transects.		SP_dis_amph_FW, SP_dis_rept_FW, SP_dis_rept_FW
Priority Insect surveys[8]	Monitoring of pollinators and dragonflies, e.g. as implemented by the European Butterfly Monitoring Scheme (eBMS) and as suggested by the proposal for an EU Pollinator Monitoring Scheme (EU PoMS).	Butterfly transects, other insect transects, Flower-Insect Timed (FIT) counts, pan traps, light traps.		SP_abn_inse_TER, SP_dis_inve_TER, ST_phe_inse_TER, SP_abn_inse_FW, SP_dis_inse_FW, CC_abn_inse_TER
Mainland habitat surveys	In-depth monitoring and habitat classification of freshwater and terrestrial EUNIS habitats.	Large habitat plot sampling (10km).		ES_dis_habi_FW, ES_dis_habi_TER
		Cross-Realm (Novel Technologies)		
Genetic sequencing[9]	Monitoring the genetic diversity of rare and threatened species across realms.	Full genome sampling.	10,000 or 100,000 populations across species listed in the Habitats Directive,	GC_div_unsp_TER, GC_div_unsp_FW, GC_div_unsp_MA

[8] Pollinators and dragonflies are separated from other terrestrial invertebrates because they use more observational methods, many of which are non-lethal.

[9] In this network, each population is only sampled once per 10 years.

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			sampled once per 10 years.	
Citizen science apps	Setting up and maintaining citizen science photographic apps that are used as the primary source of data collection.	Citizen science	10,000 or 100,000 sites submitting ~10 images per year.	SP_dis_alie_FW, ES_con_habi_FW, SP_dis_alie_MA, SP_dis_alie_TER, ST_phe_fung_TER, ST_phe_fung_TER
LiDAR modelling[10]	Monitoring habitat structure using LiDAR.	Airborne LiDAR	These networks take advantage of different existing datasets that span Europe. However, they should be validated against suitable data. For this purpose, we estimate costs based on validation in a network of 1 site per 50 km2 or 500 km2. Flux towers and imaging flow cytometry are only present at 10% of the cells.	ES_str_habi_FW, ES_str_plan_TER
Satellite Remote sensing models	Using existing Earth Observation data to generate EBVs (this is also a proxy for data generated with radar). Unlike the other primary monitoring networks, the costs for the modelling and workflows are entirely allocated to a central organisation like a European Biodiversity Observation Coordination Centre (EBOCC), but could be hosted in any Member State at a suitable institution.	Satellite Remote Sensing Phenocams, flux towers and imaging flow cytometry for validation. Other forms of validation would draw data from other networks.		EF_pro_habi_FW, EF_phe_habi_MA, EF_phe_ppla_MA, EF_pro_habi_MA, ST_phe_plan_TER, CC_bio_bird_TER, CC_bio_birdmamm_TER, CC_bio_birdinver_TER, ES_con_habi_TER, EF_phe_ppla_FW, EF_pro_unsp_TER, EF_dtb_fire_TER, EF_dtb_huma_TER, EF_phe_plan_TER

[10] In this network, models are compiled every 5 years from publicly available data.

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Appendix B: Estimating the Value of Ecosystem Services

Some of the economic values of ecosystem, services presented are drawn directly from the literature cited and are simply inflated to 2023 € values. However, some of these values have been upscaled from previous projections or are otherwise estimated specifically for this report. Here, we detail the steps behind these assessments.

Recreational Angling (freshwater) - There is no separate EU scale economic valuation of freshwater angling. Here, we estimate the number of people engaged in angling using the % of population participation in angling from Arlinghaus et al (2021) for each European country, using the lowest % of each category (min 1%) and population statistics from Eurostat (2023). We then multiply this by €45/day (daily rate from Carlén et al., 2021) and five days per person.

Table A1 – Inland recreational fishing

Country	Proportion of population engaged in angling	Population (Million, 2023)	Est. Anglers (Million, 2023)	Value (M€)
AUT	5%	9.1	0.46	107
BEL	1%	11.8	0.12	28
BGR	1%	6.4	0.06	15
CYP	1%	0.9	0.01	2
CZE	1%	10.8	0.11	25
DEU	5%	84.4	4.22	991
DNK	5%	5.9	0.30	70
ESP	5%	48.1	2.40	565
EST	1%	1.4	0.01	3
FIN	25%	5.6	1.39	327
FRA	1%	68.1	0.68	160
GRC	1%	10.4	0.10	24
HRV	1%	3.9	0.04	9
HUN	1%	9.6	0.10	23
IRL	1%	5.2	0.05	12
ITA	1%	58.9	0.59	138
LTU	25%	2.9	0.71	168
LUX	1%	0.7	0.01	2
LVA	1%	1.9	0.02	4
MLT	1%	0.5	0.01	1
NLD	1%	17.8	0.18	42
POL	1%	36.8	0.37	86
PRT	1%	10.5	0.10	25
ROU	1%	19.1	0.19	45
SVK	1%	5.4	0.05	13
SVN	1%	2.1	0.02	5
SWE	10%	10.5	1.05	247

Proportion of population engaged in Angling from Arlinghaus et al. (2021)

Nature based recreation (Marine): In the marine realm, there is no EU-wide study into the total recreational value of all European seas, but Czajkowski et al. (2015) gave an estimate of €15bn for the Baltic Sea alone (€20.4bn in 2023). We extrapolated this upwards based on the coastal areas of

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member state, minus those within the Baltic Sea (Finland, Estonia, Latvia, Lithuania, Poland and Germany) and 75% of the coastline of Denmark and Sweden, which are largely within the Baltic but are also within the OSPAR region of the Atlantic Ocean. This resulted in a total coastal length of 66,912km, compared to 62,298km in the Baltic (107%). Multiplying by 2.07 and inflating to 2023 € values, gives €31.11bn. This is likely to be a significant underestimation as it does not include higher value activities that are present in the Mediterranean Sea or South Atlantic such as whale watching and scuba diving (Ressurreição et al., 2022).

Carbon Sequestration (Marine): There is no EU-wide study of the value of carbon capture. However, Alarcon Blazquez et al. (2023) provide an estimate of €1.6bn/year (€1.92bn in 2023) for the OSPAR region (North-East Atlantic Ocean), based on an extrapolation of estimates in the Netherlands. We extrapolate this by assuming that carbon storage is similar across all major seas in Europe.

Table A2 – Carbon Sequestration (Marine)

Sea	Area	Area as % of OSPAR	Extrapolated Value of Carbon/Year
OSPAR	700,000	100%	€1.92bn
Baltic Sea	1,616,440	230%	€4.43bn
Mediterranean Sea	2,500,000	357%	€6.86bn
Black Sea	436,402	62%	€1.2bn

Appendix C: Estimating the Costs of Environmental Hazards

This appendix contains details on the process of estimating the costs of Environmental hazards that can be associated with the EuropaBON EBVs. Given the breadth of EBVs, we cannot provide a full estimation for all possible hazards.

Harmful Algal Blooms (freshwater): There is no EU wide estimation of the costs of Harmful Algal Blooms in freshwater systems. Instead, we use the average costs of Harmful Algal Blooms across the three case studies in Seifert-Dahnn et al (2021) and assume that there are, on average, 10 events per member state.

Crop Damage by Aphids: There is no EU-wide estimation of the damage inflicted by insects on all crops. However, Deutsch et al., 2021 estimate that the average yield loss to pests in wheat (5.4%), rice (7.1%) and maize (8.2%) across EU member states. Using average production and price data (FAOSTAT, 2023a,b) for 2020-2022, we estimate the economic costs of pest damage at €3.17bn per year across these three crops. These crops account for 31% of EU crop production., many of which have a higher price per tonne than these crops.

Human diseases from Ticks: There is no EU scale assessment of the total costs (burden) of diseases from animals. However, some studies have estimated the costs of specific vectors. The costs of diseases in humans are based on a combination of initial treatment costs and sick days, usually from specific national studies (e.g. Slunge et al., 2022).

<u>Lyme Borreliosis (Lyme disease)</u>: We used average incidence data for 2015-2019 from Burn et al., (2023) for most countries but drew on additional data sources for Sweden (2014 data - Dahl et al., 2019), Netherlands (Houben et al., 2023), Austria (2015-2018 data - Stiasny et al., 2021), Denmark (Skufca et al., 2022). Incidence in Italy is extremely low (<0.01/100,000; Trevisan et al., 2023) and has been very low in Spain (Bonet Alavés et al., 2016) but is expected to be rising. This produced a total

incidence of 146,006 per year. We then used the average direct cost of treatment from Willems et al. (2022; €4,618/case) to upscale this cost, giving an annual burden of €674M/year.

Tick-Borne Encephalitis: Using data on the incidence of Tick-Borne Encephalitis from the European Centre for Disease Prevention and Control (ECDC, 2022; 2023), there are an average of 3,042 incidents per year. Assuming an average cost of €20,504 per case in the first year with additional costs from later sick days of €3,600 in years 2 and 3, and €2,100 in years 4 and 5 from Slunge et al. (2022) gives an annual disease burden of €98M/year. The incidence of this disease has risen by 74% between 2012-2022 and is expected to rise further with climate change, which increases the activity and distribution of Ticks (Varma et al., 2022).

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