biodiversa+
European Biodiversity Partnership

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Updated roadmap for novel monitoring technologies

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What is Biodiversa+

The European Biodiversity Partnership, Biodiversa+, supports excellent biodiversity research with impact for policy and society. Connecting science, policy and practice for transformative change, Biodiversa+ is part of the European Biodiversity Strategy for 2030, which aims to put Europe's biodiversity on a path to recovery by 2030. Co-funded by the European Commission, Biodiversa+ brings together partners from research funding, research programming and environmental policy across European and associated countries to work on five main objectives:

1. Plan and support research and innovation on biodiversity through a shared strategy, annual joint calls for research projects, and capacity building activities.
2. Set up a network of harmonised schemes to improve monitoring of biodiversity and ecosystem services across Europe.
3. Contribute high-end knowledge for deploying Nature-based Solutions and valuing biodiversity in the private sector.
4. Ensure efficient science-based support for policy-making and implementation in Europe.
5. Strengthen the relevance and impact of pan-European research on biodiversity in a global context.

More information: https://www.biodiversa.eu/

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Executive Summary

The goal of this report is to understand the state of deployment of novel technologies for biodiversity monitoring, to assess their use across Biodiversa+ partners and to propose ways forward to promote its deployment at scale. This document **builds upon the previous report** "Biodiversa+ survey towards a roadmap on biodiversity monitoring novel technologies and approaches". In this second version, we have achieved a wider representation of Biodiversa+ partners and expanded our knowledge of their deployment of novel technologies. We have also added remote sensing methods and included expert consultations that helped us build a roadmap providing a set of key strategic recommendations, to enhance the use of novel technologies for biodiversity monitoring at (sub)national and transnational scales.

To build this roadmap, we conducted a survey in 2024 and updated it in 2026 for six novel technologies: bioacoustics, camera traps, environmental DNA/genomics, sensor networks, Unmanned Aerial Vehicles/drones and remote sensing. The survey asked Biodiversa+ partners about the deployment status of their technologies, their targeted taxa and the Essential Biodiversity Variables measured. It also asked about the challenges and constraints they face in deploying these technologies. During the Biodiversa+ Barcelona events in 2025, we also consulted the wider Biodiversa+ network and other collaborators who are experts in novel technologies about the goals, barriers and main progress towards implementing these technologies on a large scale. Overall, our survey revealed **significant variability in technology deployment.** Some taxa and environments are still in their initial stages of deployment or have only expressed an intention to adopt these novel technologies. In contrast, others have achieved full deployment in operational environments for a number of taxa, such as birds and mammals. Full deployment is generally more common in terrestrial environments. In addition, we found that **technologies aimed at the species and community levels** are currently more developed than those aimed at monitoring ecosystem features.

The following **strategic recommendations** are offered to further advance the routine implementation of novel methodologies for biodiversity monitoring: 1) **coordination mechanisms and bodies** need to be explored and pursued further to facilitate interdisciplinary collaboration and **agree on standards, best practices and avoid duplicated efforts**; 2) special attention should be paid to **cooperation with the private sector**, as this is a key stakeholder for technological advancement and holds a potential funder role in collaboration with public sources; 3) supporting and fostering **collaborative data infrastructures** will help reduce duplicated efforts and overall costs, produce FAIR outputs and favour exchange; 4) promoting accessible and reliable **databases and libraries** will enable the **validation, comparability and reliability** of novel technology data; 5) novel technology implementation requires **new expertise positions** in data, software development, technology and coordination, which must be combined with the current ecological and biological expertise. Furthermore, 6) the implementation of novel technologies should allow **long-term monitoring trends**, for which **integration plans** must be designed. Finally, 7) local or pilot initiatives should **align with national, regional and international organisations and policy needs** wherever possible. Biodiversa+ will continue to support joint ventures and activities aimed at enhancing collaboration and knowledge transfer to help deploy these novel technologies. This is essential to achieving the larger goal of harmonising this rapidly growing source of biodiversity monitoring data across Europe.

Introduction

One of the main objectives of Biodiversa+, the European Biodiversity Partnership, is to promote and support transnational biodiversity monitoring by building a transnational (pan-European) network of harmonised monitoring schemes on common priorities for Biodiversa+ members. Biodiversa+ partners are representatives of European countries or sub-national regions participating in the partnership. To this end, Biodiversa+ works on the support for the development and deployment of new technologies and approaches for biodiversity monitoring and aims at building a roadmap that shows the current state of deployment of novel technologies across Europe and partners. To achieve this, we released a survey to Biodiversa+ partners in 2024 (Ramilo-Henry et al. 2024), and updated it in 2026, in order to collect data on the state of deployment of operational entities that use novel technologies for biodiversity monitoring aimed at supporting EU Biodiversity strategy 2030 and national and subnational counterparts. In addition, we gathered Biodiversa+ partners' and other key stakeholders' views on how to favour deployment of novel technologies across Europe during a Science Café exercise at the first Biodiversa+ Science Fair event in Barcelona in May 2025. The potential of these novel technologies has been recognised by biodiversity research and monitoring activities, but their actual level of deployment in policy-relevant biodiversity monitoring still needs to be improved as major bottlenecks have been identified in previous assessments.

This roadmap will guide future Biodiversa+ work on novel technologies for biodiversity monitoring. This includes organising capacity-building events and building on the work of our key collaborator, EuropaBON (see Deliverable 4.2 by Dornelas et al., 2023), who consulted experts in their network about the use of novel technologies and their technology readiness level. It also includes the WILDLABS 'State of conservation technology' reports (WILDLABS 2021, 2023, 2025). Collaborating with other key actors in the biodiversity monitoring community, such as Horizon projects dealing with the implementation of novel technologies (e.g. MARCO-BOLO, OBSGESSION and MAMBO), the BioAgora Monitoring Knowledge Expert Network (KEN), National Biodiversity Monitoring Coordination Centres (NBMCCs) proposed by Biodiversa+ and the EU parliament preparatory action for the EU Biodiversity Observation Coordination Centre (EBOCC) will reinforce Biodiversa+'s work towards the implementation of novel technologies for biodiversity monitoring.

This report will present the definitions and methodologies used by Biodiversa+ to develop this roadmap in Section 2. Section 3 will present the results of the mapping survey, investigating the trends and assessment of the state of deployment of novel technologies, as well as the associated gaps and constraints for its deployment. Section 4 will describe the Science Café discussion on the deployment of novel technologies in Europe, where different stakeholders, including researchers, policymakers, managers and representatives from the private sector, provided their insights into the current situation in Europe. Section 5 discusses the deployment level of new technologies and the targeted EBVs in relation to EuropaBON's previous report in 2023 (Deliverable 4.2) and WILDLABs reports, the targeted taxa and associated constraints, the Science Café discussions results, and how Biodiversa+'s work contributes to the actual deployment of novel technologies among partners. Section 6 will highlight the main recommendations for the large-scale implementation of novel technologies, and Section 7 will present the overall conclusions of this report.

1. Definitions and methodology of the Biodiversa+ survey

Our aim was to build a roadmap using a survey designed for Biodiversa+ partners, which would help us gather information on the level of deployment of novel technologies within their organisations. This would allow us to understand the types of technologies used by Biodiversa+ partners to monitor biodiversity and how far they have progressed in their deployment, as well as identifying the challenges they face in implementing these novel technologies. This general overview can help indicate where to focus efforts within the partnership and guide future efforts and investments at EU level, making them more time- and cost-efficient.

We adopted the EuropaBON deliverable 4.2 definition of novel technology: a methodology and technology that is "not yet widely applied in biodiversity monitoring, regardless of when proof of concept was published or otherwise released" (Dornelas et al., 2023). We developed a first version in 2024, when we limited our survey to five novel technologies to gain a deeper understanding of each method. In the present 2026 update, we have also included remote sensing as a technology to be evaluated, due to its relevance at the European level, particularly for ecosystem-targeted EBVs. To ensure comparability of the results between the 2024 and 2026 surveys, we have kept UAVs/drones and remote sensing as separate technologies, despite acknowledging that remote sensing approaches typically incorporate UAVs/drones. The novel methodologies selected and the structure of our survey (Annex I) were based on the EuropaBON deliverable 4.2 and the WildLabs survey (WILDLABS, 2021; Speaker et al 2022) as references. EuropaBON consulted experts in novel methods for biodiversity monitoring to assess their suitability for large scale deployment across Europe and evaluated the technology readiness level of all identified tools. WILDLABs State of Conservation Technology reports gather the perspectives and needs of the global conservation technology community and describe trends that highlight changes and progress in the fields of technology for conservation at global level. The surveyed novel technologies in our report were the following:

- **Bioacoustics**: The production, transmission, and reception of animal sounds in nature. Examples of the use of novel bioacoustics methods include but are not limited to species classifiers using artificial intelligence (AI) (e.g. BirdNET).
- **Camera-based sensors**: remotely operated devices used to record wildlife activity. These can be left in the field for extended periods of time and can be activated to capture photos or videos.
- **eDNA/Genomics**: A technique involving the collection of DNA or RNA samples from the environment, e.g. water, soil, sediment or air. eDNA is analysed using different molecular techniques, including metabarcoding, shotgun sequencing and quantitative PCR.
- **Sensor networks**: These are highly distributed networks of sensor devices, usually deployed in large numbers to monitor an environment or system, that gather environmental information, such as temperature, pressure, and relative humidity.
- **Unmanned Aerial Vehicles (UAVs)/drones**: Air vehicles that fly autonomously or are remotely piloted. Novel methods involving UAVs include, but are not limited to, three-dimensional (3D) mapping, aerial imaging, oblique photogrammetry, sensing, laser scanning, the Internet-of-Things (IoT), computer vision, and artificial intelligence (AI).

- **Remote sensing**: A process of gathering information about objects or areas from a distance, usually from aircraft or satellites. Examples of remote sensing methods include aerial photography, radar, and satellite imagery (Wang et al. 2010).

To understand the level of deployment of the novel technology we have used an adaptation of the NASA Technology Readiness Scale, which was also used in EuropaBON Deliverable 4.2. This scale assesses the readiness of the technology. In our case, we are only interested in the actual deployment level of the novel technology as this was our task objective. Therefore, we took the top three levels from the deployment category of the NASA Technology Readiness Scale and added our own bottom three levels that indicate levels of "no deployment" and levels of interest (see Figure 1). The survey also contained questions on the following:

- **The type of biodiversity monitoring** carried out by partners per novel technology.
- **The taxa monitored** using novel technologies (e.g., algae, amphibians/reptiles, aquatic invertebrates, birds, fish, fungi, mammals, plants or terrestrial invertebrates).
- **Essential Biodiversity Variables (EBVs)**: EBVs are defined as "the minimum set of variables needed to quantitatively measure changes in biodiversity and ecosystem service delivery systematically over time and space, with the overarching aim of standardising and coordinating biodiversity monitoring" (Quoss et al. 2024). They were initially developed by GEO BON and further developed by EuropaBON to harmonise biodiversity monitoring metrics. We asked partners which EBVs they targeted when using novel technologies for biodiversity monitoring:
  - **Genetic composition**: Effective population size, inbreeding, genetic differentiation and intraspecific genetic diversity.
  - **Species populations**: Species abundance and species distribution.
  - **Species traits**: Morphology, movement, phenology, reproduction and physiology.
  - **Community composition**: Community abundance, interaction diversity, taxonomic/phylogenetic diversity, trait diversity.
  - **Ecosystem functioning**: Primary productivity, ecosystem phenology and ecosystem disturbances.
  - **Ecosystem structure**: Ecosystem vertical profile, ecosystem distribution, live cover fraction.
- **Gaps and challenges**: faced by partners that may hinder their ability to further develop or use the novel technologies.

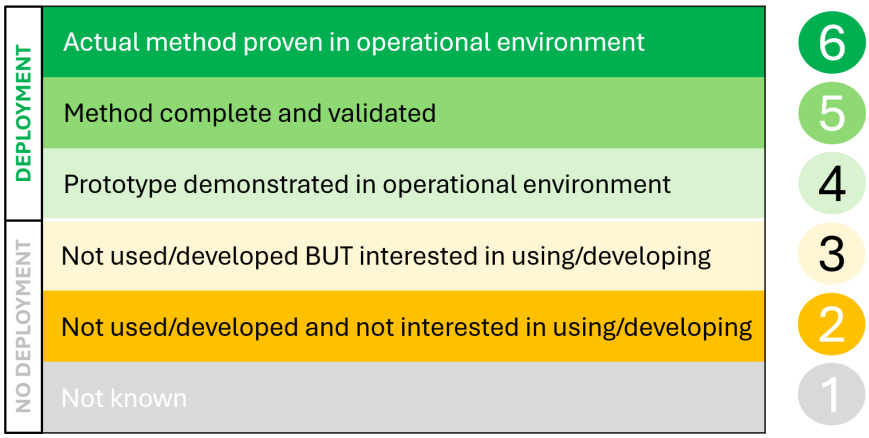

Figure 1. Adapted NASA Technology Readiness Scale. Levels 4-6 fall under one category in NASA's scale of deployment, while levels 1-3 were adapted for this report to quantify the state of no deployment.

2. State of deployment of novel technologies across Biodiversa+ partners

2.1. State of deployment per novel technologies across partners

In total, the survey received 37 responses from 23 Biodiversa+ partners: 19 at the national level and four at the sub-national level. Of these, 21 responses were provided at the initial launch of the survey in 2024 representing 17 partners, and 16 responses were provided for the 2026 update. We obtained new results from six additional partners in the latter group (see Annex II). Figure 2 shows an overview of the deployment stage of the six novel technologies among the respondents. Camera traps were deployed by the highest number of respondents overall, with 18 out of 23 partners using them in an operational environment and the remaining partners demonstrating at least a prototype. Bioacoustics were also widely deployed, with 15 out of 23 partners using them in an operational environment and six demonstrating at least a prototype. These were closely followed by eDNA, remote sensing and UAVs/drones, with 12, 11 and 10 partners deploying them in an operational environment and nice, eight and six demonstrating at least a prototype, respectively. The novel technology with the lowest level of deployment was sensor networks, with only six out of 23 partners used them in an operational environment and only four partners demonstrated at least a prototype in an operational environment. Despite being the least implemented, sensor networks received the highest level of reported interest in deployment among the non-implemented novel technologies, with six partners indicating an interest (Figure 2).

Looking at the deployment by realm, partners mostly deploy novel technologies within the terrestrial realm for all surveyed technologies except for eDNA/genomics, which was mostly applied in freshwater environments. Figure 3 shows the deployment percentages per realm and technology for those partners who reported actual deployment levels. For the marine realm in particular, these percentages refer only to partners with marine domains within their territories, and not to all responding partners. Overall, the majority of partners deploying bioacoustics, camera traps, sensor networks, UAVs/drones and remote sensing do so in the terrestrial realm (83-95% for all the aforementioned technologies, and 100% for UAVs/drones). Only eDNA/genomics approaches showed their highest deployment percentage in freshwater environments (81% of partners), compared to 67% in the terrestrial realm and 56% in the marine realm (Figure 3). With the exception of the high deployment of eDNA/genomics in freshwater environments, deployment of the remaining five novel technologies in freshwater and marine environments was at a low-to-medium level, ranging from 24% to 42%. Partners also mentioned other realms for two novel technologies: 10% reported deploying eDNA/genomics in the aerial realm, and 5% reported deploying camera traps in this realm. Additionally, 8% of partners reported deploying sensor networks for general environmental/climate ecosystem features, which we have included under the category “others” to represent all partner responses (see Figure 3).

The targeted EBVs monitored by partners varies depending on EBV groups and technology employed (Figure 5). Overall, we identify a higher tendency to monitor species populations variables (up to 100% of partners), followed by species traits and community composition (up to 69,6% partners for both). Ecosystem variables are also often targeted, with ecosystem structure more targeted than ecosystem functioning EBVs (up to 73,9% and 56,5% of partners, respectively). Genetic composition is the less targeted EBV group (by up to 21,7% of partners) (Figure 6).

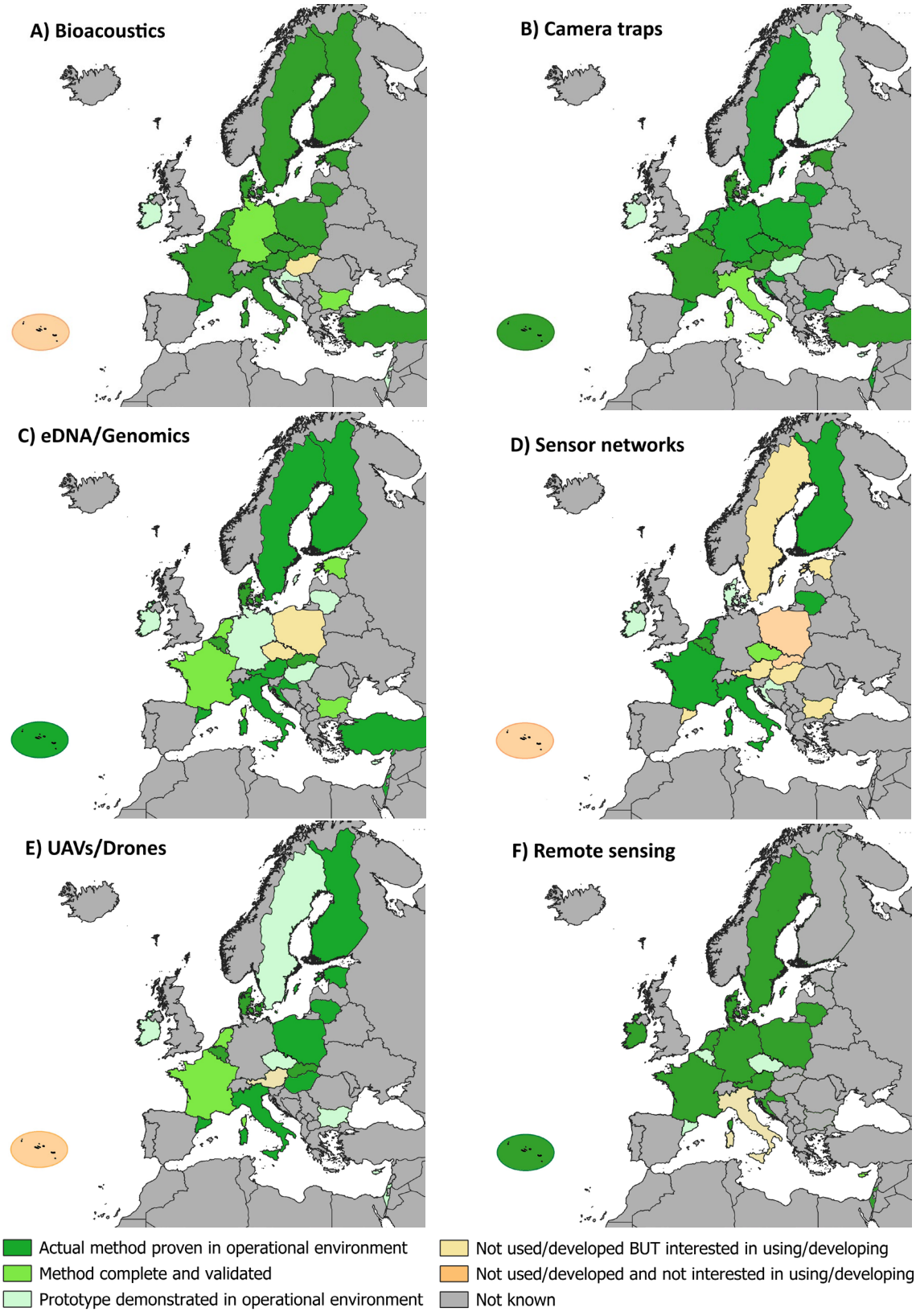

Figure 2. Reported deployment status of six novel technologies among responding Biodiversa+ partners: A) Bioacoustics, B) Camera traps, C) eDNA/Genomics, D) Sensor networks, E) UAVs/drones, F) Remote sensing. Colours indicate deployment categories according to the scale described in Figure 1. A list of partners who responded to the survey is available in Annex II.

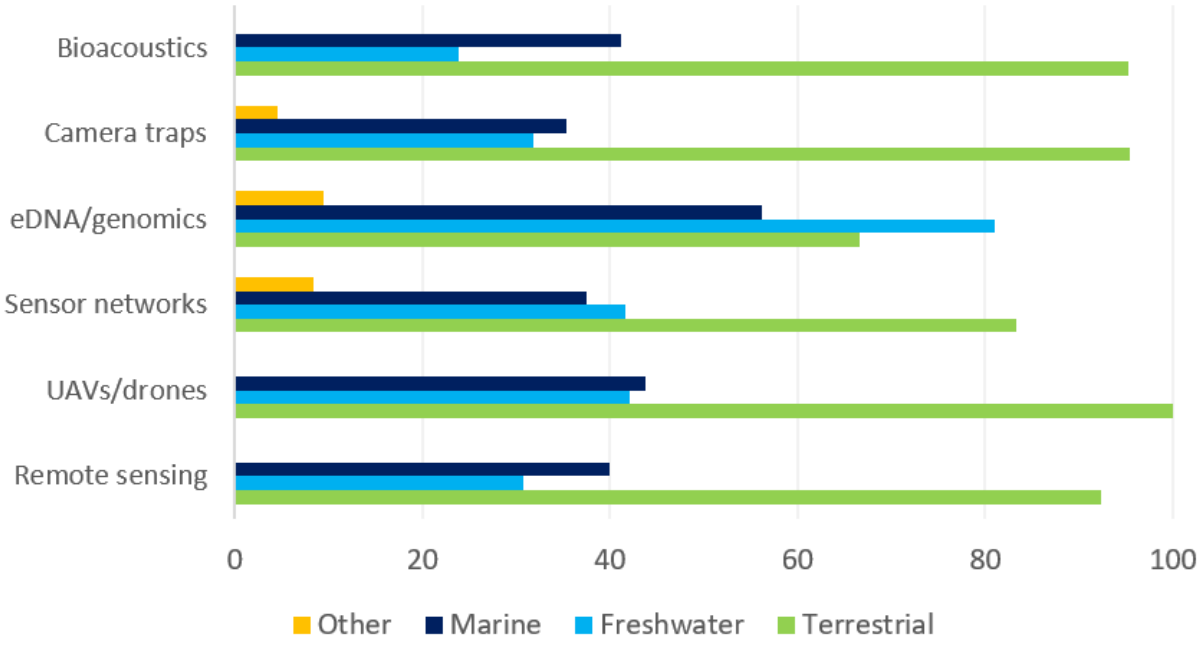

Figure 3. Percentage of partners reporting deployment of the six surveyed novel technologies per realm, i.e., marine (dark blue), freshwater (light blue), terrestrial (green) or others, e.g., aerial (orange).

2.1.1. Bioacoustics

A variety of taxa were found to be monitored using novel bioacoustics tools (Figure 4). The highest levels of deployment were found among mammals and birds (74% and 44% actual deployment, and 35% and 9% working towards deployment, respectively). In contrast, fish, terrestrial invertebrates and plants showed low levels of deployment, with only 13%, 13% and 4% of partners reporting use, respectively. However, 9-26% of all respondents expressed interest in developing/using bioacoustics methods for those taxa as well as amphibians/reptiles.

EBVs were also investigated, and species populations, (i.e., species distributions and abundances) were found to be the most commonly monitored EBVs using novel bioacoustics methods (83% and 70% of partners, respectively). Community composition and species traits EBVs were also targeted (by 9-35%, and 4-40% of partners, respectively), whereas ecosystem and genetic-related EBVs were the least common EBVs (between none and 22% of respondents), see Figure 5.

Survey respondents have described several applications of bioacoustics in biodiversity monitoring. Many have mentioned using different devices such as Wildlife Acoustics Song Meters, hydrophones, ultrasound detectors, AudioMoths, Batlogger A+, BUGGS, CPos, Dictaphone Olympus DM-720 or Pettersson D1000X, and microsound detectors. A few also mentioned the use of analysis software, primarily BirdNET, Raven Pro, BatExplorer and BatScope. Partners have also indicated some use of data synthesis systems for biodiversity monitoring using novel bioacoustics methods (see Table 1).

2.1.2. Camera traps

Camera traps were also used to monitor a wide range of taxa (Figure 4). The highest levels of deployment were seen for mammals (65% of partners reporting deployment), followed by birds (26%) and terrestrial invertebrates (22%). The lowest levels of deployment were observed for fish, amphibians/reptiles and aquatic invertebrates with only 4-17% of partners using camera trap methods. Some partners have already demonstrated a prototype in the operational environment, particularly for mammals, birds, fish, plants and terrestrial invertebrates. Of those not yet deploying, 13% and 9% reported interest in using them for fish, and amphibians/reptiles, aquatic and terrestrial invertebrates, respectively.

The most common EBVs monitored with novel camera trap methods were species populations (78-87% of partners), followed by some species trait EBVs (up to 52% of partners) and some community composition EBVs (up to 39% of partners). Ecosystem structure, ecosystem functioning and genetic composition EBVs were very rarely monitored with this method (up to 26% of partners for the first two, and up to 13% for the third) (Figure 5).

Survey respondents have described several uses of camera sensors in biodiversity monitoring, using devices such as AMI traps, Model Wilsus, Wildlife Monitoring Solutions, the Automated Wildlife camera network, motion sensor cameras, CamAlien Monitoring, Home Vista Secacam and the Digital Trail Camera OGM H501 and cameras by Reolink or Burrel. Respondents also indicated that they had used data synthesis systems to monitor biodiversity alongside novel camera trap methods. The systems used by partners are listed in Table 1.

2.1.3. eDNA and genomics

eDNA/genomics methods are being used to monitor all the taxa included in this questionnaire. Actual deployment ranges from 43% for aquatic invertebrates to 4% for birds and other taxa, such as myxozoa parasites. This is the only novel technology with the potential to be applied to all taxa. Additionally, prototypes were demonstrated in an operational environment by 4-17% of partners for all taxa, and approximately 4-22% of partners expressed interest in using this technology (Figure 4).

The most commonly monitored EBV using novel eDNA methods was species population (61-74% of partners), followed by community composition (9-57% of partners). In contrast to the results for other surveyed technologies, some partners used this technology to monitor genetic composition EBVs (9-18% of partners). The least monitored EBVs were those related to ecosystem functioning and structure (up to 13% of partners) (Figure 5).

Survey respondents described several techniques for using eDNA in biodiversity monitoring. These included eDNA barcoding and metabarcoding, airborne eDNA, IOLR (12S genetic marker), and targeted detection techniques such as ddPCR, qPCR and PCR-based techniques (e.g. microsatellite markers, mitochondrial DNA analysis, genetic sex determination). Some population genomics were also mentioned, such as bat genomics, amplicon sequencing, and RadSeq for genetic composition.

Respondents indicated limited use of data synthesis systems for monitoring biodiversity using novel eDNA/genomic methods. Non-AI computational tools were most commonly used, for biodiversity monitoring across all taxa. Others, such as mobile applications, data management and processing tools, protected area management tools, and artificial intelligence tools were used for specific taxa groups (see Table 1).

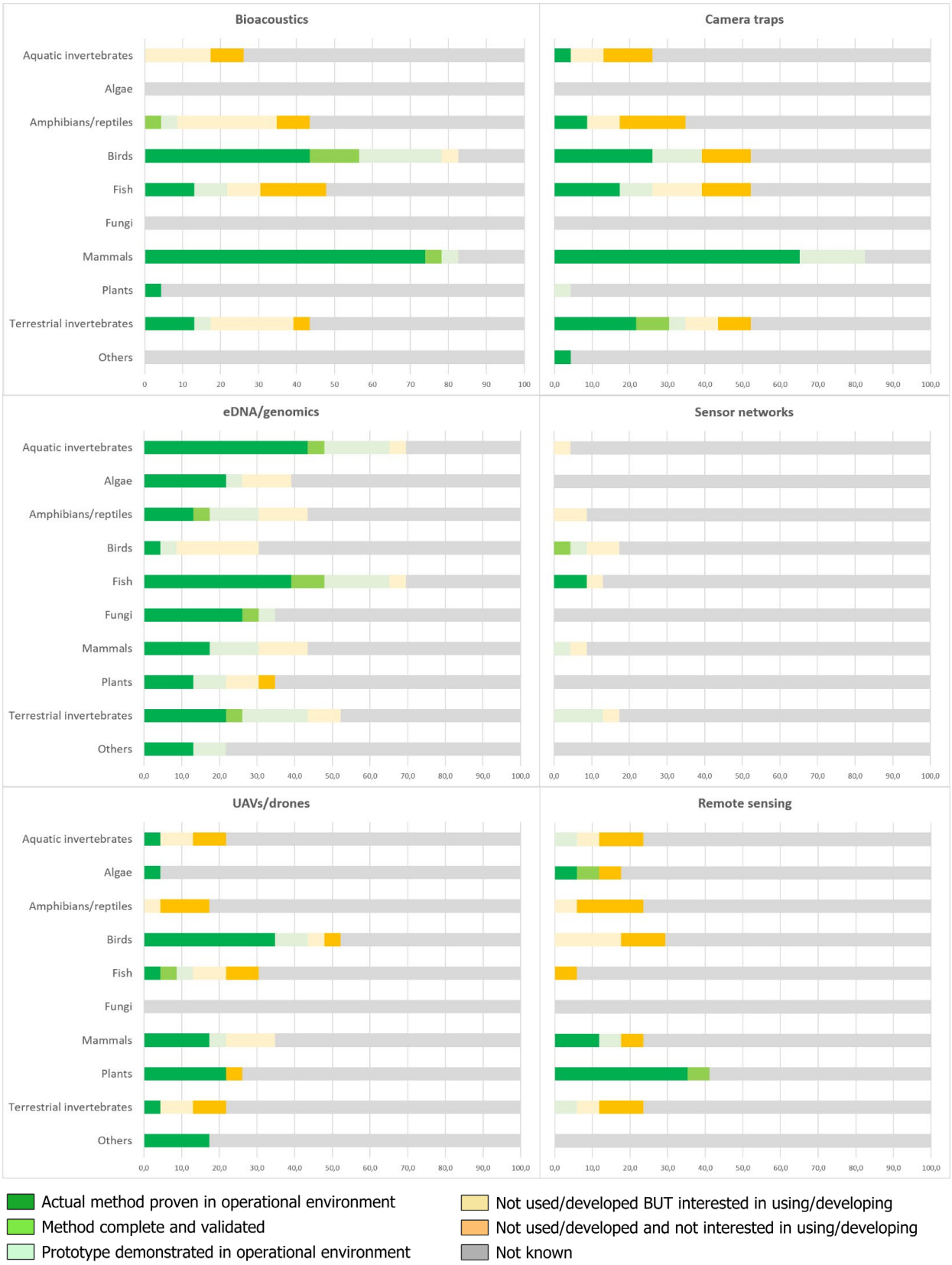

Figure 4. Percentage of responding Biodiversa+ partners reporting different levels of deployment of novel technologies for monitoring the taxa listed above Colours indicate deployment categories according to the scale described in Figure 1.

2.1.4. Sensor networks

Sensor networks were found to be under-deployed, with only six out of 23 partners deploying this technology. This is evident from the higher proportion of respondents selecting the “unknown” and “no development” classes selected or providing no response (Figure 4). Fish were the only taxon for which sensor network methods have been deployed in the operational environment by 9% of partners, while only 4% of partners had validated methods for birds in the operational environment. Some partners (4-9%) expressed an interest to deploy this novel technology for different taxa (see Figure 4).

As very few respondents use sensor networks, only a small proportion of respondents monitor any EBVs. The most common were ecosystem functioning (up to 22%) and species populations (4-13%) (Figure 5).

The few sensor network methods that were described by partners were mostly used in monitoring programmes to measure ambient and abiotic conditions. The used devices varied greatly and included TMS4 loggers, Ruisdael, RIVM, GPS sensors, Barotrauma Detection System sensors and Fish Backpack sensors by TalTech Biorobotics, 3D mobile bird radars, FerryBox systems and profiling buoys and Argo floats, LOOP network, flux towers and organic sensors. In addition, one respondent described a highly integrated system comprising several microclimate stations that collect various air and soil and vegetation parameters. This system is remotely accessible and powered by photovoltaic systems, with automated data and image collection.

Respondents indicated very little use of data synthesis systems for sensor networks, with only three partners using data management processing tools for mammals, birds and terrestrial invertebrates, and only one using artificial intelligence tools for monitoring terrestrial invertebrates (Table 1).

2.1.5. UAVs and drones

A high number of taxa are being monitored using drones. Partners have reported the highest levels of deployment for birds, plants and mammals and other taxa, with 35%, 22% and 17% of partners deploying them, respectively. Within the category ‘Others’, we have included those answers by partners that refer not to taxa, but other biodiversity features, like ecotopes or particular terrestrial and marine habitats. However, several taxa have low deployment levels, including fish, algae, and terrestrial and aquatic invertebrates, all of which have a deployment level of 4% (Figure 4).

In terms of the EBVs monitored with drones, a dispersed proportion of respondents used a variety of EBVs, except for genetic composition (Figure 5). The most common EBVs were species distributions (35-44% of partners), followed by ecosystem functioning (up to 35%), ecosystem structure (up to 30%), community composition (up to 26%), and species traits (up to 17%).

Respondents to the survey have described several uses of drones for biodiversity monitoring, such as standard flying and sailing drones for video and photography, and remotely operated vehicles (ROV), e.g., Gladius M2, for underwater monitoring, with multispectral sensors, for NDVI measurements and LiDAR and RGB cameras.

Respondents indicated little use of data synthesis systems for monitoring biodiversity with novel drone methods (25% of all respondents). Of those, most kinds of data synthesis tools were used for several taxa, except for AI tools (see Table 1).

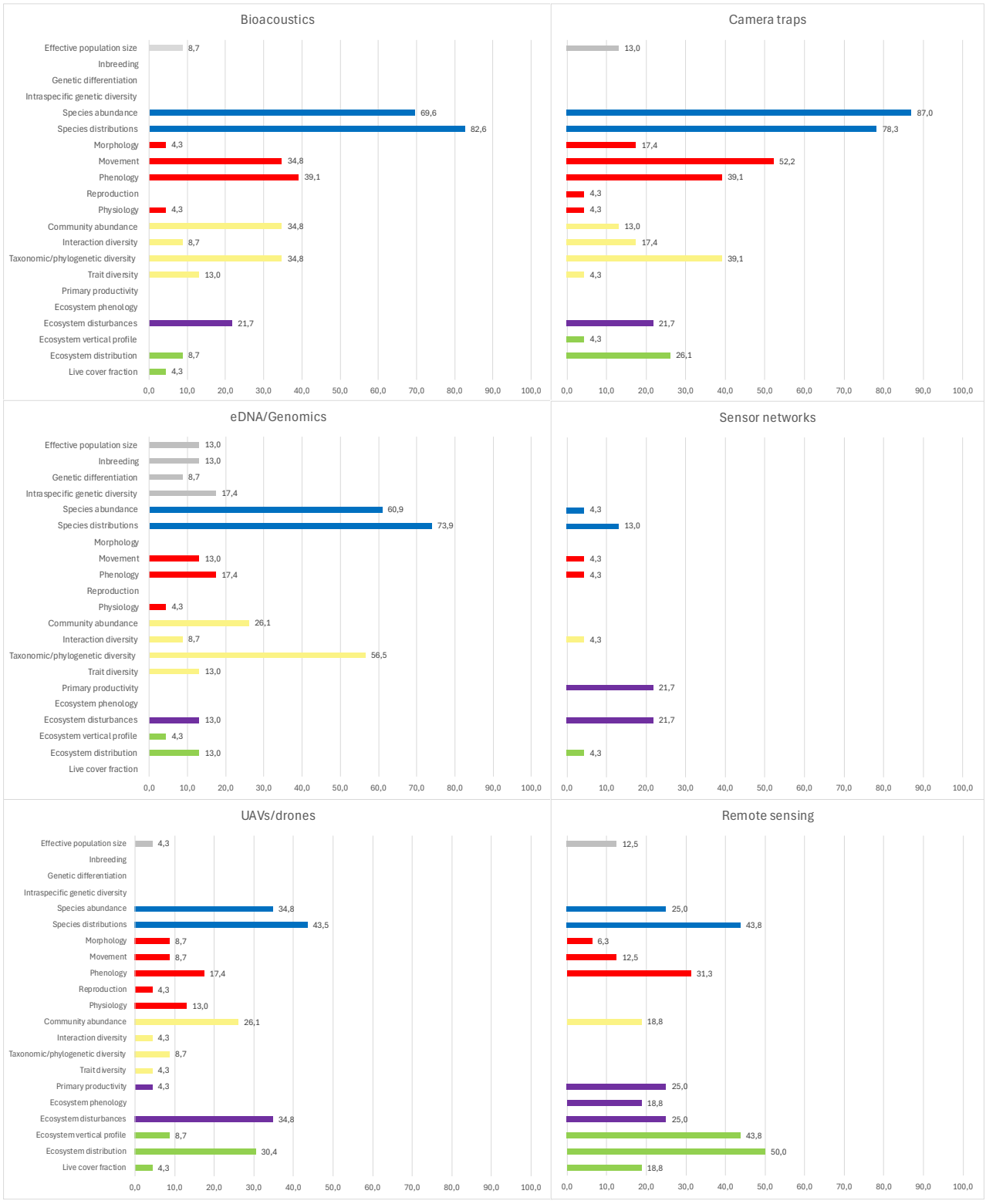

Figure 5. Monitored Essential Biodiversity Variables (EBVs) using all surveyed novel technologies. The following colours represent grouped variables: genetic composition (grey), species populations (blue), species traits (red), community composition (yellow), ecosystem functioning (purple) and ecosystem structure (green). Percentages represent the number of Biodiversa+ partners reporting use of novel technologies to monitor each EBV.

2.1.6. Remote sensing

It is important to note that for remote sensing we obtained a total of 17 responses from partners, since this novel technology was not initially included in the 2024 survey. Plants were the most commonly targeted taxon, with 35% of partners deploying this novel technology in the operational environment. This was followed by mammals and algae, with 12% and 6% of partners actually deploying the technology, respectively (Figure 4). Although deployment was rather low for the surveyed taxa, 6-18% of partners reported interest in applying this technology to birds and terrestrial and aquatic invertebrates.

The most targeted group of EBVs by partners for this technology were ecosystem structure EBVs (19-50% of partners), followed by species population (25-34%) and ecosystem functioning EBVs (19-25%). The least targeted EBVs were species traits (up to 31% of partners), and community and genetic composition very low targeted (up to 19% of partners) (Figure 5).

The main remote sensing techniques reported by partners were satellite-based Earth Observation data (e.g. orthophotos and Sentinel-2), LiDAR thermal imaging, aircraft, aerial imaging for 3D vertical profiles, radar and laser scanning. Partners also mentioned platforms, such as Copernicus Land Monitoring Service (CLMS) and aerial or modelled products based on in situ data. Partners indicated some use of data synthesis systems for remote sensing, particularly for mammals and plants (see Table 1).

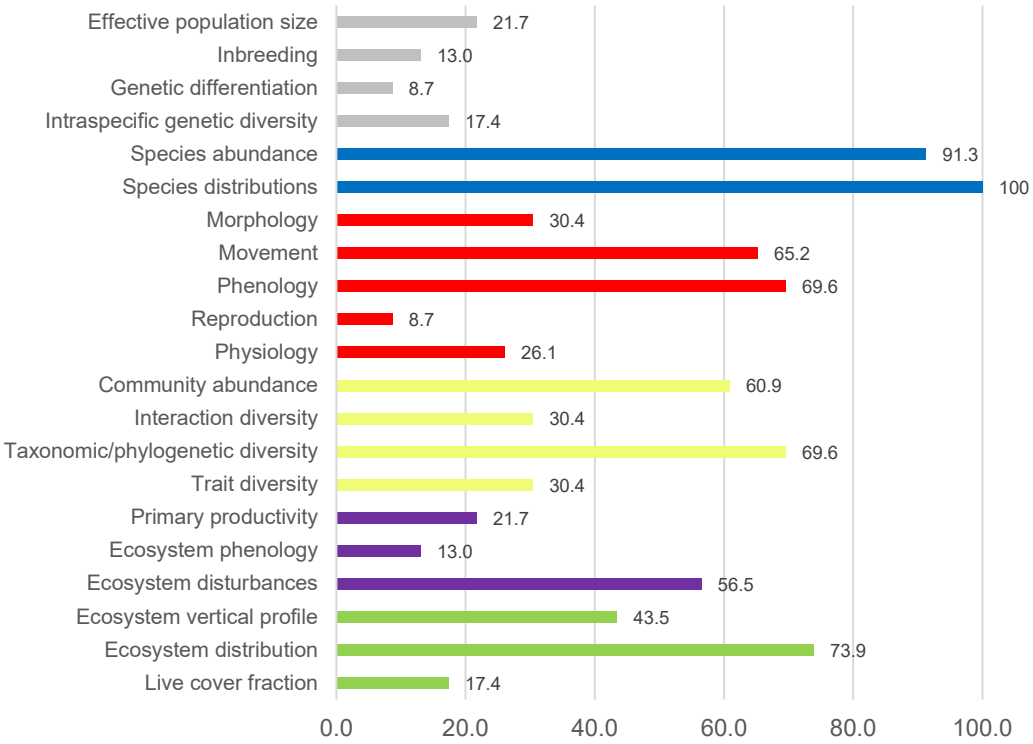

Figure 6. Overview of monitored Essential Biodiversity Variables (EBVs) reported by Biodiversa+ partners. The following colours represent grouped variables: genetic composition (grey), species populations (blue), species traits (red), community composition (yellow), ecosystem functioning (purple) and ecosystem structure (green). Percentages represent the number of Biodiversa+ partners reporting use of novel technologies to monitor each EBV.

Table 1. Overview of the use of data synthesis systems for different taxa reported by partners for biodiversity monitoring with all surveyed novel technologies.

	Bioacoustics	Camera traps	eDNA/ genomics	Sensor networks	UAVs/ drones	Remote sensing
Mobile applications	Birds Mammals	Aquatic invertebrates Birds Mammals Terrestrial invertebrates	Fish Mammals Terrestrial invertebrates		Aquatic invertebrates Birds Mammals Plants Terrestrial invertebrates	Mammals Plants
AI tools	Birds Mammals Terrestrial invertebrates	Aquatic invertebrates Birds Mammals Terrestrial invertebrates	Aquatic invertebrates Amphibians/ reptiles Fish Terrestrial invertebrates	Terrestrial invertebrates		Plants
Data management and processing tools	Aquatic invertebrates Amphibians/ reptiles Birds Fish Mammals Terrestrial invertebrates	Aquatic invertebrates Birds Fish Mammals Terrestrial invertebrates	Aquatic invertebrates Amphibians/ reptiles Birds Fish Mammals Terrestrial invertebrates	Birds Mammals Terrestrial invertebrates	Aquatic invertebrates Birds Mammals Plants Terrestrial invertebrates	Mammals Plants
Non-AI computational tools	Mammals Terrestrial invertebrates	Birds Mammals	All taxa		Aquatic invertebrates Birds Mammals Plants	Plants
Protected Area management tool	Birds Mammals Terrestrial invertebrates	Mammals	Amphibians/ reptiles Fish		Aquatic invertebrates Birds Mammals Plants Terrestrial invertebrates	Mammals Plants

2.2. Gaps and constraints of the state of deployment of novel technologies

Partners reported facing a variety of constraints (25 in total grouped into eight categories) when deploying the selected novel technologies (Figure 7). Data issues such as data storage, analysis, synthesis, and integration were the most commonly reported constraints (29% of all constraints across all novel technologies), followed by other common constraints such as costs, lack of capacity/training and technical difficulties (20%, 19% and 17% of all constraints, respectively, across all novel technologies).

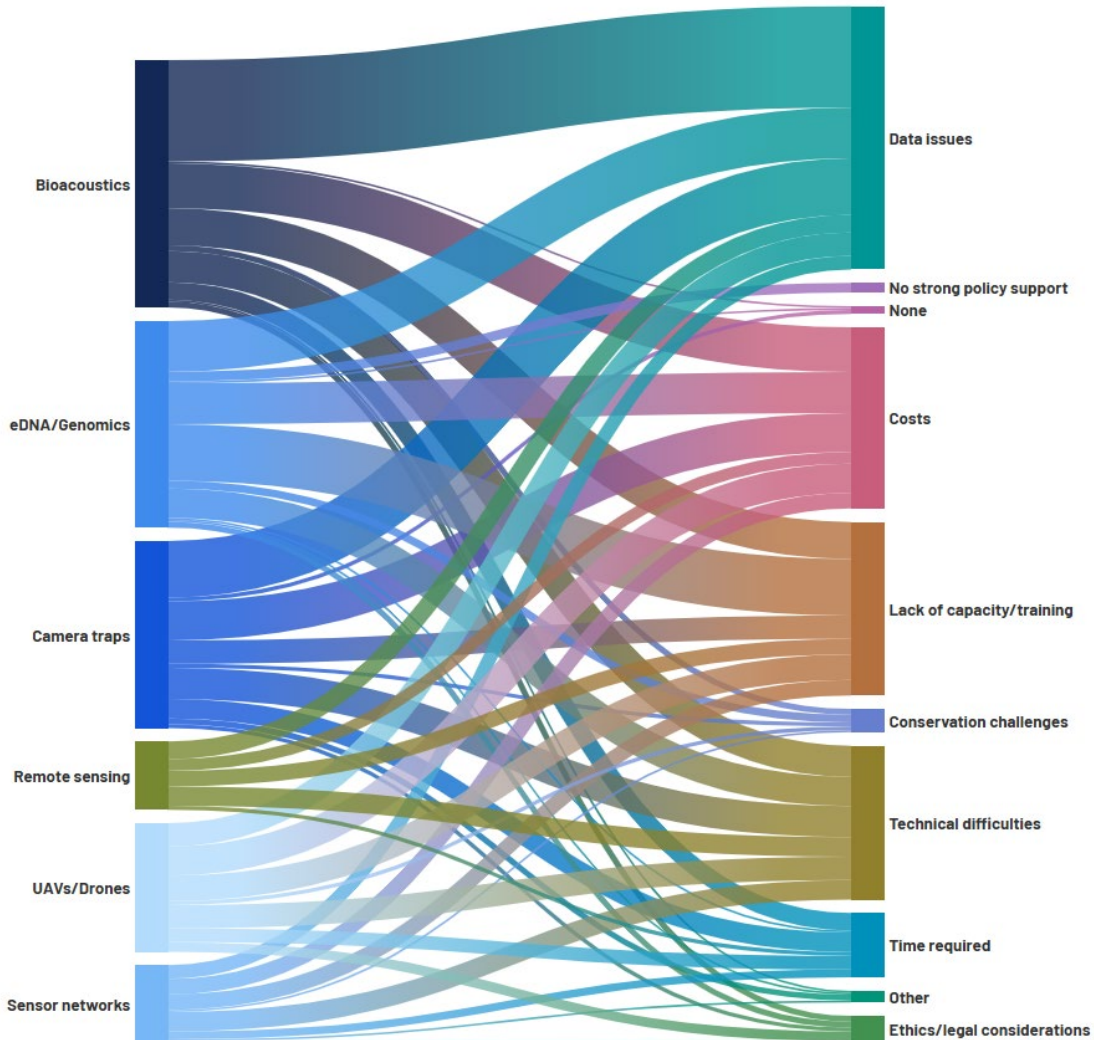

Figure 7. Sankey diagram displaying the number of challenges and constraints (right side) faced by Biodiversa+ partners in the development of novel technologies (left side). Coloured bands indicate relationships between the challenges or constraints and novel technology type.

2.2.1. Bioacoustics

Out of all partners deploying bioacoustics methods, 82% indicated facing constraints in their deployment of novel bioacoustics methods for biodiversity monitoring, with records of a total of 22 different constraints. The most common constraints were data-related (41% of partners), specifically data analysis,

storage and integration. Costs, lack of capacity/training and technical difficulties were also common constraints, cited by 18%, 15% and 13% of respondents, respectively. Six respondents mentioned plans to deploy bioacoustics methods further. A few mentioned the monitoring of new taxa, while others mentioned using new methods such as automation of bat echolocators.

2.2.2. Camera traps

Partners mentioned facing 16 different challenges related to the deployment of camera traps, with 82% of all respondents mentioning at least one. Data-related issues, particularly data storage and data integration, were the most frequently reported, with 30% of partners reporting them. Other common constraints were costs (cited by 21% of partners), technical difficulties (cited by 17% of partners) and lack of capacity/training (cited by 13% of partners). Several respondents mentioned difficulties with automating the species identification process, citing a lack of suitable software. Notably, 11 respondents expressed interest in further developing their camera-based methods, with most aiming to expand the use of automation and machine learning for image analysis.

2.2.3. eDNA and genomics

Twenty constraints were mentioned for eDNA/genomics methods by 87% of the Biodiversa+ partners. Lack of capacity or training was the most common constraint (mentioned by 27% of partners) closely followed by data issues (mentioned by 25% of partners), specifically in difficulties in comparing results and lack of reference data. Other common constraints found for the deployment of novel eDNA/genomics methods were cost and technical difficulties, mentioned by 20% and 14% of partners, respectively. Nine respondents mentioned plans to further develop their use of eDNA novel methods for routine species monitoring, a few by exploring international collaboration or addressing current library gaps.

2.2.4. Sensor networks

Only 48% of partners mentioned constraints related to the deployment of sensor networks, indicating a total of 15 different constraints. Technical difficulties were the most common constraint (mentioned by 25% of partners), followed by lack of capacity/training and costs (20% of partners for both constraints). Four respondents mentioned considering further developing their sensor network methods.

2.2.5. UAVs and drones

Partners mentioned 14 different challenges related to the deployment of UAVs/drones, with 70% of partners mentioning at least one. Costs were the most common constraint (23% of partners), but partners also reported lack of capacity or training (20% of partners) and technical difficulties and data issues (18% of partners for both). Five partners mentioned plans to further develop their drone methods for biodiversity monitoring.

2.2.6. Remote sensing

A total of 63% of partners mentioned 10 different challenges related to the deployment of remote sensing techniques (except for drones). The most common constraints were technical difficulties (29% of partners), data issues, in particular referring to data storage and integration (26% of partners), and lack of capacity or training (23% of partners). Other common constraints were lack of funding (17% of all respondents). Three partners mentioned interest to further develop their remote sensing methods.

3. Goals, barriers and progress towards implementation of novel technologies

3.1. Science Café discussion dynamics

In May 2025, Biodiversa+ organised a series of capacity-building events in Barcelona on the theme of "Connecting people, technology, and data for biodiversity monitoring" (highlights and content available here: Highlights from the Biodiversity Monitoring Science Fair – Biodiversa +). During this week, we held a two-day Science Fair on biodiversity monitoring using novel technologies, where we welcomed a marketplace for the private sector to showcase novel technology devices. There were also presentations from European Horizon projects showcasing the latest developments in cutting-edge technologies, as well as a poster session on the various applications of novel methods, and panel sessions on bioacoustics and on eDNA. An interactive discussion session was held with the Horizon project MARCO-BOLO on reporting biodiversity monitoring using eDNA in marine environments. Additionally, we initiated a collaboration with the BioAgora Monitoring Knowledge Expert Network (KEN), which encouraged several key European projects to participate in the event.

On the last day, we held a Science Café on the topic of "Use and implementation of novel technologies for biodiversity monitoring" to explore the implementation of novel technologies across Europe in more depth. During this session, attendees rotated between six discussion stations, each focusing on a different aspect of the use of novel technologies.:

1. **Harmonisation of common methods and protocols**
2. **Data management and storage**
3. **Upscaling methods and protocols for policy**
4. **Costs and expertise required for first implementation**
5. **Integration of historical and novel technology data and methods**
6. **Knowledge transfer and capacity building**

These topics were identified by the organisers as being the most challenging for the implementation of novel technologies. To enable all participants to discuss each topic, six 20-minute rounds were scheduled. The three-hours session comprised two-hour discussion sessions, with a 30-minute break between them, and 10 minutes at the beginning to explain the process and answer questions, and 20 minutes at the end for presenting highlights of the discussions. Groups of participants were pre-designated using the list of expected participants for the day. An equal number of people were placed in each group (six in total, one per round), with a maximum of 15 people per topic/table. Participants from different tables were also mixed in each round. In other words, by changing tables and topics, participants would also change discussion groups. This approach was chosen to minimise repeated group dynamics, maximise diverse conversation and foster networking. Each participant received a personalised schedule for the workshop by signing the registration sheet at the beginning of the event (which was mandatory). This meant that all participants knew in advance which table to go to in each round, with the help and guidance of the on-site team.

Each table was led by two experts: one presented the topic and encouraged participants to engage in conversation, while the other took notes on group discussions and provided support if needed. A total of 15 people acted as facilitators for the session: 12 at the tables and three coordinating. An A2 sheet of paper was placed at each table for each round of discussions (18 in total, with three rounds per table and post-it notes used on both sides of the sheet), to allow attendees to capture their ideas using the Speedboat dynamic (Figure 8). In brief, the workshop uses four elements: a sailboat, a lighthouse, anchors and winds. Each discussion group is represented by a sailboat, i.e., a group of people working together towards a common goal. Together, the group needs to identify their goals or where they wish to be headed, represented by the lighthouse, i.e., the ideal situations or common objectives they would like to achieve in the near future. They should then identify anchors, representing current problems or challenges that prevent or slow down the process of achieving the goals, and winds, representing positive actions or processes that help move forward more quickly towards the objectives.

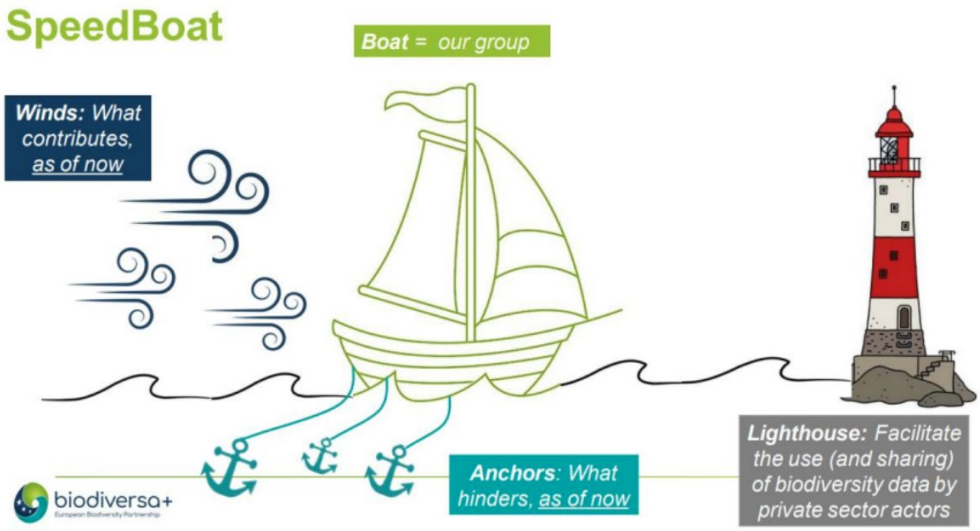

Figure 8. Graphical representation of the speedboat exercise used to frame and stimulate discussions around different topics related to novel technology implementation.

In addition, at the start of the session, we asked the participants to indicate their role in biodiversity monitoring by selecting a coloured sticker from the following options: (i) **scientist** (yellow), (ii) **policy-maker** (red), (iii) **biodiversity manager** (blue) and (iv) **private sector** (green). Participants placed a coloured sticker on their name tags. At the end of each round, before moving to the next topic of discussion, participants examined all the ideas discussed on the A2 paper during that round and placed their coloured sticker on the Post-it note representing the discussion topic that they believed to be the highest priority. This enabled us to identify visually whether priorities were shared among different stakeholders. At the end of the session, the expert moderators identified the most relevant topics and presented them as highlights to all participants.

3.2. Science Café discussions

This section summarises the views and insights from a total of 61 participants (34 scientists, 9 policymakers, 6 managers and 12 private sector representatives) who took part in the Science Café discussions at the Biodiversa+ Science Fair events in Barcelona. Using the Speedboat exercise described in the previous section of this report, we collected the main impressions and ideas of all participants regarding the current state of implementation of novel technologies and how to move forward, writing them on post-it notes to facilitate comparison and collation. Participants made 163 comments on how to achieve the identified goals (lighthouses), 173 comments on the barriers they face (anchors) and 179 comments on factors that facilitate progress (winds). After sharing their own views, the participants were then asked to prioritise one idea from those collected.

Overall, the topics most frequently mentioned across all tables could be categorised as follows: the need for harmonisation and standardisation; data management, workflows and frameworks; fostering long-term monitoring; infrastructures, funding and support; and knowledge dissemination (i.e., connection to policy, capacity building, expertise generation, and interdisciplinary collaboration). The specific ideas discussed per topic were as follows.

3.2.1. Harmonisation of common methods and protocols

The most frequently mentioned **goals** were the harmonisation of protocols and guidelines, followed by standardisation, and data management and workflows. Regarding **barriers**, participants most often identified challenges in implementing protocols and workflows, and stakeholder conflict. Other common barriers included a lack of standardisation and data mobilisation and accessibility, costs, historical debts and the need and difficulty of choosing indicators. **Actions favouring progress** included interdisciplinary collaboration (e.g. international cooperation, cooperation between scientists and policymakers, such as Biodiversa+ and EJP Soil; public involvement; regular group meetings; etc.), current tools to enhance harmonisation (such as the use of EBVs, stricter project reporting, flexibility in methods, and the use of AI) and standardisation. Other identified progress were the current state of development of novel technologies, the creation of guidelines, and current infrastructures and centralized data portals, like GBIF or OBIS (Figure 9).

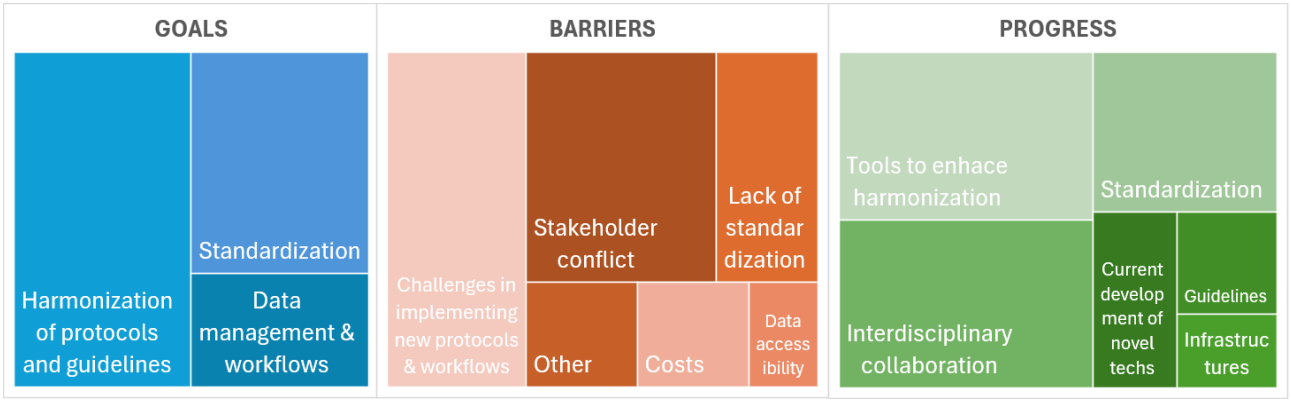

Figure 9. Results from the discussions on "harmonisation of common methods and protocols". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

Among these topics, participants identified several key **priorities**. As a goal, they identified the development of guidelines mentioned by scientists, policymakers and the private sector. As barriers, participants highlighted the trade-off between transnational harmonisation and non-harmonised data from the past (mentioned by scientists, policymakers and managers), the problematics of avoiding duplicated efforts (mentioned by scientists and policymakers) and the high number of different stakeholders (mentioned by all except managers).

Participants identified several actions that facilitate progress: all stakeholders mentioned interdisciplinary collaboration, particularly international cooperation in monitoring programmes such as the Common Bird Census and Butterfly Monitoring Schemes, as well as joined initiatives or infrastructures such as GBIF and the IUCN.

Participant groups disagreed on several priorities: Frameworks and regulation development through co-creation workshops to define protocols were mentioned by all, except policy makers; promotion of metadata and its standards were mentioned by all, except the participants from the private sector; and the current development of novel technologies methods was mentioned by all, except managers.

3.2.2. Data management and storage

The identified **goals** reflected the need for standardisation and shared infrastructures, as well as the importance of increasing long-term storage capacity, establishing frameworks for different data types, and the need for centralized guidance for decision-making. Participants identified several main **barriers**: current data governance and tradition; lack of standardised methods and protocols; storage optimization; costs; and existing data flows. Regarding **actions favouring progress**, participants highlighted three main points: shared infrastructures and available tools (e.g. current platform and repositories adapting to novel technologies, the use of AI and machine learning, cloud services, the use of EBVs, etc.); the generation of new capacities and expertise (e.g. growing recognition of standards and new formats, training workshops for data management, the expertise of data officers and computer scientists, large synthesis and data policy publications, etc.); and fostering of standardisation and accessibility (open access, FAIR data (Wilkinson et al. 2016), sharing historical data, cross-comparability, etc.) (Figure 10).

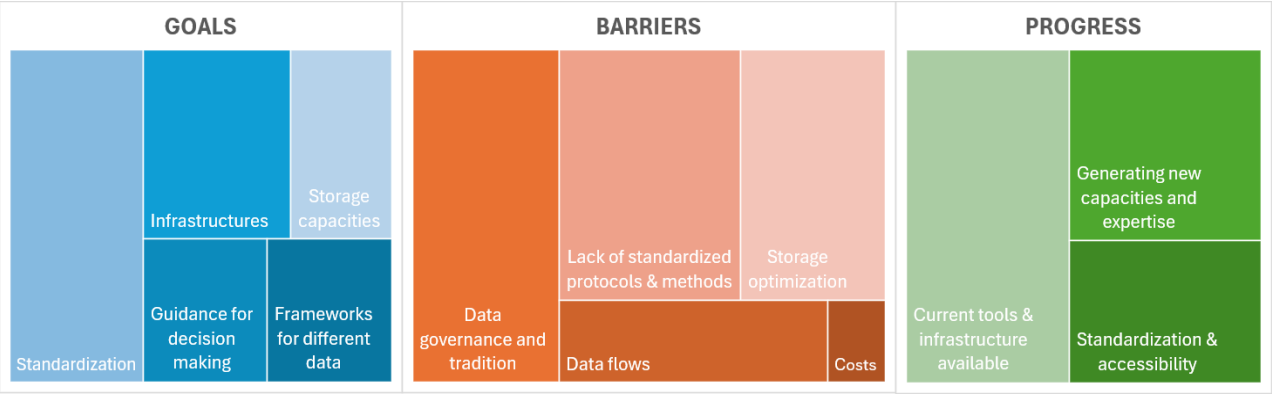

Figure 10. Results from the discussion on "Data management and storage". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

Within these ideas, the following goals were **prioritized**: standardisation (particularly the implementation of FAIR principles and the fostering of data literacy and management skills, which were prioritized by all stakeholders); differentiation between raw and analysed data (prioritized by scientists, policymakers and respondents from the private sector); and the need for a European data centre or repository (mostly prioritized by scientists). The most prioritized barriers identified by all stakeholders except managers were costs (high costs and limited storage capacity), lack of centralization and standardisation for all stakeholders, lack of storage standards, and the need for a data manager figure (training and generating expertise). Regarding actions favouring progress, all stakeholders prioritized the adaptation of platforms to novel technologies; all respondents except managers prioritised the use of IA and machine learning; and finally, all respondents except policymakers prioritized the need of data officers and computer scientists.

3.2.3. Upscaling methods and protocols for policy

The main **goals** towards upscaling for policy were harmonisation, standardization and interdisciplinary collaboration, as well as data integration and data reliability were also mentioned. The most common **barrier** identified was the lack of funding and support, but others like methods and protocols, stakeholders' conflict, data accessibility, standardisation and technology readiness were also relevant. Regarding **actions favouring progress**, most ideas dealt with the role of policies (political willingness, piloting for testing, FAIR and open data to be a political task, long-term funding, etc.), standardisation (definition of minimum requirements, European directives as a way to standardise), interdisciplinary collaboration (like thematic hubs meetings for discussions across stakeholders) and, less often, with promoting success stories (promotion of project outputs and science demonstrating effectiveness) (Figure 11).

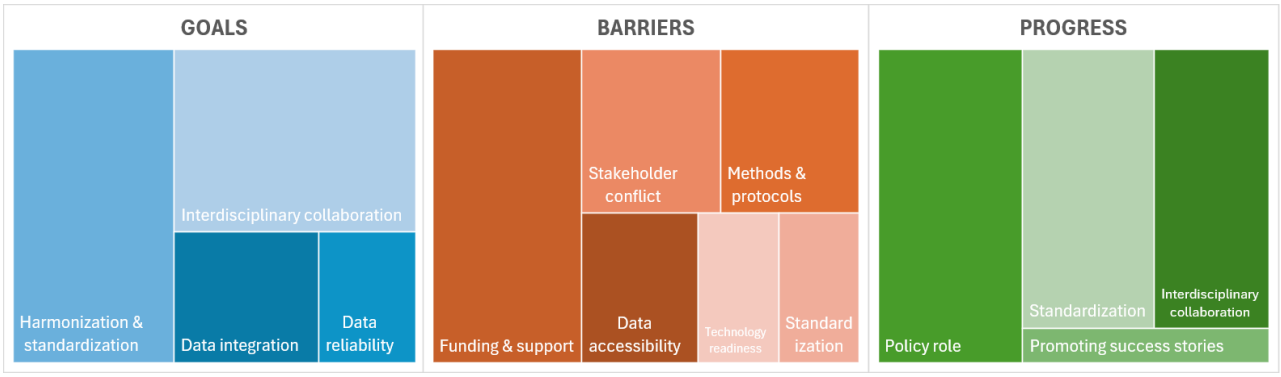

Figure 11 Results from the discussions on "Upscaling methods and protocols for policy". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

Most stakeholders **prioritized** defining standards and protocols (agreed by all actors), creating guidelines for standardisation (mentioned by all except policy makers) and understanding policy needs (mentioned by all except managers) as goals. Barriers prioritised were the need for funding (mentioned by scientists), the resistance to change protocols, and the variety of different data outputs (mentioned by respondents from the private sector and scientists). As actions favouring progress, participants prioritised examples of standardised metrics (mentioned by all stakeholders except managers) and the importance of pilots

for novel technologies (like Biodiversa+ pilots, policies in other countries, comparability, potential of upscaling from local to national policies; by scientists and the private sector).

3.2.4. Costs and expertise required for first implementation

The main identified **goals** were shared infrastructures, stable funding, standardisation, different types of expertise needed (technological, human-based and industrial) and capacity-building. The most frequently mentioned **barriers,** the most frequently mentioned were funding, policy and administrative constraints, expertise and stakeholder conflict (particularly with the private sector). The most common **actions** identified as **favouring progress** were sharing infrastructures (National coordination centres, a willingness to establish a European data centre and the use of citizen science infrastructures and their training technologies), securing funding (seed money for the private sector and predictable funds and costs), and capacity building (educating new experts in specific areas of need, helping to interpret outputs, educating the private sector on biodiversity, financed trainings for guiding first implementation of novel technologies). Interdisciplinary collaboration, especially with the private sector, was also frequently mentioned. FAIR data and workflows, as well as shorter implementation times between data collection and reporting, were also discussed (see Figure 12).

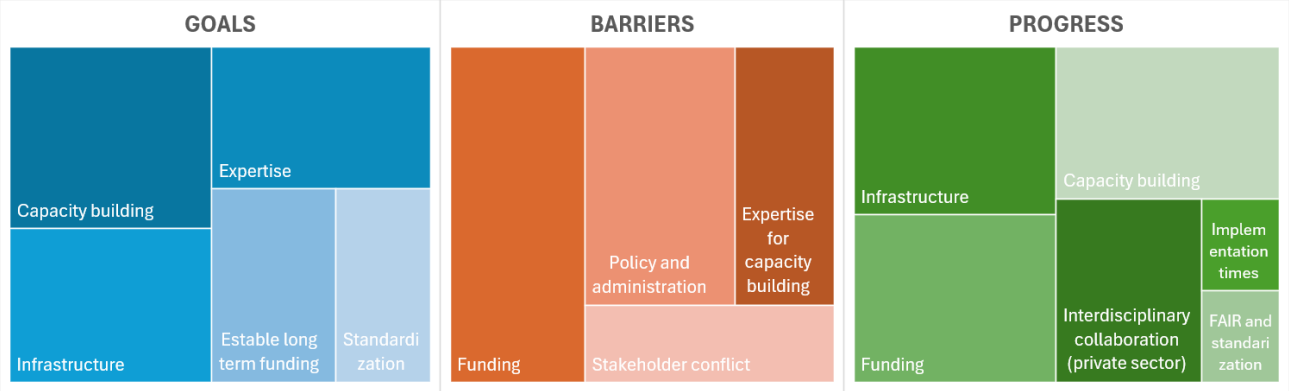

Figure 12. Results from the discussions on "Costs and expertise". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

The **prioritisation** across these ideas as for goals highlighted standardisation, infrastructures and stable funding, as the most urgent, particularly agreeing on the importance of long-term funding and human expertise in the use of novel technologies. For barriers, stakeholders agreed on the need of linking to policy needs (by all except for scientists), the problematics of short-term funding (by all except for policy makers) and the private sector tendency to make changes for sensors (by scientists and private sector). Regarding actions towards progress, the role of National Biodiversity Monitoring Coordination centres (NBMCC) was highly prioritized by all stakeholders, as well as FAIR data and workflows (all stakeholders), and the need of educating new experts on specific needs (all except managers)

3.2.5. Integration of historical and novel technology data and methods

Most common **goals** included fostering long-term monitoring and data quality, followed by accessibility of data and policies and frameworks (agreements, use of EBVs, etc.). The main **barriers** identified were related to the lack of harmonisation (no standardisation, lack of accessibility and sharing, no FAIR data, non-digitalization, etc.) followed by lack of financing and support and, lastly, lack of reliability and replicability and lack of expertise and tools. Key **actions favouring progress** were standardisation and comparability (common platform for metadata, metadata standards, EBVs, GBIF and DwC standards, etc.), expertise and tools (AI, modelling for predictions, evaluation of taxonomical expertise and sampling methods from historical data, etc.) and data mobilisation and accessibility (easy and open access historical data repositories, validations of data, supporting the Dissentis map (a roadmap to liberate data from scientific publications and make biodiversity data an integral part of our daily knowledge), FAIR data). Interdisciplinary collaboration (existing organisms gathering data, like OBIS and GBIF, funders support, initiatives acting as networks for cooperation) was also mentioned (Figure 13).

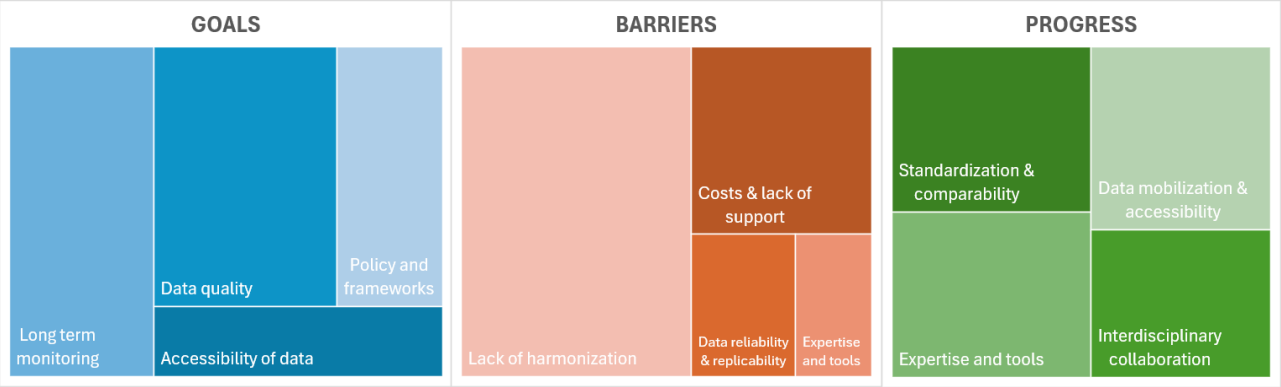

Figure 13. Results from the discussions on "Integration of historical and new technology data". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

Among those ideas, the most **prioritized** goal by far was the establishment of long-term monitoring for long-term observations, identifying impacts and making robust predictions, especially by scientists and policy makers. Scientists also highlighted the establishment of policies for reference data and use of EBVs, and supporting taxonomy assessments (the last also prioritized by policy makers and managers). Barriers prioritized were the issues of data privacy and lack of standardisation (all except managers) and highlighted the fact that the required digitalization is highly demanding in time and funding. On actions towards progress, ideas prioritized were related again to FAIR principles and its application, AI to help extract historical information (by scientists and policy makers), metadata standards and information (by all except private sector), and the role of existing organisations like GIBF and OBIS (by scientists and the private sector).

3.2.6. Knowledge transfer and capacity building

For knowledge transfer, main **goals** identified were the need for interdisciplinary collaboration, followed by the need of a centralized knowledge centre, suggestions to foster capacity building, and promotion of standardisation, policies and funding. Common **barriers** identified stakeholder conflict (miscommunication, necessity of translations, different contexts between institutions), reluctance for data sharing, standardisation framework and application, policies (country silos, different speeds, no motivation), and costs. Participants highlighted as **actions favouring progress** the interdisciplinary collaboration (in person workshops, conferences, meetings and round tables, online training, co-designed projects, more coordination, BioAgora support, etc.), support from policies (legal frameworks, mandates for knowledge transfer and laws for encouraging, use and sharing information on new technologies, funding, translations, policy briefs from projects, etc.), expertise (need of hybrid positions specific for knowledge transfer and science policy, acting as bridge and brokers of information, knowledge translators, foster better communication and translation of technical language), standardisation (agreed standards, FAIR, testing phases, comparability and calibration events for methods and devices, etc.) and raising awareness (citizen science, new appealing narratives, foster trust in novel technologies) (Figure 14). Among those, the **prioritisation** was diverse but overall focused on funding and collaboration. Scientists also gravitated towards the centralized data centre and standardisation. From the enlisted actions towards progress, policies, standardisation and collaboration were the most prioritized.

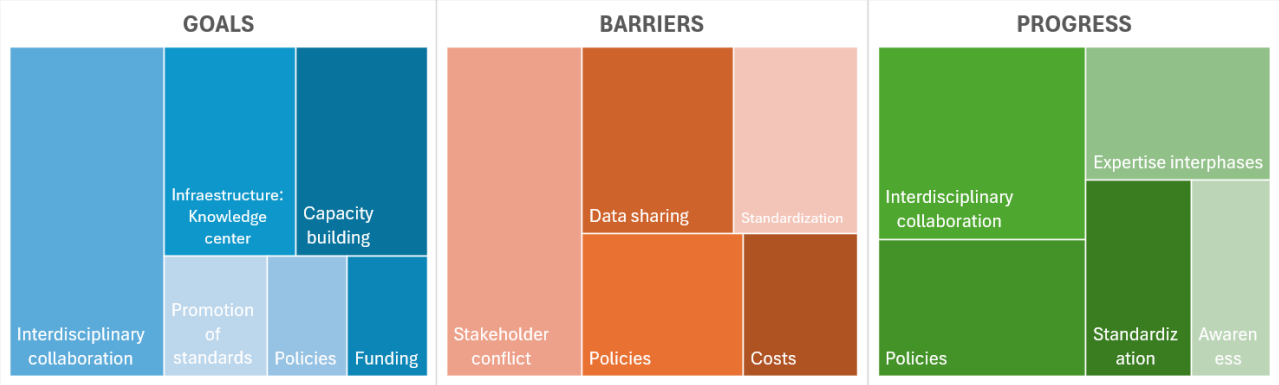

Figure 14. Results from discussion on "Knowledge transfer and capacity building". Area size of the rectangles indicates the percentage of the total number of post-it notes per topic for the three categories: goals (in blue), barriers (in red) and actions favouring progress (in green).

4. Roadmap towards routine implementation of novel technologies for biodiversity monitoring

The state of deployment of the novel technologies surveyed in this report varies considerably. The number of Biodiversa+ partners deploying each novel technology in an operational environment ranges between six to 18. Camera traps and bioacoustics are the most widely used technologies for biodiversity monitoring, mostly in terrestrial environments. In contrast, eDNA is the most widely used technology across taxa and across EBVs, and it is the most deployed technology for aquatic environments, especially freshwater. Sensor networks are in the early stages of deployment, with few respondents using this technology for biodiversity monitoring and with several indicating they had not previously heard of it. Nevertheless, sensor networks, together with remote sensing approaches, demonstrate the greatest potential for monitoring ecosystem-related EBVs.

4.1. Advances in novel technologies deployment in comparison to EuropaBON (Deliverable 4.2) and WILDLABs conservation technology reports

Deliverable 4.2 of the EuropaBON project (Dornelas et al., 2023; hereafter referred to as 'EuropaBON') aimed to identify and characterise novel methods for biodiversity monitoring, and to assess their suitability for large-scale deployment across Europe. Novel technologies were classified according to the EBVs they addressed, the target taxa, and the broad method type, consulting experts on novel technologies via surveys and a virtual workshop. Overall, EuropaBON provided insights based on expert knowledge and evaluated the technology readiness level of all identified novel technologies within three categories: research, development, and deployment.

In contrast, the present report aims to investigate the actual deployment of novel technologies in Europe. To this end we consulted biodiversity managers at national and subnational levels on the implementation of novel technologies in support of the EU Biodiversity strategy 2030, and we provide strategic recommendations to advance the routine implementation of novel methodologies for biodiversity monitoring. We ranked the level of deployment using an adapted version of the NASA Technology Readiness Scale, categorising technologies as either deployed or not deployed. Below we discuss a comparison of the findings of both reports to assess the alignment of expert knowledge with the state of novel technology implementation as of 2026.

In addition, we also compare our results with those of the State of Conservation Technology reports by WILDLABS (Speaker et al. 2022; WILDLABS 2023, 2025). WILDLABS has been conducting a series of surveys starting in 2020, initially aiming to capture the perspectives and needs of the global conservation technology community. Currently, the surveys also describe five-year trends that highlight changes and progress in the maturing fields of technology for conservation biology. While not focusing specifically on biodiversity monitoring, the information they provide aligns to some extent with that in our report and can help us better understand the current use of novel technologies in Europe in relation to global technology development trends.

4.2. State of deployment by technology and EBVs

In the area of **bioacoustics**, our results vary depending on the taxon. There is a high level of deployment in the operational environment, primarily for mammals and birds. Moderate deployment is observed for fish, terrestrial invertebrates, and plants. Conversely, there is a low or non-existent level of deployment for other taxa, even when potential applications appear feasible in some cases, e.g. for aquatic invertebrates and amphibians/reptiles. Most of our results are similar to those of EuropaBON and WILDLABS. EuropaBON reported a high level of development, mostly relevant for birds and with potential application for fish, according to experts. They also reported interest in applying bioacoustics to amphibians in combination with AI technologies, which is reflected in our results. WILDLABS has reported increasing engagement with this technology over the past five years, and it is currently (2026) the fourth most used technology across the WILDLABS community.

Our results also align with those of EuropaBON and WILDLABS with regard to the use of **camera traps**. Camera traps are the most widely used technology featured in our report. Similarly, WILDLABS highlights that camera traps have been one of the most widely used technologies over the past five years and continue to be so in 2025, forming the basis for many newer innovations. Our report shows high deployment levels in most taxa, primarily mammals, but also birds and terrestrial invertebrates. Meanwhile EuropaBON reported expert interest in applying this methodology to amphibians and reptiles, which some partners use or which are still in the development phase. This is consistent with the low levels of deployment and interest in use for amphibians and reptiles and aquatic invertebrates gathered in our survey. In fact, EuropaBON reported some deployment examples for terrestrial invertebrates, which align with our findings.

According to our respondents and EuropaBON experts, the methodologies associated with **eDNA/genomics** are among the most widely deployed technologies across taxa with the actual methods being used in operational environments (see also Laamanen et al. 2025 for a review of TRLs of eDNA methods in routine implementation for biodiversity monitoring). This report shows high deployment levels, particularly for aquatic invertebrates and fish, and moderate deployment levels for terrestrial invertebrates, fungi and algae. There are varying deployment levels among respondents, but interest in using these methods is high across all taxa surveyed. Similarly, EuropaBON described eDNA techniques as being among the most likely to be implemented due to their wide range of applications. They reported that eDNA was also widely applied to most taxa, and that it was one of the few exclusive methods that could be deployed at high levels for some taxa, such as amphibians and reptiles. It was also particularly relevant for others, such as aquatic invertebrates. These findings are corroborated by the responses of Biodiversa+ partners. However, these results conflict with those of WILDLABS. They report a decrease in the use of eDNA/genomics, despite these technologies still being perceived as having great potential for conservation.

The low level of deployment we identify for **sensor networks** is consistent with EuropaBON's findings, which also noted a smaller number of records compared to other novel methodologies. However, of these records, the technology readiness level was, in most cases, at least at a high development stage. Very few records were at a high deployment stage. This is similar to our results in terms of the low number of respondents using this novel technology, and the fact that the majority of respondents are not at any deployment stage. Where these systems are deployed, they appear to be oriented towards the systematic gathering of environmental data in terrestrial or freshwater environments. They are also used by a few

partners for fish monitoring and could be used to monitor birds and terrestrial invertebrates. Although WILDLABS also reports low usage of this technology, they repeatedly identify sensor networks as technologies with the greatest potential over the past few years, despite them also being reported as the technology with the lowest overall performance.

Deployment of both **remote sensing** and **UAVs/drones** is high. For remote sensing, partners report the use of the technology in operational environments, primarily for monitoring plants, but also for algae and mammals. UAVs and drones are mostly used to monitor birds, followed by plants and mammals. Partners also emphasise using both technologies to assess different aspects of habitat monitoring, an area that was not explicitly covered in our report. These results are consistent with those of EuropaBON, which also reported high deployment levels for monitoring birds, mammals, and plants using UAVs or remote sensing. According to WILDLABS, remote sensing and UAVs/drones are the technologies with the highest overall performance at present, but they are used differently. Remote sensing is the second most widely used technology for conservation, with a similar stable trend to camera traps over the last five years. It is currently also perceived as a technology with great potential for conservation. In contrast, UAVs/drones were among the most widely used technologies in 2020, but the community currently (in 2026) reports lower usage and no longer perceives them as technologies with such potential, similarly to the trends reported for eDNA/genomics. Different specific goals between the monitoring and conservation communities, as well as different reporting scales (European versus global) may also explain the difference in the use of novel technologies and the resulting discrepancies in our report.

Overall, the monitoring of the different **Essential Biodiversity Variables** also varies depending on the novel technology employed. However we observe a higher tendency to monitor species population variables, which are most prominent for bioacoustics, camera traps, and eDNA/genomics. Although these results are less evident in our report for remote sensing or sensor networks, they are consistent with EuropaBON's results which showed that the overwhelming majority of novel methods were used to quantify species distributions and abundances. In contrast, few partners appear to monitor genetic composition EBVs, and of those who do, most use eDNA/genomics for this purpose. This is also consistent with the EuropaBON results, where the genetic composition variables were among the least studied.

Four of the targeted technologies -bioacoustics, camera traps, eDNA/genomics and UAV/drones - are used to monitor most of the traits included in each of the species' population, species traits and community composition EBV groups. Traits related to ecosystems are not targeted as often and are reported at a higher level for UAV/drones and remote sensing. The two novel technologies that target the most EBVs are eDNA/genomics and UAVs/drones, with eDNA/genomics mostly being used for all EBVs, except for morphology and reproduction (species traits), primary productivity, ecosystem disturbances and ecosystem phenology (ecosystem functioning), and live cover fraction (ecosystem structure). It is therefore the technology most commonly used for genetic composition EBVs. Meanwhile, UAV/drones monitoring targets all EBVs except those related to genetic composition and ecosystem phenology (ecosystem functioning), demonstrating great potential for monitoring different levels of biodiversity monitoring, with the exception of genetics. Conversely, sensor networks are the novel technology that targets the fewest EBVs, likely due to a lack of partners employing this technology for monitoring purposes, although EuropaBON ranked the technology readiness level as medium to high in their assessment (Dornelas et al. 2023).

The least commonly targeted metrics in our report are intraspecific genetic diversity, genetic differentiation and inbreeding (a not surprising result given that most technologies are not abel to capture and collect genetic samples), followed by reproduction, ecosystem phenology, ecosystem vertical profile, live cover fraction and primary productivity. Of these, genetic diversity and ecosystem vertical profile are similar to the findings by EuropaBON. In contrast, interaction diversity, which is also one of the least targeted metrics in EuropaBON, was relatively frequently monitored according to our survey with 5-18% of respondents monitoring this EBV in the selected novel technologies.

4.3. State of deployment by taxa and associated constraints

A more detailed analysis of the different taxa and the state of deployment of the novel technologies shows that **terrestrial invertebrates** are more commonly monitored using camera traps and eDNA, with these methods being used in operational environments. Some respondents described monitoring pollinator species using camera traps as well as eDNA metabarcoding and barcoding techniques. This is similar to the results from EuropaBON, in which the most highly ranked novel methods were automated imaging and recognition techniques for insects. However, the constraints related to this are a lack of taxonomically comprehensive and precise reference data/training data libraries, which is one of the most common constraints identified in our survey regarding the deployment of eDNA.

All five technologies (except sensor networks) are used to monitor **mammals**; however, bioacoustics, camera traps and remote sensing show the most records at the highest deployment stages. Several respondents monitor marine mammals and bats using novel bioacoustic methods. Camera traps are also used to monitor large terrestrial mammals such as ungulates and carnivores, while remote sensing techniques are mainly used to monitor marine mammals. These results are similar to those found in the EuropaBON where camera traps have had a strong track record for monitoring mammals, as does bioacoustic monitoring for vocalising species. Lack of funding is a common constraint for the development of camera traps in this survey as it was for the EuropaBON experts. However, data storage and integration also play a key role.

Environmental DNA and genomics are the most commonly used technologies for monitoring **fish**. This differs from what EuropaBON experts mentioned, as a large portion of fish monitoring in Europe currently relies on fishery-dependent techniques or in situ diver surveys. In 2023 the experts did, however, suggest that the use of eDNA was a promising approach for fish monitoring. They mentioned the poor standardisation and reference libraries, which are still common constraints in the use of eDNA, as highlighted in this report. Nevertheless, eDNA remains the most widely applied technique in all aquatic environments.

Birds are one of the most commonly monitored taxa, with the highest level of deployment of novel bioacoustics methods and UAVs/drones. The use of camera traps is also often reported for monitoring of birds. EuropaBON experts also found that the novel monitoring methods used for bird biodiversity monitoring varied. Constraints encountered when deploying bioacoustics for bird monitoring include the challenges of data analysis and synthesis, as mentioned by both experts and respondents to our survey. Similarly, EuropaBON mentioned the use of data synthesis systems such as mobile applications, which have been used by experts and Biodiversa+ partners to aid with data structure and usability (data gathered from citizen science projects).

Similarly to EuropaBON, environmental DNA is also commonly used as a highly deployed novel technology for monitoring the biodiversity of **aquatic invertebrates**. Partners describe using novel eDNA techniques to monitor aquatic invertebrates, including coral and crustacean species, as well as freshwater mussels and aquatic insects. As with fish, poor standardisation, the difficulties in comparing results and a lack of reference libraries are common constraints in the use of eDNA, according to EuropaBON experts and Biodiversa+ partners.

Overall, **amphibians/reptiles, algae and plants** have lower deployment levels across all novel technologies compared to other taxa. However, all three show the highest deployment levels in eDNA methods and, especially for plants, also with UAVs/drones and remote sensing techniques. This is similar to what the EuropaBON experts mentioned, except for algae, which were not included in that report. Novel methods for monitoring amphibians and reptiles were ranked the lowest in terms of technology readiness, largely due to the need for validation and testing. eDNA was the only suitable method identified. In the case of plants, the most dominant technology is remote sensing, whereby plants are often monitored in relation to their habitat. However, our survey did not evaluate the latter.

The constraints identified in our report and in EuropaBON's are largely consistent with the overall constraints identified by WILDLAB when they asked about the systemic challenges that inhibit the development and adoption of conservation technology. The WILDLAB community identified limited funding, duplication of efforts and insufficient support for technology adoption and capacity building as the most pressing big picture challenges they face. When asked what prevented them from effectively engaging with these tools, respondents reported cost as the most critical concern, followed by lack of technical skills and the time required to engage. In contrast, technology developers prioritised financing, coordination, and a deeper understanding of the tool landscape to avoid duplication of efforts.

Given the constraints identified for the deployment of novel technologies across taxa and partners, Biodiversa+'s work to enhance transnational monitoring, particularly through the **Biodiversa+ monitoring pilots**, addresses some of the challenges and gaps highlighted in this report. The Soil (2023-2026) and MetaBug (2026-2028) pilots are improving transnational eDNA-based monitoring of soil organisms (Seeber et al. 2024, 2025) and testing a new general insect monitoring proposal, respectively. MetaBug, in particular, is working to harmonise field and laboratory protocols, including DNA approaches in support of the EU Pollinator Monitoring Scheme (EUPoMS). The IAS (2023-2027) and ABMS (2024-2025) pilots are also working to improve AI-based recognition for image-based sensors by testing detection algorithms for nocturnal and invasive insects respectively, and favouring the transnational implementation of routine camera-based sensors for monitoring (Høye et al. 2024, 2025). Specifically, the IAS pilot also aims to implement a transnational monitoring scheme using image-based sensors to detect and monitor invasive plant species (Høye et al. 2024, 2025). The ABMS pilot (Alison et al. 2025) also supported transnational monitoring of birds and bats by deploying bioacoustic sensors integrated with the image-based sensors. Furthermore, the current BiodivPond (2026-2028) pilot implements bioacoustic and eDNA technologies combined with citizen science approaches to monitor aquatic macroinvertebrates, amphibians and bats. This pilot tests the implementation of a new, standardized, transnational monitoring scheme in freshwater ecosystems. In the marine realm, the EuRockFish pilot (2024-2026) integrates eDNA with remote underwater video technologies and visual observations, combining them into a harmonised set of monitoring protocols and data analysis for marine rocky fish communities. Finally, two Biodiversa+ pilots, the Habitat pilot (2024-2025) (Wiman et al. 2026) and the SenseForest pilot (2026-2028), focus on remote-sensing approaches for grasslands, wetlands and

forests. Both pilots are providing insights into the harmonisation of current remote sensing methodologies (including UAVs/drones) being implemented by Biodiversa+ partners for habitat monitoring.

Despite the methodological differences between the Biodiversa+, EuropaBON and WILDLABS approaches, the overall picture of the implementation of novel technologies is very similar. This indicates that the present report provides a robust overview of the European monitoring landscape with regard to the discussed methods, and that the implementation of these methods generally follows international trends as identified by the WILDLABS community surveys.

4.4. Towards novel technology integration in routine biodiversity monitoring

The present report identifies the challenges in deploying novel technologies and preventing their implementation and aims to propose solutions to current constraints.

In order to **promote the harmonisation of novel technology methodologies**, it is necessary to develop accessible protocols and guidelines that are both standardised and flexible. A set of minimum requirements must also be agreed upon, based on interdisciplinary collaboration. Those agreements should address policy requirements and be realistic for all stakeholders involved, including scientists, technicians and the private sector. To assess how to work towards minimum agreements in biodiversity monitoring, Biodiversa+ has proposed some general common minimum requirements for biodiversity monitoring harmonisation and identified more than 60 existing monitoring communities across Europe that already or potentially play a vital role in driving harmonisation. They also proposed a monitoring governance model that includes establishing Thematic Hubs to better leverage the expertise within these monitoring communities centred around specific biodiversity domains (Silva del Pozo, 2025). These Thematic Hubs should then connect to National Biodiversity Monitoring Coordination Centres (NBMCCs) and an overarching European Biodiversity Observation Coordination Centre (EBOCC) to support effective transnational monitoring and connect to policy (Lipsanen et al. 2026).

In this report, we identify significant differences in the implementation of novel technologies across taxa, emphasising the importance of collaboration not only within, but also between monitoring communities, to promote development and deployment for different taxa and environments. Coordination via the proposed Thematic Hubs could be a key step in achieving that. In the case of novel technologies, this could be reinforced by establishing Technical Hubs or technological communities of practice. These could deal more specifically with the technical and data-related aspects of novel technology implementation. This would likewise benefit NBMCCs and the monitoring communities. This governance model should build upon existing networks for the implementation of novel technologies, such as the eLTER Research Infrastructure, that is developing a set of harmonised Standard Observations, some of which include acoustic biomonitoring, flying insects, soil and water eDNA, and provides access to at about 250 sites across all ecosystem types in Europe. Several of the Biodiversa+ partners that participated in this report already collaborate within eLTER.

In addition, **collaborations with the private sector** also need to be encouraged. While joining forces with the private sector is often perceived as challenging due to differing objectives and workflows compared to scientific and public monitoring, the novel technology community could greatly benefit from it. Biodiversa+ aims to increase opportunities for collaboration and networking with these key

stakeholders. Some examples are the Science Fair marketplace and the Business and Biodiversity Workshop during the Barcelona events in 2025, and the first Biodiversity Monitoring Week in Montpellier in 2026, which included the Alliance for Nature as a co-organizer representing the private sector. However, more targeted efforts are needed to build a more cohesive and coordinated biodiversity monitoring community, as described by Kissling et al. (2026). Further integrating the private sector, as a key stakeholder group, is a central part of that goal. Some pathways to explore could be the foundation of public-private partnerships and enhanced private engagement via the EU parliament preparatory action for the EBOCC (Kissling et al. 2026), or via the EU business and biodiversity platform.

To overcome difficulties with **data mobilisation and accessibility**, current strategies should aim at more transparency by sharing not only the obtained data, but also descriptions of entire workflows and all associated materials (metadata, scripts, references, etc.) in a FAIR and accessible manner. This will allow for better comparability and interoperability, even if the current monitoring landscape is not yet fully standardised or harmonised. There is a particular high demand for further work towards **common international agreements on standards** for novel technologies. A key example of this is the work by the International eDNA Standardisation Task Force (IESTF), which brings together leading researchers, policymakers, industry partners and standards bodies to develop and promote consistent, high-quality standards for eDNA methods. Similar working groups or other initiatives could benefit other novel technology communities, helping them to normalise and agree on standards for metadata and ensuring the comparability and interoperability of novel technology results. Some European projects are also proposing relevant next steps towards standardising the sharing and accessibility of information. These include the Data Management Plan created by MARCO-BOLO (Laguionie et al. 2023), which has been highlighted by the EC as an example for future initiatives; the advances in creating a single access point, the Biodiversity Explorer, by the Biodiversity Meets Data project, which combines high-throughput biodiversity monitoring tools with AI taxon identification services; the harmonised data hub by BIOcean5D; and the ongoing work by Biodiversa+ to create BioDash, a common metadata dashboard for all ongoing biodiversity monitoring initiatives in Europe. The latter could also be greatly beneficial to the novel technology community by helping managers find similar initiatives in other countries for collaboration and for capacity building for specific technologies.

Furthermore, scientific communities and data experts should continue to encourage **the use of EBVs** and assess how data generated by novel technologies can be translated into the proposed EBVs, as well as how these can be integrated with data from existing monitoring. The EU parliament preparatory action for the EBOCC, which started in 2026, is expected to advance this work for selected EBVs around six different thematic areas. Some Horizon projects dealing with novel technologies (non-exhaustive examples include B-cubed, OBSGESSION, MAMBO and MARCO-BOLO, among many others) are also investigating the use of EBVs for different novel technologies. Also, the BioDash platform previously mentioned will incorporate EBV grammar into its database, helping map and link available data to the EBVs frameworks. Nevertheless, the concept of EBVs is still new to many, and it will require time and promotion to be fully established and accepted by the different monitoring communities. Biodiversa+ will continue the work to produce resources to favour the use of EBVs and, whenever possible, lead by example using or producing EBVs in their activities.

The use of novel technologies generates substantially more data than traditional monitoring, which poses several challenges in terms of **management and storage**. This problem is shared across technologies, regions and scales. AI and machine learning are already easing the burden of data management and

digital storage, and further developments will continue to help in the near future. However, a strategy based on **common data infrastructures and storage** across countries could help reduce costs and effort, as highlighted by Bresadola and Bjärhall (2025), and encourage agreements on data mobilisation, sharing and standardisation. Continued support for existing common data portals is essential (e.g., GBIF and OBIS for species occurrences, and ERGA and NCBI GenBank databases for genetic information), and some portals are making efforts to accommodate the data generated by these novel technologies into their repositories (e.g., Abarenkof et al, 2023). Nevertheless, users of novel technologies among Biodiversa+ partners often emphasize the need for a **European data centre** to optimise resources. In particular, common data centres and repositories could play a pivotal role in overcoming a significant constraint for some novel technologies, such as eDNA, bioacoustics and image-based approaches, which lack **reference databases and libraries**. Some national and European projects, such as ARISE in the Netherlands, or the European initiatives ERGA and eDNAquaplan, are attempting to create genetic reference databases. Still, this remains a priority to ensure the efficient deployment of many novel technologies, especially in regions where research is less intensive, which are often some of the most biodiverse areas of Europe.

Common European data centres can also stimulate transnational collaboration and help to normalise the use of selected standards for novel technologies among countries. Making such infrastructures a shared responsibility would require great coordination efforts, stable financing and well-structured governance to establish data management officers, clear data ownership rules, security programmes, etc. However, it would reduce overall costs and necessary resources. Such a biodiversity infrastructure would also require **new roles and skill sets beyond the scope of biological and ecological sciences**, such as engineering, (bio)informatics, online security, data managers and coordination. Creating these new roles would increase capacities in data management and interoperability, relieve pressure on scientists and managers, and improve coordination and technical support, as well as facilitating capacity-building opportunities. There is already a European example that could be an inspiration for such a shared infrastructure. The EMBL European Bioinformatics Institute, which offers resources and tools for the field of molecular biology, and its Data Science Centre, which ensures that data generated are expertly curated, annotated, managed, integrated, visualised, and shared. Setting this up took many years and a lot of resources but resulted in a world-leading facility that is now crucial to the field of molecular biology. A similar facility for biodiversity would be a tremendous advance for the field and its impact on policy and society.

Novel technologies are currently mostly piloted on a local scale, which often leads to fragmented knowledge, duplicated effort and reducing efficiency and the capacity to scale up methodologies. In order to **upscale novel technologies** at a (sub)national and transnational level, it is necessary to design explicit upscaling plans. These plans require more coordination and agreements on a minimum set of standardisation criteria for workflows, based on significant interdisciplinary collaboration efforts. They must acknowledge how the generation of the new data can be integrated and complement current ongoing traditional monitoring in harmonisation plans, particularly those producing well-established long-term trends. Biodiversa+ could potentially help facilitate and support the development of these plans together with thematic hubs experts and interested administrative bodies at different scales, once roles and expectations are clarified. In this line, Biodiversa+ has previously emphasised the pivotal role of the use of EBVs for means of harmonisation and standardisation across scales (Silva del Pozo, 2023) Examples of successful implementation of novel technology in support of long-term observations should

be publicised to encourage policy makers to support the upscaling processes. Furthermore, piloting at local scales should be better communicated and coordinated across regions. The Biodiversa+ pilots testing novel technology solutions for transnational monitoring, as discussed in the previous section, demonstrate the potential efficiency of co-development upscaling processes when coordination capacities are in place. This allows methodologies to be defined collaboratively, ensuring compatibility across borders while maintaining scientific rigour (Bresadola and Bjahäll, 2025). Moreover, the BioDash monitoring database, currently being developed by Biodiversa+, could potentially ease and facilitate coordination among pilot monitoring activities in different countries. In the future, expert thematic hubs should continue the work to steer implementation of novel technologies by co-developing with managers, policy makers and, when relevant, the private sector. Coordination for this could be greatly facilitated by an established EBOCC, after its current preparatory action phase. EBOCC has a transversal core potential outside of the current piloted thematic areas, and, if established, it could also inherit the role of pilot incubator, which Biodiversa+ proved to be promising for transnational novel technology implementation.

In line with the importance of long-term observations for identifying trends that can inform policy makers, another highly relevant topic is the **accessibility and mobilisation of historical data**. Although this data is essential for long-term observations and monitoring and is key to studying its integration with new technological approaches, it often remains difficult to find and inaccessible. Policies and frameworks that support the conversion of these data to harmonizable and FAIR formats need to be established. To this end, the digitalisation and standardisation process must be explicitly promoted and funded at both national and European scale. This process could be greatly facilitated by the use of AI technologies, but it would also require the engagement of data specialists and taxonomical expertise to solve nomenclature challenges and agree on compatible taxonomic lists across countries, in line with the work of the Horizon project TETTRIS (and its continuation in the upcoming TETTRIx). Financing and policy support will be essential to facilitate access to, mobilise and digitise historical data for long-term observations.

One of the most common challenges associated with novel technologies is **cost**, particularly for initial implementation, but also for storage and data management. The current financing landscape, consisting of mostly short-term projects, is leading to many new technologies being piloted, but not necessarily to their mainstream use. Additionally, Biodiversa+ partners have identified the tendency to change devices of the private sector as a risk to the continued use of novel technologies. It is important to note that, while novel technologies require initial short-term costs for joining the network and setting up an operational monitoring scheme, they offer lower maintenance and operational expenses over time. To minimise costs, shared infrastructures and the centralisation of data management capacities at the European level could provide cost-sharing benefits. Bresadola & Bjärhall (2025), also identified the need to foster long-term monitoring and emphasized the importance of collaborating with EU bodies such as the EEA and the EU parliament preparatory action for the EBOCC, to support the design and implementation of these facilities. In addition, policy actors need to be consistently included when co-designing monitoring schemes, not only to assess protocols and methods, but also for ensuring long-term governance. New funding possibilities should also be explored, particularly for long-term stable funding. One emerging proposal that could be further investigated is Nature credits, which could offer a way to complement public funding with private investment.

Another cross-cutting challenge is **capacity building** and **knowledge transfer**, which are essential aspects of transnational collaboration requiring interdisciplinary cooperation, coordination,

communication skills and policy support. The EU parliament preparatory action for the EBOCC, which is currently being piloted, will play a key role in the knowledge transfer in its six selected thematic areas. The proposed NBMCCs by Biodiversa+ (Lipsanen et al. 2026) could also be responsible for coordinating capacity building at national scale, including with regards to novel technologies. Regular training sessions can help to ensure adherence to protocols and maintain data quality. To this end, new hybrid roles focusing on knowledge translation, standardisation, coordination and communication would need to be created. In response to the capacity building needs expressed by some Biodiversa+ partners, Biodiversa+ launched a series of capacity-building webinars on novel technologies which started in late 2024 (available on the Biodiversa+ YouTube channel). However, many other initiatives also recognise this need, offering capacity building towards shared goals including topics related to novel technologies, like the MOD Alliance and the GOOS webinar series for the marine realm. Biodiversa+ will continue to promote novel technologies, support joint ventures, and enhance cooperation aimed at deployment of novel technologies across Europe. This will be achieved by setting up workshops to support the implementation of novel technologies building up on the strategic recommendations of the present report.

5. Strategic recommendations for the integration of novel technologies for biodiversity monitoring

The integration of novel technologies into biodiversity monitoring has the potential to greatly enhance its efficiency and scalability. Based on insights into the deployment of novel technologies among Biodiversa+ partners, this report presents seven strategic recommendations.

- **Explore potential coordination mechanisms and bodies within the novel technology monitoring community.**

  Coordination mechanisms allow for better transnational collaboration and community cohesiveness. This would facilitate the development of standards and protocols, the coordination of local-scale pilots to avoid duplication of efforts, the search for funding, and the capacity building around the implementation of novel technologies and data issues. These are all key constraints affecting the actual deployment of novel technologies on a large scale. Coordination is also particularly important for breaking down current silos across different environments. The present report shows that expertise exists within Europe, but it lacks organisational and communication capacities. Coordination can help to increase knowledge transfer among key stakeholders enabling the routine implementation of novel technologies. Biodiversa+ can help catalyse and support harmonization, with proposals such as the establishment of National Biodiversity Monitoring Coordination Centres (NBMCCs) and of Thematic or Technical hubs engaging communities of use/practice and supporting the creation of integration plans. Topical expert groups should therefore actively engage in community building networks moving forward, such as the creation of standardisation working groups across taxa and expertise, the organisation of intercalibration events, or joining the eLTER research infrastructure in agreement with their (sub)national counterparts, among others included in this report.

- **Explore and foster collaborations with the private sector.**

  Although novel technologies are receiving significant attention and support from public funding, the collaboration and potential financing role of the private sector could be promoted further. Private financing sources could be particularly relevant for novel technologies given the synergies provided by technology development. This could lead to new opportunities for public-private collaboration, which would greatly benefit the deployment of novel technologies at a large scale.

- **Promote collaborative data infrastructures.**

  Creating shared data centres is a key step for the use of biodiversity data in general and the implementation of novel technologies for all stakeholders in particular. This should be done while also continuing to support and foster existing infrastructures and repositories for data sharing, analysis and storage that guarantee the FAIR principles. Collaborative infrastructures and shared and accessible workflows will help reduce costs and facilitate data comparability and exchange across regions.

- **Integrate new expertise positions.**

  Traditional monitoring relied mainly on biological and ecological expertise. While this knowledge is still critical and irreplaceable to interpret the data, novel technology implementation also requires new expert positions in the areas of engineering, data management, software and

AI/machine learning development, as well as coordination and technical and technological assistance for biodiversity monitoring related positions.

- **Promote reference databases.**

  Initiatives that promote and fund the creation of publicly accessible and reliable reference databases will normalise routine implementation of these technologies and enable data comparability across novel technologies and regions. This is particularly challenging and relevant for taxa that have been less intensively studied, where novel technologies could have the greatest impact in advancing knowledge and detecting unknown biodiversity trends. Reliable reference databases and libraries are particularly essential for molecular-based technologies, such as eDNA/genomics, as well as for training sound and image algorithms. Thus, funders should continue to invest in the creation and curation of accessible databases and libraries at both (sub)national and European level, with particular efforts directed to the most biodiverse regions of Europe.

- **Design integration plans for novel technologies.**

  Although the potential of novel technologies for biodiversity monitoring has been widely recognised, there is still a need to demonstrate how these technologies can complement and integrate with ongoing long-term trends to produce workflows and usable indicators, without affecting well-established long-term monitoring series. Initiatives that work on frameworks to integrate trends obtained from traditional monitoring with novel technological advances, such as EBVs, will be key to the sustained maintenance of long-term observations and for obtaining policy support. Such plans need to be co-designed by topical experts in close cooperation with policy makers to support (sub)national and European policies and strategies.

- **Align with national and international initiatives.**

  Novel technology monitoring should rely on international, European, regional or national initiatives, where they exist, to help integrate data (e.g., birds for PECBMS and pollinators for the upcoming implementation of EuPOMS, etc.). Novel technology monitoring should also consider policy requirements and common reporting obligations to optimise costs and efficiency. Likewise, policy makers should further support integration of novel technologies in (sub)national monitoring programmes and in European mandates, for example, by allowing and encouraging its use for EU Member States reporting exercises.

6. Key takeaways

This report reveals a wealth of information about the state of deployment of novel technologies for biodiversity monitoring among Biodiversa+ partners across Europe, as well as the challenges they face in implementing these technologies. The responses of Biodiversa+ partners helped us identify the main patterns. Most novel technologies target species or community EBVs, rather than ecosystem EBVs. This suggests that novel technologies are advancing faster in the analysis of species ecology than in the analysis of ecosystem features. However, remote sensing and sensor networks appear to have the greatest potential for covering ecosystem-related EBVs. Other technologies, such as bioacoustics, camera traps and UAVs/drones, are widely implemented for certain taxa (mostly mammals and birds) and are most often used in terrestrial environments. In contrast, eDNA/genomics is primarily used in aquatic environments and shows the greatest potential for filling knowledge gaps for a vast amount of unknown taxa. Nevertheless, despite the highly variable state of deployment of the targeted novel technologies and realms, all methods are currently fully deployed in the field by at least one partner. This means that the necessary skills and knowledge to improve deployment levels are available within the Biodiversa+ partnership.

All partners face technology challenges, many of which could be alleviated by enhancing the coordination of ongoing novel technology networks and strengthening the ties between members of the community. Biodiversa+ can help catalyse harmonization by bringing together topical experts, policy makers and the private sector in joint ventures enabling sharing experiences to advance key challenges such as fostering standardisation to ensure data comparability, finding shared pathways to overcome data management and data storage issues in the long term, or integrating novel technology workflows and pipelines currently being developed in parallel in different countries. In addition, Biodiversa+ provides capacity-building through a series of webinars on novel technologies to promote knowledge of these technologies and will continue to do so by setting up workshops to foster interdisciplinary collaboration. Although developing common protocols and technical applications for shared data management and analysis may initially be a more difficult path than working unilaterally, in the medium to long term it can generate scale multiplier effects in the use and application of these types of new technologies. Policy makers and funders of biodiversity monitoring programmes should also acknowledge the complementary potential of novel technologies by enabling and funding its use at (sub)national and European level. A key positive driver for novel technology use would be allowing new methods for EU reporting, but others like continuing to fund and support collaborative infrastructures, as well as accessible reference databases and libraries that increase reliability for novel technologies informing policy, will be essential for routine implementation.

Europe should work towards establishing a knowledge exchange network that could facilitate the continuous development, standardisation and implementation of novel technologies for biodiversity monitoring as well as identify priorities for further research and standardisation and implementation of collaborative developments. Examples of such networks include those developed to support the Science Service for biodiversity of the European Commission or the more targeted initiatives such as the European research infrastructure eLTER, in which some partners collaborate, and the preparatory action for the European Biodiversity Observation Coordination Centre. This centre could provide a venue where novel technology experience from across Europe could be brought together for its selected EBVs. All these initiatives will help Biodiversa+ partners to better articulate and respond more effectively to emerging challenges and to advance towards more effective harmonisation of the tools and research used for biodiversity monitoring across Europe.

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ANNEX I – Survey received by Biodiversa+ partners

Biodiversa+ survey towards a roadmap on biodiversity monitoring novel technologies and approaches

Introduction

One of the main objectives of Biodiversa+ is to promote and support transnational biodiversity monitoring, by building a transnational (pan-European) network of harmonised monitoring schemes on common priorities for Biodiversa+ members. This current survey is built upon deliverable 4.2 by EuropaBON, "Novel technologies of biodiversity monitoring" and is specifically related to Biodiversa+ task 2.3 "**Develop and/or deploy new technologies/approaches for biodiversity monitoring**" (https://doi.org/10.3897/arphapreprints.e105600).

This survey aims at tackling the **testing and deployment of new technologies and approaches for biodiversity monitoring across Biodiversa+ partners** aimed at supporting EU Biodiversity strategy 2030 and National and subnational counterparts. The potential of these novel technologies has been recognized by biodiversity research and monitoring activities, but their actual level of deployment in policy relevant biodiversity monitoring still needs to be explored and major constraints bottlenecks identified in previous assessments.

This survey specifically aims at:

1. Understanding the level of **deployment of novel technologies used for policy relevant biodiversity monitoring activities by Biodiversa+ partners at several scales** (transnational, national and sub-national). We will focus, more specifically, on five novel technologies, bioacoustics, camera trapping, eDNA and genomics, network sensors, and UVAs/drones.
2. **Identify challenges and gaps Biodiversa+ partners are facing** with their deployment/use of novel technologies for the monitoring of biodiversity.

This survey is specifically addressed to Biodiversa+ partners and in the case that you are unable to answer questions due to limited information, we highly encourage you to complete it with the support of your colleagues and when relevant to you, third parties. Please share names and contact details of any third party that have helped to complete this survey in the respective sections.

To get more detailed feedback on some elements, bilateral interviews may follow for a better understanding on the state of deployment of novel technologies used for biodiversity monitoring in your country or region. The results will be used to further guide the Biodiversa+ biodiversity monitoring capacity building activities for partners, as well as to develop roadmaps on how novel technologies can be operationalized for transnational pan-European biodiversity monitoring. Many thanks in advance for your support!

Privacy Notice

Biodiversa+ conducts this survey to develop a roadmap on biodiversity monitoring novel technologies and approaches.
By answering this questionnaire, you accept that DACC, FRB, MoE_FI, three Biodiversa+ partners, will collect your contact details namely: your first and last names, the full name of your organisation, the acronym and country of your organisation, your email address will be processed to better analyse your answers and contact you later on, if needed.

These data will be securely processed and stored, in compliance with the European General Data Protection Regulation 2016/679, and used only for the purposes of this consultation. The deletion of your personal data will take place on the 30th of September 2028, at the end of Biodiversa+.

At any time, please keep in mind that you will have the possibility to consult, modify, update or delete your personal data by contacting the Biodiversa+ Operational Team at the following email address: nadia.balduccio@eurac.edu

☐ By ticking this box, I confirm that I read the above-mentioned conditions and accept to share my personal data.

Information on your organisation

Name
Email address
Name of your organisation (in English)
Acronym of your organisation (as mentioned in the Biodiversa+ Grant Agreement)
Level of the information that you are going to present: National/ Sub-national / Other (free text)
Type of respondent (select from the options below):

- Ministry of Environment
- Environmental Agency
- Funding Agency
- Research Ministry
- Other (free text)

Section I – Novel technologies

A novel technology can be defined as a method/technology that is "not yet widely applied in biodiversity monitoring, regardless of when proof of concept was published or otherwise released" (https://doi.org/10.3897/arphapreprints.e105600). This questionnaire targets the use of novel technologies in policy related biodiversity monitoring overseen by the respondent. In this updated version of the survey, we include remote sensing techniques as separate from UAVs/drones, due to the different times of implementation of these techniques in general, compared to the recent use of drones/UAVs.

- **Bioacoustics** is the production, transmission, and reception of animal sounds in nature. The use of bioacoustics can, for example, give insight into species diversity, habitat health, and wildlife behaviour (WildlifeAcoustics, 2024). Examples of the use of novel bioacoustics methods include but are not limited to species classifiers (Artificial intelligence, i.e. BirdNET).
- **Camera traps** are devices used remotely to record wildlife activity. They can be left in the field for long periods of time and can be activated to take photos or videos (Green et al., 2020). Examples of the use of novel camera techniques include but are not limited to, the use of artificial intelligence and image classification.
- **Environmental DNA** (or eDNA) is a technique that involves collecting DNA or RNA samples (genomics) from the environ- ment, such as from water, soil, sediment, or air (Norros et al., 2022). There are several eDNA novel analyses which include but are not limited to, metabarcoding, shotgun sequencing or quantitative PCR (Winding, 2024).
- **Sensor networks** are highly distributed networks of sensors (which are devices that gather environmental information in a specific location, such as temperature, pressure, and relative humidity) usually deployed in large numbers to monitor an envi- ronment or system (Goulart et al., 2022). Examples of the network sensors include but are not limited to the use of IoT and off-grid communications.
- **Unmanned Aerial Vehicles (UAVs)**, also known as drones, are air vehicles that fly autonomously or are remotely piloted. Examples of novel methods with the use of UAVs include, but are not limited to, three-dimensional (3D) mapping, aerial ima- ging, oblique photogrammetry, sensing, laser scanning, the Internet-of-Things (IoT), computer vision, and artificial intelligence (AI) (Mohsan et al., 2023).

- **Remote sensing** are methods of obtaining information about objects or areas from a distance, typically from aircraft or satelli- tes. Examples of remote-sensing methods include aerial photography, radar, and satellite imagery (Wang et al. 2010).

Ia) To what level of deployment is each technology being used currently?

- Bioacoustics
  - **If yes, to what level of deployment is each technology being used currently?**
    - Actual method used in operational environment
    - Method complete and validated but not used in operational environment
    - Prototype demonstrated in operational environment
    - Not used/developed but interested in using/developing
    - Not used/developed and not interested in using/developing
    - Not known
- Camera trap
  - **If yes, to what level of deployment is each technology being used currently?**
    - Actual method used in operational environment
    - Method complete and validated but not used in operational environment
    - Prototype demonstrated in operational environment
    - Not used/developed but interested in using/developing
    - Not used/developed and not interested in using/developing
    - Not known
- UAVs/Drones
  - **If yes, to what level of deployment is each technology being used currently?**
    - Actual method used in operational environment
    - Method complete and validated but not used in operational environment
    - Prototype demonstrated in operational environment
    - Not used/developed but interested in using/developing
    - Not used/developed and not interested in using/developing
    - Not known
- eDNA/Genomics
  - **If yes, to what level of deployment is each technology being used currently?**
    - Actual method used in operational environment
    - Method complete and validated but not used in operational environment
    - Prototype demonstrated in operational environment
    - Not used/developed but interested in using/developing
    - Not used/developed and not interested in using/developing
    - Not known
- Sensor networks
  - **If yes, to what level of deployment is each technology being used currently?**
    - Actual method used in operational environment
    - Method complete and validated but not used in operational environment
    - Prototype demonstrated in operational environment
    - Not used/developed but interested in using/developing
    - Not used/developed and not interested in using/developing
    - Not known

Section II – Bioacoustics

Bioacoustics is the production, transmission, and reception of animal sounds in nature. The use of bioacoustics can, for example, give insight into species diversity, habitat health, and wildlife behaviour (WildlifeAcoustics, 2024). Examples of the use of novel bioacoustics methods include but are not limited to species classifiers (Artificial intelligence, i.e. BirdNET).

Please only answer the following questions if you use **bioacoustics** in the operational environment, or have completed and validated bioacoustics methods but have not yet used them in the environment or have a prototype(s) in the operational envi- ronment. If not, please skip the questions below and continue to the next section.

IIa) Do you use bioacoustics novel techniques for addressing the monitoring of:

- Species traits
  - Physiology
  - Phenology
  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity
- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction
- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

IIb) Describe what bioacoustics techniques/technologies you use.

IIc) In which realms do you apply bioacoustics?

- Freshwater
- Marine
- Terrestrail
- Other:

IId) What taxa do you use bioacoustics novel techniques for? To what level of deployment is each technology being used currently?

- Terrestrial invertebrates[6]
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Fish
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Birds
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

- Aquatic invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Amphibians/reptiles
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Other taxa
  - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

IIe) When using bioacoustics methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities? If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

IIf) Do you find any constraints/challenges you-re facing with the use or deployment of bioacoustics novel methods?

- None
- Competition between data standards
- Conservation challenges
- Ethics/legal considerations
- Data storage
- Data integration
- Data security
- Data analysis
- Data synthesis
- Unharmonised sound libraries
- Lack of funding
- Lack of technical skills
- Lack of knowledge on use of approaches
- Time required
- Maintenance costs
- Training access
- Technical difficulties
- Lack of data/model infrastructures
- Other:

IIg) Do you have plans on innovating/developing the use of this tech more? (if yes please describe what and how).

Section III – Camera traps

Camera traps, devices used remotely to record wildlife activity. They can be left in the field for long periods of time and can be activated to take photos or videos (Green et al., 2020). Examples of the use of novel camera techniques include but are not limited to, the use of artificial intelligence and image classification.

Please only answer the following questions if you use **camera traps** in the operational environment, or have completed and validated bioacoustics methods but have not yet used them in the environment or have a prototype(s) in the operational envi- ronment. If not, please skip the questions below and continue to the next section.

IIIa) Do you use camera trapping novel techniques for addressing:

- Species traits
  - Physiology
  - Phenology

  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity
- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction
- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

IIIb) Describe what camera trapping techniques/technologies you use.

IIIc) In which realms do you apply camera traps?
- Freshwater
- Marine
- Terrestrail
- Other:

IIId) What taxa do you use camera trapping novel techniques for? To what level of deployment is each technology being used currently?
- Terrestrial invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:

- Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

- Fish
    - How many species of this taxa (and which ones) do you use this novel tech to monitor:
    - Deployment level
        a) Actual method used in operational environment
        b) Method complete and validated but not used in operational environment
        c) Prototype demonstrated in operational environment
        d) Not used/developed but interested in using/developing
        e) Not used/developed and not interested in using/developing
        f) Not known
    - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
        - Mobile applications
        - Artificial intelligence tools
        - Protected Area management tools
        - Data management and processing tools
        - Non-AI computational tools
        - Other:
- Birds
    - How many species of this taxa (and which ones) do you use this novel tech to monitor:
    - Deployment level
        a) Actual method used in operational environment
        b) Method complete and validated but not used in operational environment
        c) Prototype demonstrated in operational environment
        d) Not used/developed but interested in using/developing
        e) Not used/developed and not interested in using/developing
        f) Not known
    - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
        - Mobile applications
        - Artificial intelligence tools
        - Protected Area management tools
        - Data management and processing tools
        - Non-AI computational tools
        - Other:
- Aquatic invertebrates
    - How many species of this taxa (and which ones) do you use this novel tech to monitor:
    - Deployment level

a) Actual method used in operational environment
b) Method complete and validated but not used in operational environment
c) Prototype demonstrated in operational environment
d) Not used/developed but interested in using/developing
e) Not used/developed and not interested in using/developing
f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

- Amphibians/reptiles
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Other taxa
  - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

IIIe) When using camera trapping methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities?
If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

IIIf) Do you find any constraints/challenges you-re facing with the use or deployment of this novel technology?[MH11]

- None
- Competition between data standards
- Lack of/limited capacity
- Conservation challenges
- Ethics/legal considerations
- Data storage
- Data integration
- Lack of funding
- Lack of technical skills
- Lack of knowledge on use of approaches
- Time required
- Maintenance costs
- Training access
- Technical difficulties
- Data security
- Lack of data/model infrastructures
- Other:

IIIg) Do you have plans on innovating/developing the use of this tech more (if yes please describe what and how).

Section IV – eDNA and genomics

Environmental DNA (or eDNA) is a technique that involves collecting DNA or RNA samples (genomics) from the environment, such as from water, soil, sediment, or air (Norros et al., 2022). There are several eDNA novel analyses which include but are not limited to, metabarcoding, shotgun sequencing or quantitative PCR (Winding, 2024).

Please only answer the following questions if you use **eDNA/genomics** in the operational environment, or have completed and validated bioacoustics methods but have not yet used them in the environment or have a prototype(s) in the operational envi- ronment. If not, please skip the questions below and continue to the next section.

IVa) Do you use eDNA/Genomics novel techniques for addressing:

- Species traits
  - Physiology
  - Phenology
  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity

- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction
- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

IVb) Describe what eDNA/Genomics techniques/technologies you use.

IVc) In which realms do you apply eDNA/Genomics?

- Freshwater
- Marine
- Terrestrail
- Other:

IVd) What taxa do you use eDNA/Genomics novel techniques for? To what level of deployment is each technology being used currently?

- Terrestrial invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Plants
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications

- Artificial intelligence tools
- Protected Area management tools
- Data management and processing tools
- Non-AI computational tools
- Other:

- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Fish
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Birds
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools

- Protected Area management tools
- Data management and processing tools
- Non-AI computational tools
- Other:

- Aquatic invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Amphibians/reptiles
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Algae
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools

- Data management and processing tools
- Non-AI computational tools
- Other:

- Fungi
  - How many species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Other taxa
  - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

IVe) When using eDNA/Genomics methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities? If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

IVf) Do you find any constraints/challenges you-re facing with the use or deployment of this novel technology?

- None
- Competition between data standards
- Difficulties in comparing results
- Lack of/limited capacity
- Conservation challenges
- Ethics/legal considerations
- Lack of funding

- Lack of technical skills
- Lack of knowledge on use of approaches
- Lack of reference data bases/libraries
- Time required
- Maintenance costs
- Training access
- Technical difficulties
- Data security
- Lack of human forces
- No strong policy support
- Other:

IVg) Do you have plans on innovating/developing the use of this tech more (if yes please describe what and how).

Section V – UAV/drones

Unmanned Aerial Vehicles (UAVs), also known as drones, are air vehicles that fly autonomously or are remotely piloted. Examples of novel methods with the use of UAVs include, but are not limited to, three-dimensional (3D) mapping, aerial imaging, oblique photogrammetry, sensing, laser scanning, the Internet-of-Things (IoT), computer vision, and artificial intelligence (AI) (Mohsan et al., 2023).

Please only answer the following questions if you use **UAVs/drones** in the operational environment, or have completed and validated bioacoustics methods but have not yet used them in the environment or have a prototype(s) in the operational envi- ronment. If not, please skip the questions below and continue to the next section.

Va) Do you use UAV/drones novel techniques for addressing:

- Species traits
  - Physiology
  - Phenology
  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity
- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction
- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

Vb) Describe what UAV/drones techniques/technologies you use.

Vc) In which realms do you apply UAVs/drones?

- Freshwater
- Marine
- Terrestrail
- Other:

Vd) What taxa do you use UAV/drones novel techniques for? To what level of deployment is each technology being used currently?

- Terrestrial invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Plants
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

- Fish
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Birds
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Aquatic invertebrates
  - How many species of this taxa do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known

- If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
  - Mobile applications
  - Artificial intelligence tools
  - Protected Area management tools
  - Data management and processing tools
  - Non-AI computational tools
  - Other:

- Amphibians/reptiles
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Other taxa
  - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

Ve) When using UAV/Drones methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities? If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

Vf) Do you find any constraints/challenges you-re facing with the use or deployment of this novel technology?

- None
- Competition between data standards
- Difficulties in comparing results
- Lack of/limited capacity
- Scaling sustainably
- Conservation challenges
- Ethics/legal considerations
- Lack of funding
- Lack of technical skills
- Lack of knowledge on use of approaches
- Time required
- Maintenance costs
- Training access
- Technical difficulties
- Data security
- Data storage
- Data integration
- Other:

Vg) Do you have plans on innovating/developing the use of this tech more (if yes please describe what and how).

Section VI – Sensor networks

Sensor networks are highly distributed networks of sensors (which are devices that gather environmental information in a specific location, such as temperature, pressure, and relative humidity) usually deployed in large numbers to monitor an environment or system (Goulart et al., 2022). Examples of the sensor networks include but are not limited to the use of IoT and off-grid communications.

Please only answer the following questions if you use **sensor networks** in the operational environment, or have completed and validated bioacoustics methods but have not yet used them in the environment or have a prototype(s) in the operational envi- ronment. If not, please skip the questions below and continue to the next section.

VIa) Do you use sensor networks novel techniques for addressing: (tick relevant boxes)

- Species traits
  - Physiology
  - Phenology
  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity
- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction

- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

VIb) Describe what sensor networks techniques/technologies you use.

VIc) In which realms do you apply sensor networks?
- Freshwater
- Marine
- Terrestrail
- Other:

VId) What taxa do you use sensor networks novel techniques for? To what level of deployment is each technology being used currently?
- Terrestrial invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools

- Other:

- Fish
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Birds
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Aquatic invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

- Amphibians/reptiles
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Other taxa
  - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:

VIe) When using sensor network methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities? If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

VIf) Do you find any constraints/challenges you-re facing with the use or deployment of this novel technology?

- None
- Competition between data standards
- Difficulties in comparing results
- Lack of/limited capacity
- Conservation challenges
- Ethics/legal considerations
- Lack of funding
- Lack of technical skills
- Lack of knowledge on use of approaches
- Time required

- Maintenance costs
- Training access
- Technical difficulties
- Data security
- Data storage
- Data integration
- Deployment difficulties
- Management difficulties
- Other:

VIg) Do you have plans on innovating/developing the use of this tech more (if yes please describe what and how).

Section VII – Remote sensing

A method of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Examples of re- mote-sensing methods include aerial photography, radar, and satellite imagery (Wang et al. 2010). **Please note that we do not include use of remote sensing/drones in this section.**

Please only answer the following questions if you use **remote sensing (except drones/UAVs)** in the operational environment, or have completed and validated remote sensing methods but have not yet used them in the environment or have a prototype(s) in the operational environment. If not, please skip the questions below and continue to the next section.

VIIa) Do you use remote sensing novel techniques for addressing:

- Species traits
  - Physiology
  - Phenology
  - Movement
  - Morphology
  - Reproduction
- Species populations
  - Species distributions
  - Species abundances
- Genetic composition
  - Effective population size
  - Inbreeding
  - Genetic differentiation
  - Intraspecific genetic diversity
- Ecosystem structure
  - Ecosystem vertical profile
  - Ecosystem distribution
  - Live cover fraction
- Ecosystem functioning
  - Primary productivity
  - Ecosystem disturbances
  - Ecosystem phenology
- Community composition
  - Trait diversity
  - Taxonomic/phylogenetic diversity
  - Interaction diversity
  - Community abundance

VIIb) Describe what remote sensing techniques/technologies you use.

VIIc) In which realms do you apply remote sensing?

- Freshwater
- Marine
- Terrestrail
- Other:

VIId) What taxa do you use remote sensing novel techniques for? To what level of deployment is each technology being used currently?

- Terrestrial invertebrates
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Plants
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
- Mammals
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**

- Mobile applications
- Artificial intelligence tools
- Protected Area management tools
- Data management and processing tools
- Non-AI computational tools
- Other:

- Fish
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Birds
  - How many species of this taxa (and which ones) do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications
    - Artificial intelligence tools
    - Protected Area management tools
    - Data management and processing tools
    - Non-AI computational tools
    - Other:
- Aquatic invertebrates
  - How many species of this taxa do you use this novel tech to monitor:
  - Deployment level
    a) Actual method used in operational environment
    b) Method complete and validated but not used in operational environment
    c) Prototype demonstrated in operational environment
    d) Not used/developed but interested in using/developing
    e) Not used/developed and not interested in using/developing
    f) Not known
  - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
    - Mobile applications

        - Artificial intelligence tools
        - Protected Area management tools
        - Data management and processing tools
        - Non-AI computational tools
        - Other:
- Amphibians/reptiles
    - How many species of this taxa (and which ones) do you use this novel tech to monitor:
    - Deployment level
        a) Actual method used in operational environment
        b) Method complete and validated but not used in operational environment
        c) Prototype demonstrated in operational environment
        d) Not used/developed but interested in using/developing
        e) Not used/developed and not interested in using/developing
        f) Not known
    - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
        - Mobile applications
        - Artificial intelligence tools
        - Protected Area management tools
        - Data management and processing tools
        - Non-AI computational tools
        - Other:
- Other taxa
    - How many different species of other taxa (and which ones) do you use this novel tech to monitor:
    - Deployment level
        a) Actual method used in operational environment
        b) Method complete and validated but not used in operational environment
        c) Prototype demonstrated in operational environment
        d) Not used/developed but interested in using/developing
        e) Not used/developed and not interested in using/developing
        f) Not known
    - If a, b, or c were ticked: **do you use novel methods in any data synthesis systems (**the integration of separate datasets conducted across various locations and time points to obtain an overall signal or trend)**? If so, please select:**
        - Mobile applications
        - Artificial intelligence tools
        - Protected Area management tools
        - Data management and processing tools
        - Non-AI computational tools
        - Other:

VIIe) When using remote sensing methods for biodiversity monitoring, are you involving other international/ national/ sub-national/ other entities? If yes please provide details on at what level (data collection/analysis...), what taxa/scale of monitoring, and with whom you are involved with. Please also share this organisation/entity website/link with us.

VIIf) Do you find any constraints/challenges you-re facing with the use or deployment of this novel technology?

- None
- Competition between data standards
- Difficulties in comparing results
- Lack of/limited capacity
- Scaling sustainably

- Conservation challenges
- Ethics/legal considerations
- Lack of funding
- Lack of technical skills
- Lack of knowledge on use of approaches
- Time required
- Maintenance costs
- Training access
- Technical difficulties
- Data security
- Data storage
- Data integration
- Other:

VIIg) Do you have plans on innovating/developing the use of this tech more (if yes please describe what and how).

Section VIII – Final Remarks

VIIa) Do you have any additional comments of anything you would like to share with us about your experience using/deploying novel technologies for biodiversity monitoring?

VIIb) Please list the names and contact details of any third parties that were involved in answering any questions or sharing data for the completion of this survey.

VIIc) Would you be available for a bilateral interview that follows the completion of this survey for a better understanding of the state of deployment of novel technologies used for biodiversity monitoring in your country/region? Please provide our contact details if so:

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