BiodivMon Call Text

The Funding Organisations in Biodiversa+ Partnershiphave joined efforts to organise and fund an Internation call for transnational research proposals on
"Improved transnational monitoring of biodiversity and ecosystem change for science and society (BiodivMon)"

(1) Context

Ecosystems are being degraded and biodiversity is lost at alarming rates around the world (IPBES 2018, 2019). Recently, it has been estimated that as much as 75% of the terrestrial environment, 40% of the marine environment and 50% of rivers and streams are severely altered due to human activity. In Europe, 96-98% of forests are disturbed by human activities, and 85% of grasslands, heaths, and scrubs are in non-favourable conservation status, as are 90% of wetlands and more than 70% of marine habitats (JRC 2020). This environmental impact is also one of the major drivers of the high and still accelerating rate of species extinctions. Intensification of agricultural use, natural resource exploitation, pollution, the invasion of alien species and climate change, as well as their multiple synergistic effects, drive considerable declines in the diversity of life on Earth. These losses matter. They impact human health and well-being, and in economic terms, the world loses trillions of USD each year in ecosystem services owing to land-cover change and land degradation (OECD 2019). The continuous attrition of biodiversity erodes the capacity of ecosystems to provide clean drinking water, purify our air, regulate our climate, or secure our food supplies, as well as their capacity to sustain services essential for continued functioning of the ecosystems in themselves.

In response to this biodiversity and environmental crisis, Heads of States around the world have made significant commitments for nature. Most notable are the Leaders' Pledge for Nature launched at the United Nations General Assembly in 2020, the 30 by 30 commitment to protect 30% of our land and seas by 2030, and the fostering of the restoration of at least 20% of habitats and related ecosystem processes (CBD 2021, LPN 2021). In Europe, the EU Biodiversity Strategy for 2030 commits Member States to ensure no deterioration in conservation trends and status of all protected habitats and species by 2030, and that at least 30% of species and habitats not currently in favourable status are in that category or show a strong positive trend (European Commission 2020). With its key funding programme for research and innovation Horizon Europe, the EU aims for recovering biodiversity, sustainably preserving, and restoring ecosystems and their services through improved knowledge and innovation. Activities under Horizon Europe's Cluster 6 will support the objectives of the EU Biodiversity Strategy for 2030, which is further complemented by other important strategies and initiatives such as the EU Forest Strategy for 2030, the EU Soil Strategy for 2030, and the EU Pollinators Initiative, all of which require improved transnational monitoring of biodiversity and ecosystem change.

In the context of biodiversity monitoring, substantial contributions are expected from the research community to enhance our understanding of biodiversity status, dynamics and trends. Appropriate, rigorous, and up-to-date data to improve knowledge about the state and trends of biodiversity constitute a basic requirement for the transition of all human activities and

economies to a positive path for nature. Indeed, to develop effective conservation and management strategies, the ability to assess the status and changes of biodiversity comprehensively and reliably, and aligning it with an understanding of the effects of multiple stressors on ecological systems, is fundamental.

Biodiversity is dynamic in space and time. It responds continually and over the longer-term to abiotic and biotic environmental drivers, such as biological invasions, human pressures, and climate change. It is thus necessary to efficiently monitor the status and changes of biodiversity at regular intervals in space and time, to investigate underlying mechanisms and to develop relevant management scenarios. Similarly, standardised and accurate data are needed to (i) deepen our understanding and ability to predict the short- and long-term effects on biodiversity of various conservation and management interventions, as well as drivers including climate change, and to evaluate the effect of these interventions and support evidence-based adjustments when necessary, and (ii) enable the inclusion of biodiversity into public and private accounting and reporting systems.

Literature reviews on biodiversity changes and recent assessments have revealed that information on biodiversity trends is biased towards some taxonomic groups and environments, and that important dimensions of biodiversity, e.g., genetic and functional diversity, remain to be properly studied (IPBES 2018, FAO 2020). Furthermore, a recent European Environment Agency (EEA) report identifies a series of knowledge gaps that include the need for a better characterization of the distribution and status of many habitats and species, and more generally the assessment of ecosystem condition and health (EEA 2020). There is also a need to help strengthen national bodies reporting to the EEA about progress on indicators of biodiversity change, and work supported by this call should, where appropriate, build upon and feed into reports on conservation status and trends such as EEA reports towards the EU Habitats Directive.

Particularly urgent are better harmonisation of monitoring schemes and thorough analysis of their outcomes, improved data collection through reinforcement of existing schemes and development, and implementation of new tools and technologies. Similarly, there is a need to produce more robust biodiversity trend estimates, and gain a better understanding of the drivers of biodiversity dynamics and their coupled effects, complemented by improved modelling of biodiversity scenarios. Research is further needed to develop and assess tools and approaches to monitor and quantify biodiversity, to compare data collected with novel versus established tools, and to develop innovative uses of existing monitoring schemes. Moreover, there is a need for better harmonisation of variables, data formats, and development of FAIR[1] databases (Findable, Accessible, Interoperable and Reusable), as well as rapid technological advances with respect to data collection, management and analysis. Research on these topics is needed to reinforce and supplement efforts by for example the biodiversity observation networks of the Group on Earth Observation Biodiversity Observatory Network (GEO BON) and EuropaBON[2], eLTER/LTER, GBIF, European Marine Observation and Data Network (EMODnet), European Bird Census Council (EBCC), Pan-European Common Bird Monitoring Scheme (PECBMS) and other biodiversity research and data infrastructures in Europe and globally. Merging classical biodiversity field observations with e.g., automated tools, emerging sensor technologies, eDNA techniques, remote and mobile sensing, artificial intelligence, as well as

[1] https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf
[2] https://europabon.org

citizen science, could help to identify the best strategies to reverse biodiversity loss. Approaches could also entail research to help moving from individual prototypes to widespread use, in order to develop effective conservation strategies and measures by enhancing cost-efficiency and real-time information on species abundance. This could also increase the data on less studied taxa, interactions, and habitats. Participatory citizen science, strengthened by education (and vice versa), can in collaboration with the relevant agencies be effective to increase public understanding of biodiversity and the importance of sustainability (EC 2020).

There are other important efforts to build upon, such as the Global Biodiversity Information Facility (GBIF), with data and protocols for standardised collections of scientific and citizen science data on biodiversity status, trends, and dynamics. Yet, measuring and analysing biodiversity changes across Europe to inform policy makers remains highly challenging. This is due in part to the limited spatial, temporal and species coverage of existing biodiversity monitoring schemes, the lack of standard approaches of biodiversity monitoring for many species and regions, and the limited FAIRness of existing datasets. The GEO BON group is however developing an international concept framework named Essential Biodiversity Variables (EBV) to help harmonising monitoring schemes and protocols, which is going to be a key element at the interface between science and policy and between monitoring and research. For these reasons, it will be important to assess how the use and uptake of existing data from GBIF and other facilities can be improved, and how the use of Earth Observation and harmonised protocols for standardised collection of data can be increased across Europe and globally.

To address these challenges, developing common methodologies and shared frameworks through collaborative work across countries that face similar challenges, policy targets and ecosystems is essential. This is addressed by several global legal and policy frameworks, including the Convention on Biological Diversity (CBD), UNCLOS, RAMSAR and CITES. In Europe, several environmental directives encourage a transnational approach to optimize resource use and achieve adequate coverage for environmental management and protection, such as the EU Directives on Habitats, Birds, Water Framework, and Maritime spatial planning respectively, as well as the Marine Strategy Framework Directive and the Regulation on alien invasive species (European Commission 1992, 2000, 2008, 2009, 2014a, 2014b).

(2) Expected impacts and transnational added value

Projects are encouraged to consider interdisciplinary issues, cutting across the themes identified in the call and adopting or studying a broad range of methodological approaches. This call aims at funding transdisciplinary research projects demonstrating academic excellence, as well as potential societal impact and policy impact (see: Biodiversas Guide on Policy Relevance; https://www.biodiversa.org/1543). Proposed projects should provide relevant information and practical tools to promote the use of biodiversity monitoring data to provide science-based support for policy makers, authorities, and practitioners concerned with decision making, planning, designing, and managing a broad range of environments. Outreach to society is key for successful implementation of research into practice, which means that communication aspects should be carefully designed and fully integrated in the proposed project, and visualisation and analysis tools should be participatory. More generally, applicants should consider how the knowledge can be co-produced with stakeholders and disseminated in outreach actions to maximize societal impact (see: BiodivERsA Guide on Stakeholder

Engagement; https://www.biodiversa.org/702). Participation of public and private stakeholders in research proposals is strongly encouraged.

This call will support research projects in which the approaches and skills of natural sciences, technical sciences (including computer sciences and engineering), social sciences (e.g., economy, innovation sciences, psychology, sociology), and humanities (e.g., history, law, human geography), are integrated to address the specific objectives of each proposal. Strong transnational cooperation is expected, especially regarding the use, design and maintenance of long-term monitoring schemes allowing common approaches across countries to be derived from existing and future data and methodologies. Possibilities should be explored on how to maintain successful, robust monitoring approaches developed under this call also after the end of the projects, with support from involved stakeholders, programmes, and research infrastructures. Approaches linking transnational cooperation and their outputs that can be expanded to countries beyond the funders to this call are encouraged.

Applicants should make the novelty of their research explicit and detail how it adds to the existing knowledge base, both in the government and private sectors, including previously funded or ongoing projects and programmes. Complementarity with, and building upon, ongoing efforts within Horizon Europe and internationally on this theme is strongly encouraged, while unwarranted overlap or duplication is to be avoided. The added value of complementing existing research and monitoring programmes must be clearly explained, and proposals should demonstrate awareness and clear linkages towards relevant programmes. Proposals should also clearly outline the potential for their project outputs to feed into and support European and global monitoring, reporting, data and policy frameworks and programmes (EU Biodiversity Strategy for 2030, European Environment Agency, GBIF, Joint Research Centre (JCR), Knowledge Centre for Biodiversity (KCBD), as well as relevant projects such as EuropaBON, Marine Biodiversity Monitoring in Europe (MarBioME)[3], etc.

Applicants are encouraged to use existing resources and infrastructures for their project, including the involvement of data and information from Earth Observation Programmes, transnational networks, EMODNET for marine data, and biodiversity research infrastructures (see: BiodivERsA Mapping of Biodiversity Research Infrastructures; https://www.biodiversa.org/1911). Links with other programmes and projects funded by the EU are also encouraged, for example under the LIFE Programme, Interreg and others. If projects use satellite-based earth observation, positioning, navigation and/or related timing data and services, beneficiaries must make use of Copernicus and/or Galileo/EGNOS (other data and services may additionally be used).

(3) Priorities of the Call

This call is an opportunity to advance knowledge on biodiversity through monitoring, building on previous and existing efforts across Europe and beyond. It aims to support transdisciplinary and transnational research projects with a 3-years duration. Projects should have an overall focus on improving knowledge on species distribution and abundance. Moreover, projects should contribute to refining and enhancing and upscaling existing methods, and/or developing, testing, applying and evaluating new methods to characterize, understand, and model biodiversity status, dynamics, and trends at relevant spatial and temporal scales; developing

[3] https://www.aircentre.org/projects/marbiome/

tools for better implementation and harmonisation of monitoring schemes across countries and regions; and showing the power of (new and existing) monitoring information to inform transformative policies and management.

The call covers research on biodiversity conservation in all terrestrial, freshwater, and marine environments in Europe, the Outermost Regions (ORs) and Overseas Countries and Territories (OCTs), and globally across all continents and oceans. Transdisciplinary research projects are expected to integrate research across relevant scientific disciplines, from natural sciences, technical sciences, social sciences and humanities, and include relevant public and private stakeholders.

Applicants are invited to submit proposals addressing one or more of the three themes outlined in this call. Particularly welcome are development and application of new, and/or evaluation and advancement and upscaling of existing methods, technologies, and approaches for biodiversity monitoring, including its data collection, management, and analysis. Proposals should fill gaps in terms of coverage of taxa, ecosystem types, regions, and sampling frequency and, where relevant, consider concrete linkages to operational monitoring networks, research infrastructures, and other existing efforts at national, European, and global level. Funded projects will also be invited to collaborate with different actions on biodiversity monitoring within the Biodiversa+ partnership through the coming years. Projects focusing on poorly known organism groups, under-researched species of high functional significance and under-studied ecosystems and their functioning are particularly encouraged.

Biodiversa+ strongly supports open science, including open sharing of research data and digital outputs to stimulate novel approaches to the collection, reuse, analysis, validation, and management of data and information, thus increasing the transparency of the research process and robustness of the results. Therefore, submitted projects are expected to make produced data, digital outputs, and supporting material (including metadata) publicly available, possibly after a short period of exclusivity, unless there are legitimate reasons to constrain access. In particular, raw data should be made accessible to allow for integrated data analysis across different datasets. Data and digital outputs must be discoverable through machine readable catalogues, information systems and search engines. Projects should generate FAIR[4] data and knowledge products, particularly in the context of real-time data feeds, exploring workflows that can provide "FAIR-by-design" data, i.e., data that is FAIR from its generation, and building on and widening data availability in European Research Infrastructures federated under the European Open Science Cloud (EOSC). To this end, project proposals will need to develop and implement a Data and Digital Outputs Management Plan, which will also ensure ethical approaches and compliance with the Data Policy of this call (Document 5 in the call documents). Note that BiodivERsA and the Belmont Forum have developed a guidance document on data management, open data, and the production of Data Management Plans (DMPs), which may help applicants when developing their data management plan (http://www.biodiversa.org/1677/download). Training events to exemplify the added value and variety of tools at hand for the researchers to make their data freely accessible will be organised by Biodiversa+.

[4] FAIR data principles: Findable, Accessible, Interoperable and Reusable
https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_0.pdf

RESEARCH THEME 1

Innovation and harmonisation of methods and tools for collection and management of biodiversity monitoring data

The European countries will only be able to measure progress towards the targets laid out in the EU Biodiversity Strategy for 2030 if urgent action is taken over the next decade to improve acquisition, management, and dissemination of data. This involves a critical evaluation of the value of novel technologies to complement, enrich, or even in some instances replace, traditional biodiversity monitoring methods. Harmonisation and improvement of monitoring schemes and integration of data into international open access platforms is critically needed for scientists to cross-validate information, but also to support cross-sector collaboration and cross-fertilization in research. Existing national monitoring schemes should be considered as a way to feed into European and Global initiatives. This includes to identify important data gaps, to ensure that the right information is available to scientists and end-users of biodiversity data, and to allow for evidence-based, data-driven policy and management decisions on the sustainable use of living, mineral, and energetic resources, and of preparation for future scenarios. Projects can cover all aspects, from data collection in the field to quality control, management, integration, standardisation, or analysis, of data in line with the FAIR data principles, including management of uncertainty within functional data workflows.

Important challenges under this theme include:

- Development and implementation of new or improved approaches and technologies for monitoring biodiversity. Such advances should focus on development for practical application and evaluation, with the aim to quickly implement these in biodiversity monitoring schemes from local to large spatial scales. Proposals should complement and feed into ongoing efforts on novel technology within e.g., EuropaBON, and should also take into consideration and build on efforts and output from other calls within Horizon Europe[5].
- Examples of technologies with potential to complement existing activities and help overcome key monitoring gaps are: collection and analysis of field data through artificial intelligence (AI) on both the symbolic (e.g., knowledge graphs) and sub-symbolic (e.g., deep neural networks) level; eDNA and other molecular biology-based approaches; functional ecology (biological traits, ecosystem function rates); satellite remote sensing; airborne surveys and/or drones; bio-acoustics; camera traps; automated and standardised biodiversity sensor networks; mobile applications for recording and identifying biodiversity; as well as new algorithms such as machine learning to e.g. reduce ambient noise or facilitate data processing for species identification. Proposed

[5] For example:
- Data and technologies: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2021-biodiv-01-02;
- Networking natural history museums: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2022-biodiv-01-02;
- Marine biodiversity observation: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2022-biodiv-01-01

technologies should be assessed to ensure their relevance and applicability in the particular context (complementarity, legal aspects, privacy, ethics etc.).

- Improving current monitoring approaches and technologies from demonstration to large-scale application across spatial scales, domains, and taxa, and evaluating the ability to collect pressure variables along with state variables.
- Harmonising existing operationalized protocols, methods and approaches for field data collection, Essential Biodiversity Variables (EBV), and indicators for monitoring the state of biodiversity and ecosystems, and for making them open and available to complement and feed into existing European and global initiatives.
- Optimizing the coverage and representativeness of biodiversity monitoring schemes, to support and complement existing efforts, addressing possible bias of taxonomic groups and habitats, analysis of cost-benefit ratios for different monitoring schemes, and pros and cons of upscaling and automation. This can include enhanced use of citizen science and increased public awareness including the role of (social) media and communication. Where relevant, reference should be made to existing and developing monitoring schemes at the national or transnational level[6].
- Analysis and evaluation of impacts from current biodiversity monitoring methods, and possible proposal of alternatives, with a view to sustainability of practice in sampling and data collection.
- Addressing possible bias regarding taxonomic groups and habitats, analysis of cost-benefit ratios for different monitoring schemes (also beyond monetary terms), and pros and cons of upscaling and automation.
- Improving and standardising data collection in citizen science and local/indigenous knowledge for biodiversity monitoring with regards to methodology, data quality, complementarity with scientific data and adherence to the FAIR principles, aiming to enhance their combined usability for research, management, and policy. This includes: (i) reinforcement of existing transnational networks and further development of feedback to stakeholders with user-friendly and digital tools and approaches; (ii)

[6] For example:

- EU Pollinator Monitoring Scheme: https://wikis.ec.europa.eu/pages/viewpage.action?pageId=23462107
- European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL): https://wikis.ec.europa.eu/pages/viewpage.action?pageId=25560696
- LUCAS grassland and soil modules: https://ec.europa.eu/eurostat/web/lucas/data/primary-data/2022
- European Butterfly Monitoring Scheme: https://butterfly-monitoring.net/
- Pan-European Common Bird Monitoring Scheme: https://pecbms.info/
- European Marine Observation and Data Network (EMODNet): https://emodnet.ec.europa.eu/en
- The new EU Forest Strategy: https://ec.europa.eu/environment/strategy/forest-strategy_en; and proposal for an EU Framework for Forest Monitoring and Strategic Plans: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13396-EU-forests-new-EU-Framework-for-Forest-Monitoring-and-Strategic-Plans_en
- Baltic Data Flows: https://maritime-spatial-planning.ec.europa.eu/projects/baltic-data-flows

securing and/or development of data sets and digital infrastructure to leverage and enable large-scale citizen science efforts (this can include the creation of guidelines to encourage continuity, training, and involvement of people of diverse profiles and ages in citizen science activities); (iii) employing a mixture of technical, traditional, and contemporary knowledge practices for studying biodiversity trends and monitoring through a local and long-term perspective.

- Proposals should take into consideration and build on the outputs produced by the Horizon 2020 project EuropaBON where relevant, in particular on: i) the report on EU user and policy needs for biodiversity monitoring[7]; ii) the proposed list of candidate Essential Biodiversity Variables (EBV) and Essential Ecosystem Services Variables (EESV) for European biodiversity monitoring[8]; iii) the work produced on the identification of monitoring gaps and on the analysis of monitoring workflow bottlenecks[9]; iv) the report on potential of novel technologies for biodiversity monitoring[10], and v) the EuropaBON inventory of monitoring initiatives[11].

RESEARCH THEME 2

Addressing knowledge gaps on biodiversity status, dynamics, and trends to safeguard biodiversity and to reverse biodiversity loss

Biodiversity monitoring is crucial for understanding dynamics, status, and trends through all levels of biodiversity – from genetic to ecosystem variation. Moreover, monitoring data is necessary in evaluating and assessing the efficacy and cost-benefit aspects of different approaches to bend the curve of biodiversity loss, such as ecosystem restoration, rewilding, improved protected area coverage or refined management. Evidence regarding benefits of such interventions for biodiversity can also be limited due to uncertainties and difficulties associated with the implementation of such approaches, and lack of comparable and relevant data collected in a standardised manner over the long term and with sufficient temporal and spatial resolution. Research based on obtaining and analysing data within the framework of biodiversity monitoring programmes is particularly needed to (i) obtain a comprehensive overview of the conservation status of a broad range of taxa across all regions at a high temporal and spatial resolution, (ii) assess if the potential of approaches for reversing present trajectories of biodiversity change is being realized, (iii) gain a deeper understanding of how the short-term and long-term benefits but also any disadvantages for biodiversity associated with the deployment of such approaches can best be monitored, and (iv) explore gaps and needs for monitoring data to support, e.g., models to calculate effects and cost-benefit of interventions / predictive ecology.

Important knowledge needs under this theme include:

[7] https://doi.org/10.3897/arphapreprints.e84517
[8] https://riojournal.com/topical_collection/145/ (available end 2022)
[9] https://riojournal.com/topical_collection/145/ (available early 2023)
[10] https://riojournal.com/topical_collection/145/ (available end 2022)
[11] https://monitoring.europabon.org/monitoring/

- Filling gaps in knowledge on the status of a broad range of taxa, with a particular emphasis of indicator species and groups (for example pollinators or marine invertebrates). This should include analyses identifying a monitoring resolution suitable to inform policies that address drivers of biodiversity decline, as well as assessing the effectiveness of restoration efforts, taking into consideration also related efforts and programmes[12].Developing, implementing, and assessing tools for analysis of monitoring data to support prioritization of sites for restoration and conservation to meet EU targets, to feed the agreed indicators of the EU Biodiversity Strategy for 2030 and the proposed draft indicators of the global post-2020 global biodiversity framework. Such work should also recognize the importance of connectivity of migration and dispersal routes, temporal dynamics of distribution patterns, and climate refugia.
- Enhancing methodology and data integration to provide comparable indicators of policy and management relevance, and help integrate various geographical scales into policy and management decisions, in line with the EuropaBON approach to provide a response to EU's policy needs and its proposal on EBV and EESV.
- Testing and evaluating the practical usability (taking into account human behaviour, legal frameworks, governance arrangements, etc.) for managers in public and private sectors of tools and models to monitor the distribution and condition of habitats, species, and ecosystems of conservation importance, and identification of early-warning indicators of changes. This can also include challenges regarding standards, accessibility, analysis and integration of data and meta-data. Such tools should promote and make use of the most cost-effective approaches (both monetary as well as e.g., ease of use and responsible innovation), existing research infrastructures and networks, and emerging methodologies and technologies.
- Research to enable the explicit representation and consideration of uncertainty, along the entire process from data collection to analysis, modelling, simulation and in policy and management decisions.
- Research on the use and validity of predictive modelling/digital twins to enable incorporating understanding of biodiversity in practical settings. Modelling and predictions of outcomes from proposed interventions to promote science-based practical management and policy decisions.
- Analysing monitoring schemes in terms of conservation and restoration benefits for ecosystem functions and services accounting for Blue-Green Carbon, biodiversity support, and other crucial services provided to EU citizens, as well as in terms of preservation or enhancement of Natural Capital. This can integrate analyses of socio-economic factors with direct relevance for biodiversity monitoring, including the role of human behaviour, both individually and collectively.

[12] Including relevant calls in other programmes, e.g. https://www.faccejpi.net/en/FACCEJPI/The-2022-Joint-FACCE-JPI-SusCrop-Call-on-Agrobiodiversity-is-now-open.htm.

RESEARCH THEME 3

Making use of available biodiversity monitoring data

This theme supports research that makes use of existing knowledge, theoretical tools, data, etc., by integrating them to gain new insights on biodiversity monitoring. It encompasses various scientific approaches including for example meta-analyses and research conducted at synthesis centres[13]. By providing new understanding from biodiversity monitoring data, research under this theme should help to identify and address knowledge gaps to support management and policy for conservation, restoration, and sustainable use of biodiversity. Doing so can also include studies on human initiatives regarding biodiversity monitoring, as well as on the mechanisms behind policy and decision making in Europe and beyond.

On-going biodiversity research and monitoring have promoted a basic understanding of the potential consequences of the concurrent climate, land use and societal changes for biodiversity and ecosystem services. However, severe uncertainties persist, especially at geographical and time scales relevant to biological and societal adaptation processes. For example, the identification of important thresholds for change under the effects of stressors acting alone and in concert is key to guide decisions regarding limits to extractive activities, yet access to such knowledge remains challenging. Novel approaches to biodiversity monitoring can help close these knowledge gaps, and effective integration of monitoring data may provide answers by harnessing the strengths of different existing data sources.

Important knowledge needs under this theme include:

- Development and testing (e.g., evaluation of biases and uncertainties around biodiversity indices) of analytical tools and methods that improve the capacity of existing data to expand our knowledge of biodiversity status, dynamics, and trends across Europe, and be in line with the FAIR data principles. Such tools should promote and make use of the most cost-effective approaches (both monetary as well as e.g., ease of use and responsible innovation), existing research infrastructures and networks, as well as new/emerging methodologies and technologies.
- Large scale data analysis to improve transnational monitoring schemes and databases used to understand biodiversity dimensions, their dynamics and trends. This will allow to support and complement concurrent monitoring initiatives within EU and globally. Such efforts should account for different organization levels (genetic and phenotypic traits, species, communities, and ecosystems) in various environments (e.g., below and aboveground, land and water), integrating different geographical scales (up- or downscaling), and identifying elements of biodiversity showing correlated variations. This includes for example evaluation of the relevance of data extrapolation across spatiotemporal and taxonomical scales to inform (inter-)national management strategies and policies.

[13] https://synthesis-consortium.org

- Research to integrate the output from monitoring schemes and promoting cross-cutting approaches to use of available data, in order to analyse the effects of combined threats, multiple stressors, and extreme events on different levels of biodiversity. This includes effects on population distribution, connectivity, and underlying dispersal and migration patterns, as well as the complex dynamics of ecosystem functioning and ecosystem services.

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