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PERSPECTIVE

Biodiversity monitoring in Europe: User and policy needs

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Abstract

To achieve the goals of the 2030 Global Biodiversity Framework, the European Biodiversity Strategy, and the EU Green Deal, biodiversity monitoring is critical. Monitoring efforts in Europe, however, suffer from gaps and biases in taxonomy, spatial coverage, and temporal resolution, resulting in fragmented and disconnected data. To assess user and policy needs in biodiversity monitoring, we employed a four-step user-centered stakeholder engagement process with over 300 stakeholders including a public stakeholder workshop, online survey, interviews, and a meeting with experts from 18 EU member states, the European Commission, and the European Environment Agency. The stakeholders identified policy needs, current challenges, and potential solutions. Based on the policy and stakeholder assessment, we recommend establishing a European Biodiversity Observation Coordinating Centre to optimize existing observation efforts, harmonize data, and enhance our ability to predict and respond to key challenges related to biodiversity loss in Europe.

KEYWORDS
biodiversity, challenges, conservation, data collection, European biodiversity, implementation, monitoring, policy, solutions, stakeholder engagement

1 | INTRODUCTION

Biodiversity monitoring is critical for successful conservation policy and management. Successfully implementing, assessing, and evaluating policy effectiveness and management interventions rely on the availability of high-quality, scientifically robust, and reliable monitoring data, as well as their underlying methods for collection and analysis (Perino et al., 2022). National borders, however, combined with sociopolitical barriers, such as language or mistrust between sectors, result in disconnected monitoring efforts and incoherence of data (Kühl et al., 2020). Fragmentation is also a key hurdle for gaining a comprehensive understanding of the state and trends of biodiversity (Proença et al., 2017). Therefore, biodiversity monitoring requires collaborative, integrative, and multinational approaches.

The importance of effective biodiversity monitoring has been increasingly recognized by policy and decision-makers. The recent adoption of the Kunming–Montreal Global Biodiversity Framework of the Convention on Biological Diversity (CBD) (2022) represents a significant step forward in the global conservation and restoration of biodiversity. For the first time, a global monitoring framework has been proposed to more efficiently implement and measure progress toward global biodiversity goals and targets. Similarly, the European Biodiversity Strategy 2030 places a key commitment to monitoring protected areas, and the European Commission has also announced its ambition to establish workflows for monitoring and reporting biodiversity trends as part of the new European biodiversity governance framework (DG Environment, 2021).

One of Europe's most significant policy goals is the EU Biodiversity Strategy's attempt to halt the decline of biodiversity and promote its recovery by 2030. One way to achieve this is through the restoration of a significant portion of degraded ecosystems in order to provide long-term ecosystem services, through legally binding restoration targets such as the new EU Nature Restoration Law (DG Environment, 2022). Thus, European biodiversity monitoring initiatives need to provide integrated empirical evidence for the achievement of these policy goals and evaluate their effectiveness and impact over space and time. This evidence is also crucial for evaluating the success of conservation and restoration efforts in accordance with the EU Nature Directives, the Water Framework Directive (WFD), the Common Agricultural Policy (CAP), the targets set by the EU Biodiversity Strategy, and other cornerstones of EU legislation, such as for climate and soil.

To fulfill these ambitions, the EU needs robust, reliable streams of biodiversity data across spatial and temporal scales. However, current monitoring efforts in Europe suffer from limitations such as taxonomic, spatial, and temporal gaps and biases. They are also often fragmented across ecosystems, with little continuity across spatial and temporal scales (EEA, 2020a; Hermoso et al., 2017; Geijzendorffer et al., 2016; Santana et al., 2023). Additionally, insufficient access to existing data makes it difficult for policymakers to make informed decisions and to effectively design, implement, and evaluate policies. A key first step to address these challenges and limitations is to provide a comprehensive assessment of current monitoring efforts in Europe, identify data gaps, and address workflow bottlenecks.

Many studies have focused on assessing these data needs and challenges with a data-focused approach, for example, using remote sensing data or other (semi-)automated data collection methods (Luque et al., 2018; Proença et al., 2017; Vihervaara et al., 2017). This approach, however, runs the risk of neglecting the crucial socioeconomic and cultural contexts that motivate biodiversity monitoring (Kühl et al., 2020). Indeed, few studies engage directly with data users and policymakers to map their needs for biodiversity monitoring. After all, policies and data workflows are created by people, therefore we need to better understand the needs of data users and policymakers, and identify relevant policy questions that rely on biodiversity monitoring.

Here, we employed a user-centric four-step multi-stakeholder engagement process working with over 300 stakeholders to assess the current status and to identify relevant policy questions, challenges, and possible solutions concerning biodiversity monitoring in Europe. This participatory approach closes a science–policy gap and brings data providers and end-users closer together. Based on suggestions by stakeholders, we propose five ways to address identified challenges.

2 | METHODS

We conducted a four-step stakeholder engagement process to gather expert knowledge on biodiversity monitoring with over 300 stakeholders from the science and policy sector across Europe (Figure 1; see Supporting Information S1 for full methodological details). The stakeholder engagement process included (i) a public online stakeholder conference in May 2021, (ii) an open standardized online survey distributed across Europe (Moersberger et al., 2023a, 2023b), (iii) targeted semistructured interviews, and (iv) a policy expert workshop in Sep 2021. For ii–iv, policy experts from 18 EU Member States with national contact points of the European Environment Information and Observation Network (Eionet) and eight European services took part, including experts from four Directorate-Generals of the European Commission, the European Environment Agency, and Biodiversa+. From society and science, participants included experts from

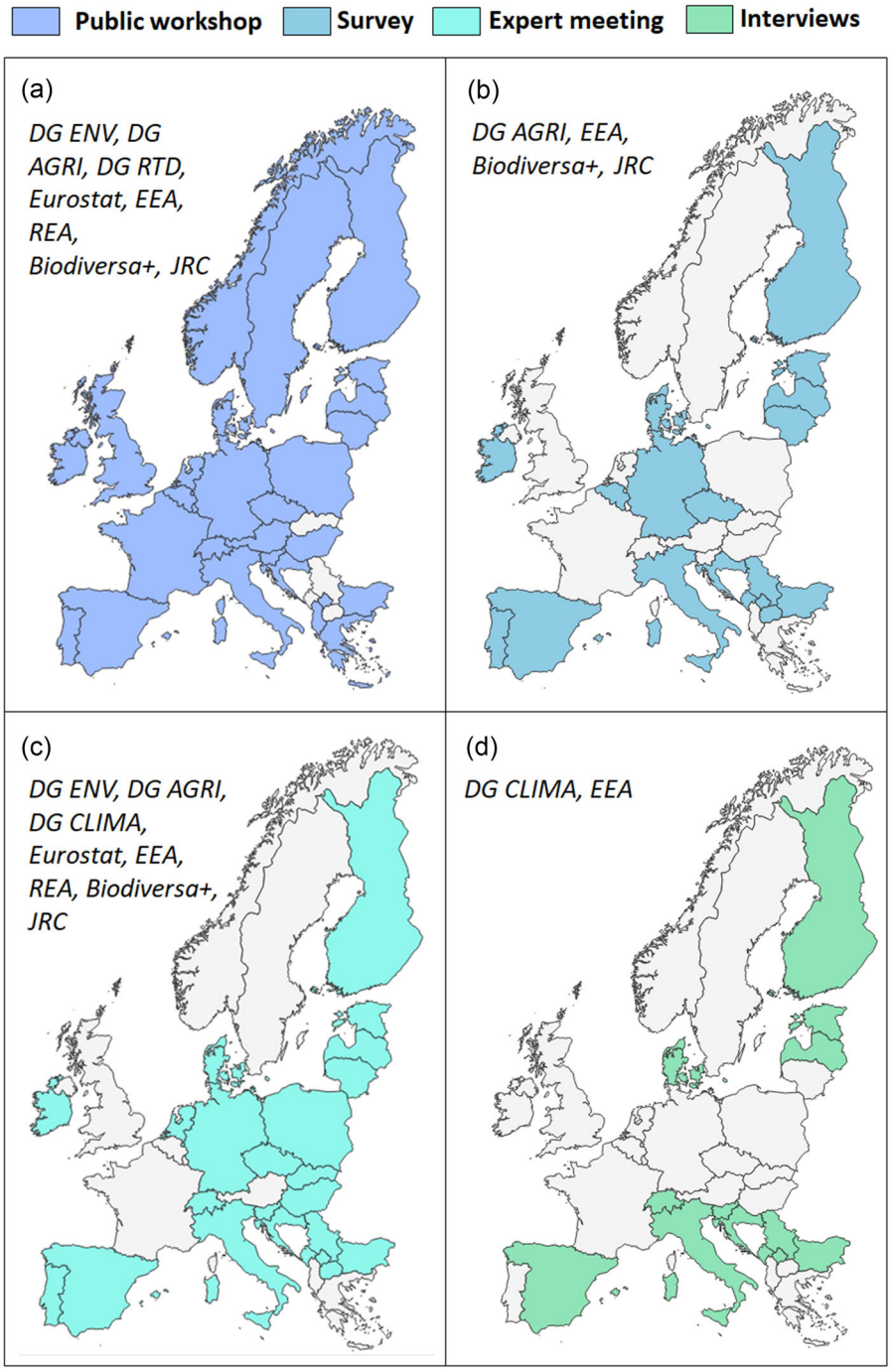

FIGURE 1 Geographic distribution of participants and European Union services present at the (a) public stakeholder conference, (b) surveys, (c) expert meeting, and (d) semistructured interviews. European Commission services include DG ENV (Directorate-General for Environment), DG AGRI (Directorate-General for Agriculture and Rural Development), DG CLIMA (Directorate-General for Climate Action), DG RTD (Directorate-General for Research and Innovation), EEA (European Environment Agency), REA (European Research Executive Agency), Biodiversa+ (European Biodiversity Partnership), and JRC (Joint Research Center).

major natural history societies, such as the European Bird Census Council (EBCC), museums, data infrastructures, universities, and other research organizations (see Supporting Information S2 for stakeholder information and Supporting Information S3 for full survey template). Responses were coded with the qualitative content analysis tool NVivo (Version 12; Edwards-Jones, 2014).

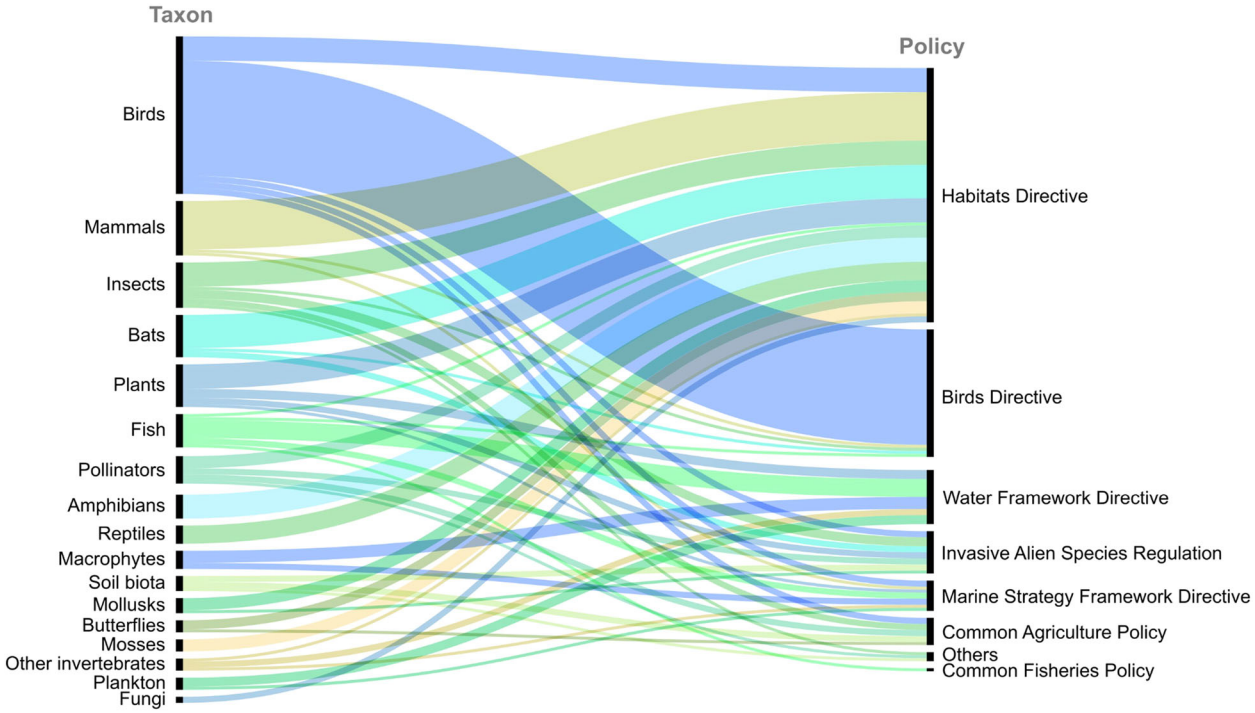

FIGURE 2 Data flows from monitoring taxonomic groups to informing various EU policies or directives. Each line in this figure represents one monitoring scheme reported in the survey from a total of 274 biodiversity monitoring programs. Hence, the thickness of streams represents the number of monitoring schemes for a given taxonomic group. Taxonomic groups are shown here as listed by respondents; hence, some smaller groupings may be included in larger groupings identified by the users during the assessment process. Taxonomic groups and policies are arranged in descending order of monitoring effort and reporting frequency, respectively.

3 | RESULTS

3.1 | Current national monitoring schemes in Europe

Our survey identified 274 biodiversity monitoring programs currently conducted by European countries and agencies, revealing a bias in biomes and taxonomic groups. Most schemes targeted terrestrial biodiversity (66%), followed by freshwater (24%) and marine/coastal biodiversity (21%). From a taxonomic perspective, birds were the most frequently monitored group, accounting for 28% of total monitoring efforts, primarily in support of the Birds Directive. Other groups with significant monitoring included mammals (18%) (particularly bats with 8%), insects (8%), plants (8%), pollinators (6%), and fish (6%). Representation of other taxonomic groups was low, ranging from 1% to 4%, with very little monitoring of microscopic taxa such as soil biota, fungi, plankton, and microorganisms (Figure 2). Genetic monitoring was mentioned as a largely underrepresented technique to inform on the state and trends of realms and taxa.

With regard to reporting scale to policy directives, the majority of schemes reported to the European level (62%), to the national level (58%), and some to international conventions (16%) such as the Regional Seas Conventions, the Ramsar Convention, or the IUCN red list. The majority of respondents indicated that biodiversity monitoring data are mainly used to report to the Habitats Directive (46%) and the Birds Directive (27%). Only a small portion of the data is used for other policies and directives such as the CAP, Common Fisheries Policy (CFP), WFD, Marine Strategy Framework Directive (MSFD), or Invasive Alien Species (IAS) Regulation (Figure 2).

3.2 | Current policy uptake of biodiversity data

The most prominent use of biodiversity data in policy was related to the Habitats Directive and the Birds Directive with national applications for species policies and management (55%), particularly for species action plans (18%), species management plans (13%), and species conservation status (17%). Habitat conservation policies and management accounted for 31%, with protected area management as the largest subcategory (10%). Biodiversity data were only moderately used for land-use management (11%), with forest management plans and land-use management plans as the largest subcategories (3% each). Meanwhile,

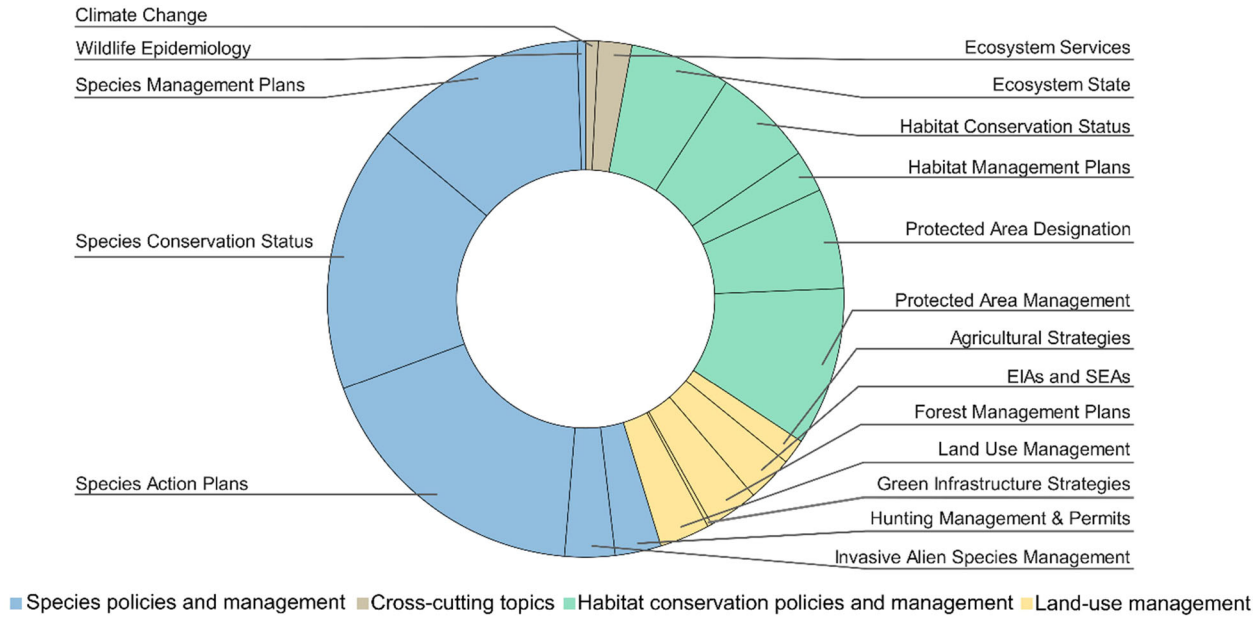

FIGURE 3 Policy uptake of data collected by biodiversity monitoring schemes in Europe, where each data segment represents the number, how often a purpose of the respective biodiversity monitoring scheme was listed by European countries and EU services.

cross-cutting topics such as climate change and ecosystem services were listed least often (3%) (Figure 3).

Our survey highlighted the regular uptake of monitoring data in national policy workflows. For example, in Estonia, biodiversity monitoring informs the regulation of hunting permits for wolves, while it has informed the designation of six new marine bird protection areas in Denmark. In the renewable energy sector, radar monitoring of bird movement—originally used for military aviation—is now used in wind energy planning to avoid collisions between migratory birds and wind turbines (Shamoun-Baranes et al., 2017).

3.3 | Key policy needs for future monitoring

Stakeholders identified four clusters of key policy questions related to biodiversity monitoring within the next decade (Table 1; for details, see Supporting Information S4). The first cluster "Assessing biodiversity and species trends" focuses on understanding biodiversity status and trends, indicators for the quality of habitats, and assessing the impact of invasive species on the environment. These analyses are also needed to inform the second cluster "Biodiversity policy impact and effectiveness" to assess the effectiveness of biodiversity policies and the outcomes of conservation management and restoration. The third cluster "Integrating biodiversity in other policy sectors" branches out and focuses on the intersection of biodiversity conservation and other policy arenas such as agriculture, water management, climate change, green and blue infrastructure projects, poverty, equity, and trade. Finally, the fourth cluster "Operationalization of monitoring" explores ways to standardize and harmonize biodiversity monitoring programs and integrate novel technologies to meet policy targets (Table 1; for more details, see Moersberger et al., 2022).

3.4 | Current monitoring challenges

The top 10 mentioned challenges to current biodiversity monitoring in Europe were related to lack of integrated data, insufficient data, insufficient resources, and biased data. Although lack of financial resources was ranked as the most important cross-cutting challenge by respondents across Europe, other challenges were ranked differently across different European regions. While Southern European countries emphasized data insufficiencies, such as limited spatial coverage, low monitoring frequency, and unavailability of raw data, Western European countries highlighted the lack of long-term monitoring policies and the lack of human and technical capacities as their main challenges (Figure 4).

3.5 | Proposed ways forward

To overcome challenges in biodiversity monitoring, stakeholders proposed five ways forward: (i) enhanced coordination and cooperation, (ii) standardization and

TABLE 1 Four main clusters and thematic subcategories of selected policy questions regarding biodiversity monitoring within the next 5–10 years as identified as priorities by European stakeholders.

Topics	Selected policy questions
I—Assessing biodiversity and species trends	
Understanding biodiversity trends	How can we better assess biodiversity and species trends, and how does this affect ecosystem services?
Indicators and metrics	How do we develop and measure indicators for habitat quality?
	How can we produce reliable data-based risk and impact assessments for habitat quality?
Invasive species	What are the impacts of invasive species on the environment, and how can we better regulate them?
II—Biodiversity policy impact and effectiveness	
Policy and finance	What is the effectiveness of major EU budgets and biodiversity policies in Europe, including support to the Natura 2000 network, species protection under the Habitats and Birds Directives, the WFD, and the EU Biodiversity Strategy?
	How can we "future proof" biodiversity policy and identify harmful subsidies?
Restoration	How can we better assess where and how to restore biodiversity in Europe, with improved outcomes for the economy and society?
	How can we monitor and restore terrestrial biodiversity and ecosystems outside areas that are subject to the Habitats Directive (mainly farmland, forest, and urban areas)?
Ecosystem services	How can we preserve biodiversity to maintain and use ecosystem services in a sustainable way?
Marine biodiversity	How can we develop effective policies for marine biodiversity, which is susceptible to different patterns than terrestrial biodiversity?
	How can major marine policies help track progress toward biodiversity targets, for example, via the Common Fisheries Policy, Marine Strategy Framework Directive, EU Maritime Spatial Planning Directive, or the "new approach for a sustainable blue economy in the EU?"
III—Integrating biodiversity in other policy sectors	
Agriculture and farming	How well is the Common Agricultural Policy (CAP) conserving/restoring biodiversity, and how can agri-environment schemes be improved to enhance positive effects on biodiversity?
	How does the Farm to Fork Strategy contribute to biodiversity, for example, through pesticide reduction or organic farming?
Water management	How can we achieve 25,000 km of free-flowing rivers by 2030?
	How to best distribute water allocations between agricultural and natural areas during drought, weighing economic benefits, vulnerabilities, and sustainable use?
Climate change adaptation and mitigation	What is needed to take climate change impacts on biodiversity and ecosystem restoration into account?
	What are the costs and benefits of policy targets toward climate change mitigation for biodiversity?
Critical green and blue infrastructure	What is the effect of infrastructure projects on biodiversity (e.g., roads, wind farms, hydropower, power lines), and how can we work toward better green infrastructure?
Telecoupling of negative effects	How are European societies exporting negative externalities outside of Europe (e.g., deforestation), and how is this impacting biodiversity in Europe?
Human health and well-being	How can we operationalize access to nature as a basic necessity?
IV—Operationalization of monitoring	
Financing	How can we make monitoring of species and habitats economically viable, and how can we match the scale of funding with the urgency of biodiversity hotspot preservation?

(Continues)

TABLE 1 (Continued)

Topics	Selected policy questions
Data standardization and harmonization	How can we seamlessly integrate and standardize monitoring, data flows, data products, and policy across realms (marine, freshwater, terrestrial) across the EU?
	How can we better integrate underrepresented groups (e.g., plants, algae, invertebrates, soil organisms) in biodiversity monitoring?
Digitization and novel technologies	How can we take advantage of novel technologies and digitalization to meet biodiversity targets and support nature?
New data sources	How can we enhance (corporate) reporting (e.g., through Environmental Impact Assessments, Life Cycle Analyses) to improve biodiversity protection and restoration?

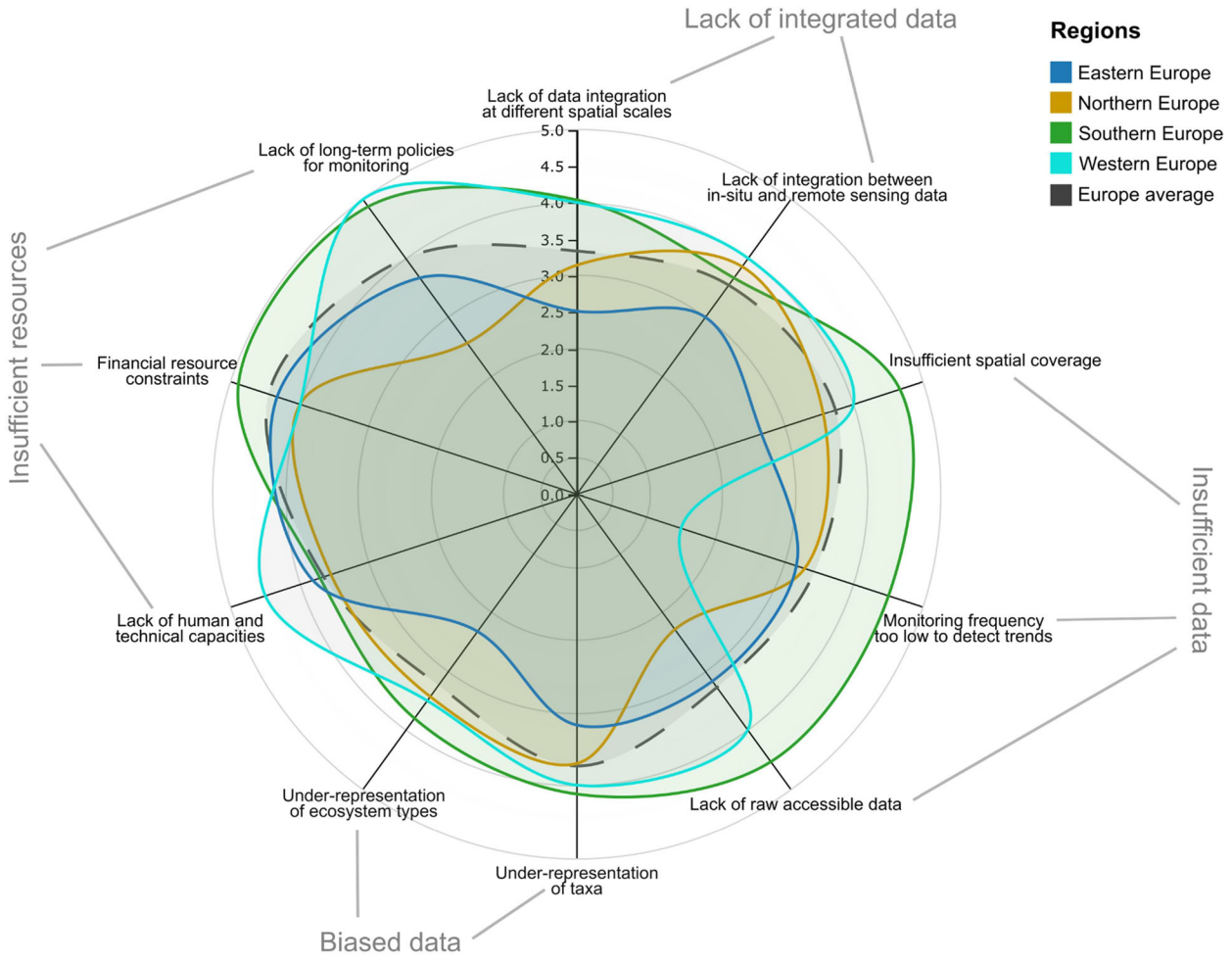

FIGURE 4 The 10 most important challenges to biodiversity monitoring differ across the four European regions (information derived from surveys and interviews). Importance is ranked on a scale of 1 (*least important*) to 5 (*most important*). Importance ranks are averaged across countries in the four regions. Regional groupings are based on the geographic regions of the UN Statistics Division (United Nations, 2019): Eastern Europe = Bulgaria, Hungary, Slovakia, Czechia, and Poland; Southern Europe = Croatia, Montenegro, Serbia, Slovenia, Spain, Portugal, Kosovo, North Macedonia, and Italy; Northern Europe = Denmark, Estonia, Finland, Latvia, Lithuania, and Ireland; and Western Europe = Switzerland, Netherlands, and Germany. The black dashed line represents the average score across all of Europe.

enhanced data gathering and sharing under the FAIR principles (Findable, Accessible, Interoperable, and Reusable; https://www.go-fair.org/fair-principles/), (iii) modeling and novel technologies, (iv) financial resources, and (v) capacity building and stakeholder engagement (Figure 5). Financial resources are critical for the implementation of all ways forward, and long-term, targeted investments may be necessary for their successful

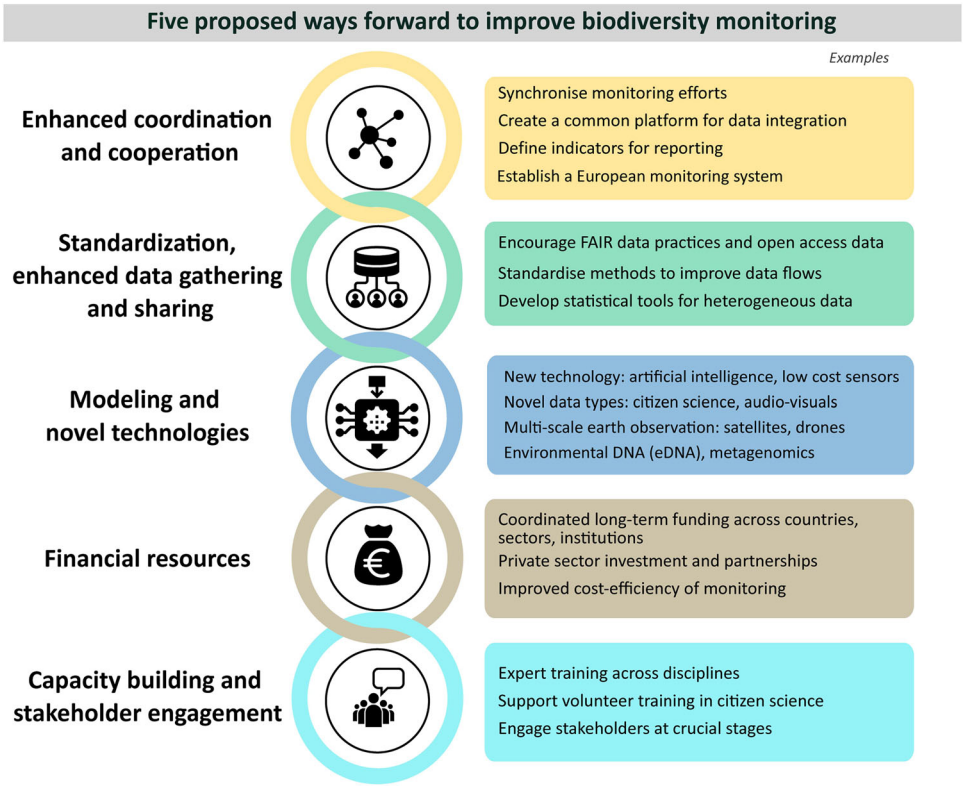

FIGURE 5 Five ways forward suggested by stakeholders to improve biodiversity monitoring and thereby policy impact in Europe.

realization. The implementation of these potential solutions can also address the future key policy questions identified in Section 3.2. Some proposed ways forward address several challenges simultaneously, and many align with previous studies (Pe'er et al., 2022; Schmidt & Van der Sluis, 2021). This emphasizes their importance and the urgency of the transition toward implementation (see also Moersberger et al., 2022).

4 | DISCUSSION

Our user and policy needs assessment reveals a rich, yet fragmented landscape of monitoring schemes in Europe, with biases toward certain biomes and taxonomic groups. Most national monitoring reports to the EU level, with a predominant focus on the Habitats and Birds Directive and little cross-sectoral use of collected data. Key user and policy needs include assessing biodiversity trends, evaluating biodiversity policy effectiveness, integrating biodiversity within other policy sectors, and standardizing monitoring programs. The top challenges to current biodiversity monitoring in Europe include inadequate data integration, biased data coverage, insufficient data availability, and limited financial resources. To overcome these challenges, stakeholders suggest five solutions: improving coordination and collaboration, standardizing data collection and sharing, employing novel technologies, increasing financial resources, and enhancing capacity building and stakeholder engagement.

The multi-stakeholder engagement process highlighted the need for comprehensive long-term monitoring programs that cover a wide range of biomes and taxonomic groups, beyond the dominant focus on terrestrial ecosystems and birds, while also recognizing and addressing sampling biases. This is in line with recent research that recognizes monitoring and data biases toward charismatic species (Pilotto et al., 2020), easily surveyed species (Hermoso et al., 2017), and species listed in the Habitats and Birds Directives (Hoek, 2022). Consequently, we currently have a limited understanding of the state and trends of biodiversity in Europe, insufficient monitoring evidence at sufficient resolution and temporal scales, and a gap between the information needs of policymakers and available data. However, stakeholders expressed their willingness to engage in more integrated and comprehensive approaches to biodiversity monitoring. They recognize the need for high-quality data, methods, and indicators to support effective conservation and restoration policy and the sustainable management of different human activities and economic sectors.

The quantity and quality of baseline biodiversity datasets generated through current monitoring schemes differ across countries. Some countries lack the

capacity to conduct nationally organized, government-funded biodiversity monitoring, while others monitor biodiversity, ecosystem state, and processes through multiple schemes. Despite often mandatory reporting obligations, many countries currently struggle to fulfill the monitoring and reporting obligations of most European environmental directives. This is partly due to limited expertise, financial and human resources, and disparate subnational and local schemes, taxonomies, and habitat classifications. Many countries, however, expressed the wish to learn from their neighbors on how to enhance national biodiversity monitoring, such as through expert exchange groups and knowledge transfer platforms. In response to these challenges, it is essential to establish platforms for sharing insights, promoting collaboration, such as the emerging Living Norway project. For instance, evaluating existing and newly designed monitoring schemes in Flanders/Belgium, Maes et al. (2023) present a comprehensive approach to biodiversity monitoring on a regional scale, offering valuable insights for other regions. Facilitating wider implementation of effective methodologies across countries should be a priority going forward. Many monitoring schemes are crucial for informing species and habitat action plans, management plans, and conservation status appraisals, including some country- and context-specific insights such as the use of bird data for wind energy planning. A notable example of a structured, large-scale consistent data acquisition across Europe is the European Butterfly Monitoring Scheme (van Swaay et al., 2022). The Streamlining European Biodiversity Indicators (SEBI) initiative and its two accepted European indicators—birds and grassland butterflies—represent valuable efforts toward standardizing biodiversity monitoring data.

Additionally, we found that most of the biodiversity assessments performed by EU Member States are reported to the Habitats and Birds Directives. This would be expected as these are thevv main biodiversity regulations in Europe. However, biodiversity monitoring data are also being used to a more limited extent in other EU policies such as the CAP, CFP, MSFD, WFD, and IAS Regulation. It is not clear whether the more limited use is because of a lack of thematic fit or because of data flow bottlenecks, which could be addressed by improved data sharing policies and practices.

Our study results show that some institutions already publish raw data to the Global Biodiversity Information Facility (GBIF), while many current national and European monitoring efforts lack or do not report detailed geo-referenced biodiversity data, which is severely hampering assessments of biodiversity and ecosystem trends, as well as infrastructure planning. While EU Member States must report on the conservation status of habitats and species every 6 years, more than 60% of countries struggle with poor data quality and completeness, and the methods for monitoring and reporting vary widely (Ellwanger et al., 2018). Often, agencies only have access to regionally aggregated assessments of species or ecosystems and the underlying specific (raw) data are not traceable or easily accessible. This lack of available/accessible data, reliance on suboptimal methods, and the use of different methodology contribute to the high level of uncertainty and lack of robustness in reporting. Other challenges include a lack of guidance in identifying monitoring priorities, lack of standardized monitoring protocols, reluctance to change existing monitoring practices, and limited in-house knowledge and technical infrastructure to adequately mobilize and access biodiversity data (see also Kühl et al., 2020; Mairota et al., 2015; Schmeller et al., 2015). While most countries use biodiversity monitoring data for modeling, some lack the capacity, expertise, and funding to exploit its full potential. This indicates the need for capacity building and knowledge exchange, as recommended by stakeholders.

The effectiveness of the five ways forward proposed by stakeholders (Figure 5) will depend on how they are implemented, and their feasibility and potential impact need to be tested. It is also important to find effective ways of engaging stakeholders in their implementation and policy uptake. For example, novel technologies (e.g., low-cost sensors, remote sensing, environmental DNA [eDNA], artificial intelligence, etc.) and citizen science activities could enhance cost-efficiency of data gathering and analysis. However, financial and capacity-building support is needed to use them effectively. Otherwise, there is a risk of resistance to change. Countries with smaller monitoring budgets and capacities also mentioned their fear of being overwhelmed by the obligation to use new technologies or methodologies due to a lack of expertise. The proposed common platform for data integration must be co-created with relevant stakeholders and embedded in existing platforms, for example, the EBV data portal (iDiv, 2023) and GBIF. Moreover, interoperability is crucial, requiring standardized data and common metadata standards for integrated monitoring. Adopting the concept of Essential Biodiversity and Essential Ecosystem Services Variables (EBVs and EESVs) as standard monitoring variables can help address issues of data integration, interoperability, and scarcity (Navarro et al., 2017).

Ultimately, the successful implementation of these potential solutions will require coordinated efforts across Europe. We recommend the establishment of a cost-efficient, user-oriented, policy-relevant, harmonized, and scalable network. Such a network would help optimize existing observation efforts, harmonize data, provide financial and technical support to stakeholders across the continent, and improve our ability to predict and respond to key issues related to biodiversity loss. EuropaBON

has been working with stakeholders to design a European Biodiversity Observation Coordinating Centre in Europe (Liquete et al., 2024). This center would facilitate cooperation, data mobilization, integration, and interoperability. It would also help align and design new sampling methods, provide workflows to generate standardized biodiversity indicators, and foster capacity building. The center can serve as a powerful tool to facilitate and boost the five ways forward identified in this study and coordinate efforts across countries, relevant European agencies, and nongovernmental organizations. With the new EU Restoration Law, these needs are amplified. Integrated monitoring and reporting will be key to effectively inform and respond to urgent 2030 policy goals for sustainable biodiversity management, conservation, and restoration.

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DATA AVAILABILITY STATEMENT

Data will be uploaded at revision stage and made openly available.

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REFERENCES

CBD. (2022). Kunming-Montreal Global biodiversity framework: Decision adopted by the Conference of the Parties of the Conven-

tion on Biological Diversity CBD/COP/DEC/15/4. 19 December 2022. Convention on Biological Diversity, Montreal, Canada. https://www.cbd.int/conferences/2021-2022/cop-15/documents

DG Environment. (2021). *EU biodiversity strategy for 2030: Bringing nature back into our lives*. Publications Office of the European Union.

DG Environment. (2022). Proposal for a nature restoration law. https://environment.ec.europa.eu/publications/nature-restoration-law_en

Edwards-Jones, A. (2014). Qualitative data analysis with NVivo. *Journal of Education for Teaching*, *40*(2), 193–195. https://doi.org/10.1080/02607476.2013.866724

EEA. (2020). Data quality & completeness for Article 17. https://tableau.discomap.eea.europa.eu/t/Natureonline/views/DataqualitycompletenessforArticle17/Article17Dataqualitycompleteness?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link&:isGuestRedirectFromVizportal=y&:embed=y

Ellwanger, G., Runge, S., Wagner, M., Ackermann, W., Neukirchen, M., Frederking, W., Müller, C., Ssymank, A., & Sukopp, U. (2018). Current status of habitat monitoring in the European Union according to Article 17 of the Habitats Directive, with an emphasis on habitat structure and functions and on Germany. *Nature Conservation*, *29*, 57–78.

Geijzendorffer, I. R., Regan, E. C., Pereira, H. M., Brotons, L., Brummitt, N., Gavish, Y., Haase, P., Martin, C. S., Mihoub, J.-B., Secades, C., Schmeller, D. S., Stoll, S., Wetzel, F. T., & Walters, M. (2016). Bridging the gap between biodiversity data and policy reporting needs: An Essential Biodiversity Variables perspective. *Journal of Applied Ecology*, *53*, 1341–1350.

Hermoso, V., Clavero, M., Villero, D., & Brotons, L. (2017). EU's conservation efforts need more strategic investment to meet continental commitments. *Conservation Letters*, *10*, 231–237.

Hoek, N. (2022). A critical analysis of the proposed EU regulation on nature restoration: Have the problems been resolved? *European Energy and Environmental Law Review*, *31*(6), 320–333.

iDiv. (2023). EBV *data port*al. https://portal.geobon.org/home

Kühl, H. S., Bowler, D. E., Bösch, L., Bruelheide, H., Dauber, J., Eichenberg, D., Eisenhauer, N., Fernández, N., Guerra, C. A., Henle, K., Herbinger, I., Isaac, N. J. B., Jansen, F., König-Ries, B., Kühn, I., Nilsen, E. B., Pe'er, G., Richter, A., Schulte, R., … Bonn, A. (2020). Effective biodiversity monitoring needs a culture of integration. *One Earth*, *3*, 462–474.

Liquete, C., Bormpoudakis, D., Maes, J., McCallum, I., Kissling, W. D., Brotons, L., Breeze, T., Moran, A., Lumbierres, M., Friedrich, L., Herrando, S., Lyche Solheim, A., Fernandez, M., Fernández, N., Hirsch, T., Carvalho, L., Vihervaara, P., Junker, J., Georgieva, I., … Pereira, H. M. (2024). D2.3 EuropaBON Proposal for an EU Biodiversity Observation Coordination Centre (EBOCC). *ARPHA Preprints*, *5*, Article e128042. https://doi.org/10.3897/arphapreprints.e128042

Luque, S., Pettorelli, N., Vihervaara, P., & Wegmann, M. (2018). Improving biodiversity monitoring using satellite remote sensing to provide solutions towards the 2020 conservation targets. *Methods in Ecology and Evolution*, *9*, 1784–1786.

Maes, D., Piesschaert, F., Ledegen, H., Van De Poel, S., Adriaens, T., Anselin, A., Belpaire, C., Breine, J., Brosens, D., Brys, R., De Bruyn, L., & Pollet, M. (2023). Monitoring schemes for species of conservation concern in Flanders (northern Belgium). An overview of long-established schemes and the design of an additional monitoring scheme. Research Institute for Nature and Forest (INBO). https://doi.org/10.21436/inbor.93332112

Mairota, P., Cafarelli, B., Didham, R. K., Lovergine, F. P., Lucas, R. M., Nagendra, H., Rocchini, D., & Tarantino, C. (2015). Challenges and opportunities in harnessing satellite remote-sensing for biodiversity monitoring. *Ecological Informatics*, *30*, 207–214.

Moersberger, H., Martin, J. G., Junker, J., Georgieva, I., Bauer, S., Beja, P., Breeze, T., Brotons, L., Bruelheide, H., Fernández, N., Fernandez, M., Jandt, U., Langer, C., Lyche Solheim, A., Maes, J., Moreira, F., Pe'er, G., Santana, J., Shamoun-Baranes, J., … Bonn, A. (2022). Europa Biodiversity Observation Network: User and policy needs assessment. *ARPHA Preprints*, *3*, Article e84517.

Moersberger, H., Martin, J. G. C., Junker, J., Georgieva, I., Maes, J., McCallum, I., Pereira, H. M., & Bonn, A. (2023a). National survey to co-design the Europa Biodiversity Observation Network (EuropaBON). *ARPHA Preprints*, *4*, Article e104251.

Moersberger, H., Martin, J. G. C., Junker, J., Georgieva, I., Maes, J., McCallum, I., Pereira, H. M., & Bonn, A. (2023b). European survey to co-design the Europa Biodiversity Observation Network (EuropaBON). *ARPHA Preprints*, *4*, Article e104168.

Navarro, L. M., Fernández, N., Guerra, C., Guralnick, R., Kissling, W. D., Londoño, M. C., Muller-Karger, F., Turak, E., Balvanera, P., & Costello, M. J. (2017). Monitoring biodiversity change through effective global coordination. *Current Opinion in Environmental Sustainability*, *29*, 158–169.

Pe'er, G., Finn, J. A., Díaz, M., Birkenstock, M., Lakner, S., Röder, N., Kazakova, Y., Šumrada, T., Bezák, P., Concepción, E. D., Dänhardt, J., Morales, M. B., Rac, I., Špulerová, J., Schindler, S., Stavrinides, M., Targetti, S., Viaggi, D., Vogiatzakis, I. N., & Guyomard, H. (2022). How can the European Common Agricultural Policy help halt biodiversity loss? Recommendations by over 300 experts. *Conservation Letters*, *15*, Article e12901. https://doi.org/10.1111/conl.12901

Perino, A., Pereira, H. M., Felipe-Lucia, M., Kim, H., Kühl, H. S., Marselle, M. R., Meya, J. N., Meyer, C., Navarro, L. M., van Klink, R., Albert, G., Barratt, C. D., Bruelheide, H., Cao, Y., Chamoin, A., Darbi, M., Dornelas, M., Eisenhauer, N., Essl, F., … Bonn, A. (2022). Biodiversity post-2020: Closing the gap between global targets and national-level implementation. *Conservation Letters*, *15*, Article e12848. https://conbio.onlinelibrary.wiley.com/doi/abs/10.1111/conl.12848

Pilotto, F., Kühn, I., Adrian, R., Alber, R., Alignier, A., Andrews, C., Bäck, J., Barbaro, L., Beaumont, D., Beenaerts, N., Benham, S., Boukal, D. S., Bretagnolle, V., Camatti, E., Canullo, R., Cardoso, P. G., Ens, B. J., Everaert, G., Evtimova, V., … Haase, P. (2020). Meta-analysis of multidecadal biodiversity trends in Europe. *Nature Communications*, *11*, Article 3486.

Proença, V., Martin, L. J., Pereira, H. M., Fernandez, M., McRae, L., Belnap, J., Böhm, M., Brummitt, N., García-Moreno, J., Gregory, R. D., Honrado, J. P., Jürgens, N., Opige, M., Schmeller, D. S., Tiago, P., & van Swaay, C. A. M. (2017). Global biodiversity monitoring: From data sources to Essential Biodiversity Variables. *Biological Conservation*, *213*, 256–263.

Santana, J., Porto, M., Brotons, L., Junker, J., Kissling, W. D., Lumbierres, M., Moe, J., Morán-Ordóñez, A., Pereira, H., Lyche Solheim, A., Villero, D., Moreira, F., & Beja, P. (2023). D3.2 Report on gaps and important new areas for monitoring in Europe. *ARPHA Preprints*, *4*, Article e103657.

Schmeller, D. S., Julliard, R., Bellingham, P. J., Böhm, M., Brummitt, N., Chiarucci, A., Couvet, D., Elmendorf, S., Forsyth, D. M., & Moreno, J. G. (2015). Towards a global terrestrial species monitoring program. *Journal of Nature Conservation*, *25*, 51–57.

Schmidt, A. M., & Van der Sluis, T. (2021). *Improving the availability of data and information on species, habitats and sites*. European Commission, Directorate-General Environment.

Shamoun-Baranes, J., van Gasteren, H., & Ross-Smith, V. (2017). Sharing the aerosphere: Conflicts and potential solutions. In P. B. Chilson, W. F. Frick, J. F. Kelly, & F. Liechti (Eds.), *Aeroecology* (pp. 465–497). Springer International Publishing.

United Nations. (2019). Standard country or area codes for statistical use (M49). Statistical Services Branch, UN Statistics Division.

Van Swaay, C. A. M., Dennis, E. B., Schmucki, R., Sevilleja, C. G., Åström, S., Balalaikins, M., Barea-Azcón, J. M., Bonelli, S., Botham, M., Cancela, J. P., Collins, S., De Flores, M., Dapporto, L., Dopagne, C., Dziekanska, I., Escobés, R., Faltynek Fric, Z., Fernández-García, J. M., Fontaine, B., … Roy, D. B. (2022). *European Grassland Butterfly Indicator 1990–2020: Technical report* (VS2022.039). Butterfly Conservation Europe & SPRING/eBMS & Vlinderstichting.

Vihervaara, P., Auvinen, A.-P., Mononen, L., Törmä, M., Ahlroth, P., Anttila, S., Böttcher, K., Forsius, M., Heino, J., Heliölä, J., Koskelainen, M., Kuussaari, M., Meissner, K., Ojala, O., Tuominen, S., Viitasalo, M., & Virkkala, R. (2017). How Essential Biodiversity Variables and remote sensing can help national biodiversity monitoring. *Global Ecology and Conservation*, *10*, 43–59.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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