The Group on Earth Observations Biodiversity Observation Network

Implementation plan for GEO Flagship

1. Executive Summary

Full title: The Group on Earth Observations Biodiversity Observation Network
Acronym: GEO BON
Status: GEO Flagship (Since 2016)

Overview:

Since its inception in 2008, GEO BON has developed a global social network and community of practice for enhanced biodiversity observations in service for improved decision-making. This network includes many world leaders in biodiversity observation as well as major partner organizations in that field. GEO BON moved into its second phase in 2014 by refocusing on its core goals, realistically assessing what is possible, and making strategic decisions on where its limited resources should go to achieve those goals. As a result, its focus has narrowed, though it still utilizes and builds upon the networks and communities of practice that have already been established and focuses not only on design and conceptual development but also operationalization of best practices for biodiversity observation. Now in its third phase since 2017, GEO BON reorganized its structure in order to better sustain its targeted and integrated effort to further refine and apply a framework for biodiversity observations through targeted and continued development of the EBVs and application of the EBV concept at multiple scales in partnership with national, regional and global partners. This approach will advance the theory and practice of efficient, user driven biodiversity observation design, leading to improved biodiversity observation data in support of decision-making.

GEO BON is committed to become, by 2025, a resource to governments, industry, researchers, and the public around the world, providing sustained and interoperable data, information, and knowledge on ecosystem services that derive from diverse communities of living organisms. GEO BON will be actively used by governments and their advisors, by the Convention of Biological Diversity (CBD), the Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Ramsar Convention. The data, information and knowledge will also be used to assess the progress in achieving the CBD's Aichi Targets by 2020 and the UN's Sustainable Development Goals (SDGs). The observations derived from this network contribute to the development of effective conservation actions, mitigation, and adaptation strategies that help ensure the sustainable use of resources. The scientific approach to observation contributes to the implementation of sustainable use management practices and policies regarding the world's biodiversity and the ecosystem services it provides.

Planned Activities:

The activities of GEO BON can be summarized according to the two core focuses of the network[1].

The development of the **Essential Biodiversity Variables**, or EBVs, which are a minimum set of variables that capture the major dimensions of biodiversity change. **EBVs** provide guidance to observation systems at all scales by helping to prioritize observations and identify standard methods for data collection and processing. The EBVs are being developed within the different GEO BON Working Groups, and organized around the different levels of organization of biodiversity: Genetic Composition, Species Populations, Species Traits, Community Composition, Ecosystem Structure and Ecosystem Functions. Similarly, the working group dedicated to Ecosystem Services is working

[1] See also Table C

towards the development of the **Essential Ecosystem Services Variables**. Within the working groups, this translates into activities that either address the conceptual basis of the EBVs within the different classes and result in the establishment of candidate lists, or the development and application of the EBV data products per se.

The reinforcement of existing, or development of new **Biodiversity Observation Networks**, or BONS. The role of the BONs is to develop, apply and test the concepts, methods and tools to implement and enhance operational networks; collecting observations and providing data to the community and users. The BONs can be organised at the national or regional level, or be thematic in scope (e.g. Marine BON – MBON). The BONs both produce, test and apply tools and applications and produce EBV relevant data that can be upscaled and downscaled to underpin more informed sustainable development and conservation decisions. Activities and outputs of BONs may also include the identification of Research and Development gaps and needs, the establishment of Technical Readiness Levels to help track progress towards the development of EBVs (particularly within thematic/biome scales), research papers, books, white papers, web apps, data collection and analysis (e.g. modelling) tools.

Going hand in hand with supporting the development of the Essential Biodiversity Variables and the Biodiversity Observation Networks, GEO BON is dedicated to improving the **delivery of information** to its various users, and has developed several online platforms to serve this purpose. The GEO BON secretariat has for instance developed, in partnership with the University of Marburg that produced the VAT System, an EBV Data Portal[2] to facilitate the visualization, sharing and analysis of EBV products and potentially, EBV-derived indicators. The first version of the EBV Data portal was launched at the CBD COP in 2018 and will continue to be developed by the GEO BON Data TF and secretariat, including with funding received through the H2020 e-Shape project (2019-2022). The secretariat also developed, together with the Alexander von Humboldt Institute in Colombia, Bon-in-a-Box[3], which is an online platform for capacity building and knowledge exchange designed to support both the work of the existing BONs and the development of new observation networks.

Finally, a common trait of most activities of the GEO BON working groups, BONs, and task forces is the policy relevance of their outputs. In this regard, GEO BON will continue to work on both identifying and supporting the needs of its users, from the scientific community to policy bodies such as the IPBES and CBD.

The structure of GEO BON was revised in the summer of 2016 to better support those key activities and is now composed of 8 Working Groups, 9 Biodiversity Observation Networks and 4 Task Forces. The Working Groups are tasked with the development of the Essential Biodiversity Variables, within the six EBV class, as well as the Essential Ecosystem Services Variables. An additional group, the BON Development working group supports the development of Biodiversity Observation Networks. The 9 BONs, which are national, regional and thematic in scope work more directly with the acquisition and mobilization of biodiversity observation (and related ecosystem services) and the delivery of information to end-users. Finally the task forces (e.g. Remote Sensing, Policy, Data) lead cross-cutting activities across Working Groups and BONs.

Main Achievements since 2008 and expected outputs by 2020

Since its establishment in 2008, GEO BON grew to be an open network of nearly 800 members from more than 550 institutions and 90 countries. In this decade, GEO BON successfully developed the framework for the Essential Biodiversity Variables, which has gained interest in both the scientific community (as illustrated by a steadily increasing number of publications on EBVs), as well as with various policy bodies (e.g. CBD, IPBES). This led to the reorganization of the network in 2016 and the establishment of dedicated working groups per EBV classes, mandated to develop EBV products. Those groups are expected to deliver at least one EBV product per EBV class by the summer of 2020. Recent years have also seen efforts for the conceptualization and operationalization of the Essential

[2] portal.geobon.org
[3] geobon.org/bon-in-a-box/

Ecosystem Services Variables, with a first scientific publication expected by the end of 2019/beginning of 2020.

In parallel, GEO BON has continued its engagement to develop Biodiversity Observation Networks and to bring together the knowledge and expertise on biodiversity and ecosystem services monitoring, data management, modeling, and reporting into an online catalogue of tools (BON-in-a-Box, with a fully operational second version expected to be delivered by 2020), and a BON development manual (in development, expected to be delivered by 2020). As of the summer of 2019, GEO BON is composed of nine endorsed BONs: China BON, French BON, Colombia BON, Asia-Pacific BON (AP BON), Arctic BON (CBMP), Americas BON (endorsed in July 2019), Freshwater BON (FWBON), Marine BON (MBON), and soil BON. Expressions of interest for the endorsement of national and thematic BONs have been shared with the GEO BON Secretariat and we hence expect the establishment of additional BONs by the end of 2020.

The GEO BON Secretariat has also developed the communication strategy of the network by developing a website and members platform, producing a regular Newsletter, and solidifying its presence on social media. GEO BON also successfully organized numerous workshops and meetings across the globe, including a first Open Science Conference and All Hands meeting in 2016 that attracted nearly 300 participants in Leipzig, Germany and a second All Hands meeting in 2018 that welcomed over 80 participants in Beijing, China. The next Open Science Conference and All Hands meeting will be organized in Leipzig in the summer of 2020 where we expect an attendance similar to the 2016 iteration.

Finally, although the long term financial sustainability of the network is still to be confirmed, GEO BON has successfully established two Secretariats, first hosted by CSIR-NRE (South Africa), then by iDiv (Germany) since 2014. GEO BON, either via the secretariat or via network members, has also been successful in securing funding for its activities, with national, regional, and global funding mechanisms, including with calls for proposals specifically tailored to support the activities of the network.

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2. Purpose

Rationale

Currently, our collective ability to detect and understand the status and trends of biodiversity, to develop sound assessments, and produce scenarios to guide more effective policy is greatly hampered by a lack of access to high quality observations. GEO BON is concerned with the development of more integrated, efficient and interoperable biodiversity observation networks that can produce more reliable, accessible and timely observations to serve these needs.

The core objective of GEO BON is the observation of biodiversity change. To achieve this objective, GEO BON focuses on the initiation and coordination of interdisciplinary efforts to set up interoperable national and regional, or thematic, biodiversity observation systems. Through its global network, GEO BON supports the sharing and dissemination of information and technology available locally or in large existing initiatives. GEO BON also supports the development and application of the most recent scientific knowledge to advance biodiversity observation collection, integration and interpretation. GEO BON is not directly involved in advocacy for on the ground conservation efforts, nor focused directly on biodiversity assessment. Instead, GEO BON is a network of stakeholders, a community of practice, focused on improving the infrastructure for monitoring biodiversity change and ensuring that both scientists and decision makers have access to better data.

Policy mandate

UN Convention on Biological Diversity[4] (UN CBD)

The establishment of GEO BON was noted by the 9th Conference of the Parties to the Convention on Biological Diversity (CBD/COP 9) at its 2008 meeting held in Bonn Germany (Decision IX/15 in UNEP/CBD/COP/9/29). Parties and relevant organizations were invited to "support this endeavor", while the CBD Secretariat was requested to continue its collaboration with GEO BON. This support was renewed at COP 10, two years later, when Parties where invited to support and/or collaborate with GEO BON in order to strengthen the "capacity to mobilize and use biodiversity data, information, and forecasts" (Decision X/7 in UNEP/CBD/COP/10/27). GEO BON was also invited to produce a report on the Adequacy of Biodiversity Observation Systems to support the CBD 2020 Targets for an Ad Hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011- 2020 (Decision X/7 in UNEP/CBD/COP/10/27), and to collaborate with the CBD Secretariat and other partners (such as the FAO and IUCN) in documenting, developing, and harmonizing the indicators needed to track the progress towards the Aichi targets (Decision XI/3 in UNEP/CBD/COP/10/27). In 2012 (CBD/COP 11), GEO BON and other partner organisations were more specifically asked to continue their work on the identification of Essential Biodiversity Variables (EBV) and the development of the underlying datasets (Decision XI/3 in UNEP/CBD/COP/11/35). At COP 13 (2016), a set of indicators of global biodiversity change supported by GEO BON was approved as part of a larger list of Indicators for the United Nations Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets (Decision XIII/28 in UNEP/CBD/COP/13/25). In 2014, Parties of the CBD, indigenous and local communities, and other stakeholders were also invited to collaborate with GEO BON and other partners that "contribute to building observing systems and to biodiversity monitoring" in order to address needs and opportunities to further enhance biodiversity observations (Decision XII/1 in UNEP/CBD/COP/12/29). The development of 'Bon in a Box' was identified as a solution to fill gaps on data, monitoring, observation systems and indicators (SBSTTA 17 Recommendation in UNEP/CBD/COP/12/2). Parties and relevant organizations were also invited to "provide support for developing countries in the preparation of their sixth national reports", including through GEO BON and the BIP (Decision XIII/27 in UNEP/CBD/COP/13/25). Parties of the CBD were invited to engage with, and support, regional and global networks such as GEO BON for data mobilization and access, which has been identified as a key scientific and technical needs for the implementation of the UN Strategic Plan for Biodiversity 2011-2020 (Decision XIII/31 in

[4] https://www.cbd.int/doc/c/ede9/9161/94ada923478ff9c9fd7304f3/sbstta-21-inf-01-en.pdf

UNEP/CBD/COP/13/25). Furthermore, GEO BON regularly represents GEO as an accredited observer at CBD plenaries.

Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES)

GEO BON is recognised by IPBES as a key partner organisation. Many GEO BON members are or have been participating in the IPBES assessments at different capacities (Coordinating Lead Authors, Lead Authors, Reviewers). In addition, IPBES user needs are triggering the research agenda of many GEO BON partners, as IPBES needs knowledge, scientific data and information for its work. GEO BON is especially engaged in the "IPBES Task Force on Knowledge and Data" and is mentioned as one of key partners to provide observation data and knowledge for the IPBES Global Assessment. The Executive Secretary of IPBES is an active member of the GEO BON Advisory Board. Furthermore, GEO BON regularly represents GEO as an accredited observer at IPBES plenaries. More recently in the context of the Global Assessment of IPBES, the teams involved in the development of the EBV-derived indicators of Global Biodiversity Change took part in an intermodel comparison exercise to provide insights on the likely impact of shared socio-economic pathways on biodiversity and ecosystem services. Several of the metrics tested against the scenarios of change map to the Essential Biodiversity Variables, which will give further visibility to GEO BON and the work of the network.

Ramsar Convention

GEO BON is an observer organisation to the Scientific and Technical Review Panel (STRP) of the Ramsar Convention. The Freshwater BON and the EU project SWOS contribute to the development of the Global Wetlands Observing System (GWOS), a key request from Ramsar.

Actual and/or planned outputs of the Initiative

EBV Development and delivery to users

The Implementation Committee of GEO BON agreed to finalize and approved a list of endorsed Essential Biodiversity Variables by 2020. Meanwhile, a minimum of one data product per EBV classes will be produced, with documented and reproducible workflows, and be made available on the GEO BON EBV Data portal by 2020, with continued efforts to develop more products in the following years. Similarly, the framework for the "Ecosystem Services Essential Variables" will have been finalized and supported by the production of a set of data products made available on the portal. By 2018, the data products available were "Changes in average local terrestrial diversity" and "Changes in local bird diversity" both products for the Alpha Diversity EBV within the Community Composition EBV class, and "Forest cover" for the Ecosystem Structure EBV class. By 2020, the EBV Data Task Force of GEO BON will have finalized the development of an EBV catalogue and EBV metadata reference guide to facilitate the integration and interoperability of the data products within the portal. The GEO BON working groups have also been tasked with the development of guidance on EBV applications for the national and regional BONs.

BON Development and delivery to users

The version 2 of BON in a Box, meant to be fully operational and containing an extensive tool database will be finalized by 2020. In parallel the BON Development manual will be finalized and published and implement an online decision matrix for BON design (connected to BON in a Box). These steps will support the full operationalization of the existing BONs and the development and endorsement of new national and regional BONs. Meanwhile, GEO BON will continue its efforts to map existing observatories and monitoring programs for biodiversity and ecosystem services which are not yet connected to the network and continue its work in identifying gaps in the global biodiversity observation system to prioritize future BON developments. As of 2018, 8 BONs were formally endorsed: China, France and Colombia for the national BONs, Asia-Pacific (AP BON) and the arctic BON (CBMP) for the regional BONs, as well as the Marine (MBON), Freshwater (FWBON) and soil BONs for the thematic BONs. The Americas BON was endorsed by the Implementation Committee of GEO BON in July 2019. Other BONs are being developed (or planned to be developed)

with the support of the network, in Quebec, Bolivia, Australia, South Africa, Switzerland, and the Tropical Andes. Note that while some countries have not gone through the process of endorsement set up by GEO BON, they are nonetheless collaborating with GEO BON within existing working groups and/or regional BONs (e.g. with AP BON).

Actual and/or intended users of the outputs

Perhaps the most important block of users are the national governments who are responsible for reporting on the status and trends in ecosystems and the biodiversity they support to meet their national mandates (e.g. national biodiversity plans, recovering species at risk, sustaining ecosystem services) and international obligations (e.g. Convention on Biological Diversity, RAMSAR Convention, Convention on Migratory Species, etc.). These users are particularly important since, more than any other group, they have the ability to enact and change policy and to implement it; both of which are dependent upon better observations, products, and tools than are currently available. Collectively, they also have the greatest access to resources to support implementation. Thus, when endorsing national BONs, the GEO BON Implementation Committee ensures that a clear connection with ministries or national agencies has been established for the candidate BON. For instance, the Colombia BON[5] is hosted and resourced by the Alexander von Humboldt Institute which is linked to the Colombian Ministry of Environment and Sustainable Development (MADS) and mandated to produce research on biodiversity and ecosystem services in support of decision making. Similarly, the China BON[6] is hosted by the Nanjing Institute of Environmental Sciences (NIES) affiliated to Ministry of Environmental Protection of China (MEP), and was, inter alia, responsible for producing the 6th National Report for China to the CBD.

Another key user group of a global biodiversity observation system and the resulting data is the scientific community that needs sound and reliable data to produce and populate models, study the drivers of biodiversity change and distribution, identify new and emerging threats to biodiversity along with effective responses, and that must create scenarios and assessments of policies to facilitate decision-making (e.g. IPBES). Many non-governmental (e.g. IUCN) and international organizations (e.g. Arctic Council) are actively involved in conducting biodiversity assessments to facilitate more effective conservation and sustainable use of biodiversity and ecosystem services and thus, are also reliant on high quality biodiversity data. Furthermore, current and future expert groups within IPBES will continuously need EBV products and derived indicators for their work in the scientific assessments of biodiversity and ecosystem services (e.g. expert group producing the assessment on invasive species 2019-2022; expert groups on Scenarios and Models).

With this in mind, it is believed that the Convention on Biological Diversity's (CBD) 2020 Aichi Targets, and the following post-2020 biodiversity framework, as well as the UN Sustainable Development Goals (SDG) and Agenda 2030 provide an impetus for improved biodiversity observations from the national to regional and, ultimately, to the global level. As such, GEO BON has identified the Parties to the CBD as key users and GEO BON has continually engaged the Parties to the CBD on key topics, including capacity building for biodiversity observations and the development of new models to inform the Aichi Targets. This interaction has led to a greater awareness of GEO BON and thus, increased collaborations with member nations and a greater understanding of national needs and challenges with regard to biodiversity observations and what is needed to support national reporting. GEO BON is also increasingly focusing attention on the Sustainable Development Goals and will, through its current work plan, be making efforts to map the EBVs to the SDGs, apply its partners' models to support SDG tracking and raise awareness of the value of GEO BON to support improved data for tracking the SDGs. GEO BON will also continue to engage the Intergovernmental Platform on Biodiversity and Ecosystem Services, the broader scientific community (e.g. the new international programme on global sustainability, Future Earth), non-governmental conservation organizations, and other relevant biodiversity conventions (e.g. RAMSAR Convention, Convention on Migratory Species).

[5] https://geobon.org/bons/national-regional-bon/national-bon/colombia-bon/
[6] https://geobon.org/bons/national-regional-bon/national-bon/china-bon/

Expected outcomes, impacts and beneficiaries from adoption of the outputs from the Initiative.

Expected outcomes

The establishment of sustainable and interoperable BONs that produce the relevant, high quality biodiversity data informed by the EBV framework is expected to be the basis of well informed decision making.

Expected impacts

Ultimately, the vision of GEO BON is to develop a globally coordinated biodiversity observation network that contributes to effective management policies for biodiversity and ecosystem services.

Expected beneficiaries

Society as a whole is the expected direct and indirect beneficiary of effective biodiversity conservation (but see sections on policy mandate and users).

3. Background and Previous Achievements

Status of implementation of planned activities and outputs for the 2017-2019 period[7]

EBV Development

Since 2017, the structure of GEO BON is complete, with each of the 6 EBV classes (Genetic Composition, Species Populations, Species Traits, Community Composition, Ecosystem Structure and Ecosystem Functions) as well as Ecosystem Services being represented by a dedicated working group. Those groups are more specifically tasked with providing lists of EBVs for each class, later to be aggregated into a final EBV list endorsed by the network, and with the development of the EBV data products per se. Meanwhile, the GEO BON Secretariat has developed an EBV Data portal[8] (in partnership with the University of Marburg) where the data products will be made available to the public, while allowing the calculation (on the fly) of temporal trends per countries and globally. The secretariat, together with the Data Task Force, is developing a set of metadata standards for the EBV products, as well as an online EBV catalogue, both implemented to facilitate the integration of new datasets in the portal.

Table 1. Main activities and deliverable for EBV development listed in the 2017-2020 Implementation Plan

Activity/Deliverable	Year	Status
All EBV classes are represented in a working group	2018	Achieved
Connection made between EBVs and EOVs	2018	Achieved [9]
Pilots for EBV operationalization with national BONs	2018	On track
Framework for the Essential Ecosystem Services Variables published	2018	Delayed but on going
One or two EBVs per class with available datasets on the EBV portal	2020	On track
Recommendations for metadata standards and on line EBV catalogue	2020	On track
Final list of EBVs endorsed by GEO BON	2020	On track

BON Development

Since 2017, two new thematic BONs have been endorsed by the network, the Freshwater BON in 2017, and the soil BON in 2018. Discussions are on-going for the establishment of BONs in the Americas, Australia, South Africa, Quebec and Switzerland. The GEO BON Secretariat (via Martin Luther University) will also start a project funded by the ERANet LAC program in 2019, to establish a BON in the Tropical Andes. In collaboration with the Instituto von Humboldt (Colombia), the BON Development WG and the Secretariat are working on version 2.0 of BON in a Box[10]. The WG continues its work on the development of a BON development manual which will be linked to BON in a Box. Finally, GEO BON participated in the Global Audit of Biodiversity Monitoring[11] led by the Cambridge Conservation Initiative, which will inform on gaps and priorities for future BON Development.

Table 2. Main activities and deliverable for BON development listed in the 2017-2020 Implementation Plan

Activity/Deliverable	Year	Status
BON in a Box Version 2 fully operational	2018	Delayed but on going
Existing and currently developing national BONs endorsed by GEO BON	2018	Achieved
Assessment and web mapping of existing biodiversity observatories	2018	Delayed but on going
Marine and Freshwater BONs operational	2020	On track
New national, regional and thematic BONs developed or enhanced	2020	On track
BON Development manual with online decision matrix available	2020	On track
Gaps in global observation systems identified and prioritized for BON development	2020	On track

[7] Note: the current GEO BON Implementation Plan was developed for the 2017-2020 period.
[8] https://vat.gfbio.org/geobon-cop/#/
[9] Muller-Karger, F. E. et al. 2018. Frontiers in Marine Science 5. (doi.org/10.3389/fmars.2018.00211)
[10] https://geobon.org/bon-in-a-box/
[11] http://www.cambridgeconservation.org/collaboration/global-audit-biodiversity-monitoring

Policy Relevant outputs

Since 2017, GEO BON has continued its engagement with various policy bodies and was represented by official delegations in the annual IPBES Plenaries, as well as in the SBSTTA and COP meetings of the CBD. And information document[12] on the relevant activities of the network for the parties of the CBD was prepared for SBSTTA 21 (Dec. 2017), and a side-event presenting the value of biodiversity monitoring for decision making was organized at COP 14 (Dec. 2018). On the occasion of the GEO BON All Hands meeting organized in Beijing in July 2018, participants produced the *Beijing call on biodiversity observations for post-2020 decision-making*[13]. This document was presented at the CBD COP14 and is part of the wider strategy and contribution of GEO BON for the post 2020 biodiversity framework of the CBD that is currently being discussed[14,15]. The GEO BON Policy Task Force is also working with the teams developing the Global Biodiversity Change Indicators, to ensure that the final products are communicated to the CBD parties for their reporting on the current biodiversity framework, and to a wider audience via the GEO BON portal. Meanwhile, the Task Force will continue its work on mapping the EBVs and EESVs to global targets and goals (e.g. Aichi targets, SDGs). Finally, the Remote Sensing Task Force has formally approached CEOS to discuss the requirement for biodiversity monitoring using satellite remote sensing.

Table 3. Main activities and deliverable for policy relevant outputs listed in the 2017-2020 Implementation Plan (green - achieved, yellow - on track, orange – delayed)

Activity/Deliverable	Year	Status
Brochure promoting the value of long term monitoring for decision making	2018	Delayed but on going
Establishment of a hub for communicating requirements to CEOS	2018	On track
Position paper linking the IPBES conceptual framework and BONs	2018	Delayed but on going
Three Global Biodiversity Change Indicators produced and available	2020	On track
IPBES Socio-ecological indicators for Ecosystem Services developed	2020	On track

Scientific outcomes and use-cases

The following sections describes some of the scientific outcomes and, when appropriate, use-cases of the EBV framework, the EBVs, and the BONs. For a more complete list of scientific publications, see Annex 2 (pages 40-42) and the GEO BON website[16]. Considering that the timeline for the delivery of EBV data products goes until the end of the current implementation period (2017-2020), use-cases should be expected to be developed more concretely in the next implementation period. Similarly, use-cases will be presented in the BON Design manual (to be delivered in 2020) as examples of operational networks.

The conceptualization of EBVs within the Species Populations and Species Traits classes has advanced in the current implementation period, notably with the publication of several scientific articles that lay the basis for the establishment of workflows to produce EBV data products in those classes:

1. Jetz, W., McGeoch, M.A., Guralnick, R., Ferrier, S., Beck, J., Costello, M.J., Fernandez, M., Geller, G.N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F.E., Pereira, H.M., Regan, E.C., Schmeller, D.S., Turak, E., (2019). Essential biodiversity variables for mapping and monitoring species populations. Nature Ecology & Evolution 1.
2. Kissling, W. D., Ahumada, J. A., Bowser, A., Fernandez, M., Fernández, N., García, E. A., … Hardisty, A. R. (2017). Building essential biodiversity variables (EBVs) of species distribution and abundance at a global scale. *Biological Reviews*.

[12] https://www.cbd.int/doc/c/ede9/9161/94ada923478ff9c9fd7304f3/sbstta-21-inf-01-en.pdf
[13] https://geobon.org/the-beijing-2018-call-on-biodiversity-observations-for-post-2020-decision-making/
[14] https://www.cbd.int/post2020/
[15] https://www.cbd.int/doc/strategic-plan/Post2020/postsbi/geobon.pdf
[16] https://geobon.org/documents/biodiversity-monitoring/

3. Kissling, W. D., Walls, R., Bowser, A., Jones, M. O., Kattge, J., Agosti, D., … Guralnick, R. P. (2018). Towards global data products of Essential Biodiversity Variables on species traits. *Nature Ecology & Evolution*, *2*(10), 1531–1540.

A use-case of the EBVs for national reporting, in Finland, was also an important step towards EBV operationalization:

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

The GEO BON network also published the GEO Handbook on Biodiversity Observation Networks[17] in 2017, with 13 chapters discussing, inter alia, monitoring across EBV classes, realms and methods:

5. M. Walters & R. J. Scholes (Eds.). (2017) The GEO Handbook on Biodiversity Observation Networks. Springer International Publishing.

The importance of Remote Sensing for the development of Essential Biodiversity Variables also led to several scientific publications, including:

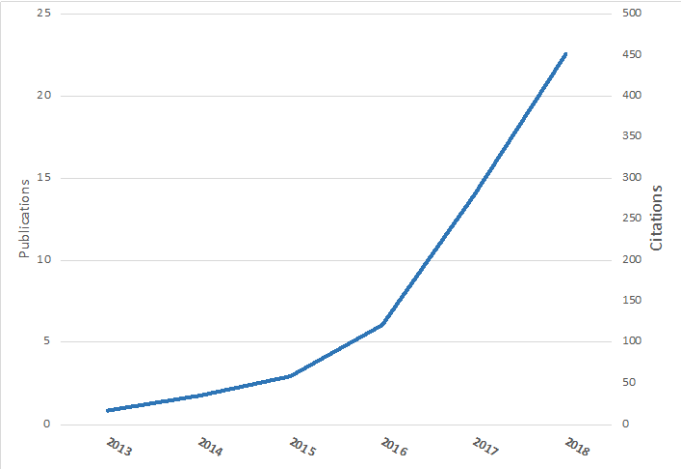
6. Paganini, M., Leidner, A. K., Geller, G., Turner, W., & Wegmann, M. (2016). The role of space agencies in remotely sensed essential biodiversity variables. *Remote Sensing in Ecology and Conservation*, *2*(3), 132–140.
7. Pettorelli, N., Wegmann, M., Skidmore, A., Mücher, S., Dawson, T. P., Fernandez, M., … Geller, G. N. (2016). Framing the concept of satellite remote sensing essential biodiversity variables: challenges and future directions. *Remote Sensing in Ecology and Conservation*, *2*(3), 122–131.
8. Skidmore, A. K., Pettorelli, N., Coops, N. C., Geller, G. N., Hansen, M., Lucas, R., … Wegmann, M. (2015). Environmental science: Agree on biodiversity metrics to track from space. *Nature*, *523*, 403–405.

Finally, the use of the EBV framework, together with the identification of end-user needs, has been used to design biodiversity observation networks, conceptually for protected areas (within the H2020 ECOPOTENTIAL project) and more concretely in New South Wales, Australia:

9. Guerra, C.A., Pendleton, L., Drakou, E.G., Proença, V., Appeltans, W., Domingos, T., Geller, G., Giamberini, S., Gill, M., Hummel, H., Imperio, S., McGeoch, M., Provenzale, A., Serral, I., Stritih, A., Turak, E., Vihervaara, P., Ziemba, A., Pereira, H.M., 2019. Finding the essential: Improving conservation monitoring across scales. Global Ecology and Conservation 18, e00601.
10. Turak, E., Brazill-Boast, J., Cooney, T., Drielsma, M., DelaCruz, J., Dunkerley, G., … Williams, K. (2017). Using the essential biodiversity variables framework to measure biodiversity change at national scale. *Biological Conservation*, *213*, 264–271.

Evidence of use of the outputs of the Initiative, particularly by end users.

Since it was first brought up to the scientific community and to other users in 2013, the Essential Biodiversity Framework has been gaining momentum and is being used and applied more widely. On the policy side, the UN CBD recognized the value of the framework and invited GEO BON and members to continue their work on developing the EBVs (Decision XI/3 in UNEP/CBD/COP/11/35). The EBV framework is also being used in IPBES Assessments. In parallel, the number of scientific publications using the EBV concept and framework has steadily increased since 2013 (Figure 1).



[17] https://www.geobon.org

Figure 1. Number of Scientific publications having "Essential Biodiversity Variables" listed as "topic" by the Web of Science (bar plot), and number of citations of these publications.

Concretely, a set of Indicators of Global Biodiversity Change, derived from EBVs, has being endorsed by both the CBD and IPBES. Some of those indicators have been also endorsed by the Biodiversity Indicator Partnership (BIP) and are being used for the Global Assessment of IPBES. The EBV framework is also used at the national scale by the French BON to document existing biodiversity observatories and infrastructure in the country[18]. Similarly, in Finland, the EBVs were used to assess the national indicators used for reporting and the biodiversity monitoring programs underlying them[19].

The flexible approach for BON Development developed and promoted by the network has been used and adapted for Australia's New South Wales, Colombia, and will be applied in the Tropical Andes in the context of an ERANet-LAC funded project. GEO BON also supported the development of the China BON[20], which is today a remarkable example of a systematic, country-wide monitoring design with broad spatial and taxonomic extent: 441 sites are part of an observation system of over 9000 transects and point counts for birds, amphibians, mammals, butterflies, and vascular plants with the participation of volunteer citizen scientists at each site.

Examples or evidence of outcomes and/or impacts based on use of outputs (e.g. policy decisions taken, behavior changes by users, risks mitigated).

N/A (but see previous section and policy mandate section)

Reflection on the effectiveness of the Initiative's governance structure and resourcing strategy.

The current structure of GEO BON (Figure 2) was designed to better reflect the two pillars of the network: the development of both the EBVs and the BONs. Having all EBV classes and ecosystem services represented by dedicated WGs is meant to greatly facilitate the parallel development of the EBV lists, workflows, and data products. The BON Development WG acts as a bridge between the different WG and BONs to allow good communication on activities and outcomes between them. Giving equal weight, within the structure, to the BONs allows those groups to continue their activities semi-independently, while actively participating in the decisions making process and implementation the network. Finally, the establishment of task forces, in close collaboration with the Secretariat, allows to delegate some of the short term and urgent cross cutting activities (e.g. metadata development, policy support) to a smaller group of individuals representative of the different WGs and BONs. In terms of financial resourcing, the Secretariat tries to the best extent possible to allocate funds to organize workshops for the different WGs, while encouraging WGs and BONs to apply for separate funding to support their activities. As an example, NASA is currently funding 8 projects[21] led by GEO BON members and targeted at both BON and EBV development.

[18] http://www.fondationbiodiversite.fr/images/documents/Rapports_Etudes/paysage-observatoires_FRB-ECOSCOPE.pdf
[19] Vihervaara, P., et al. 2017. Global Ecology and Conservation 10:43–59. (doi:10.1016/j.gecco.2017.01.007)
[20] Xu H., et al. Biodivers Conserv 2017, 26:1959-1971. (doi:10.1007/s10531-017-1339-3)
[21] https://geobon.org/about/projects/

Summary of the results of any internal or external reviews or evaluations of the Initiative.

N/A

Lessons learned from (or challenges experienced in) the previous implementation period and proposed actions for amendments or improvements.

The next implementation phase will benefit from putting more emphasis on potential synergies between the different activities of the WGs, BONs and Task Forces and allow for more cross-cutting activities. More sources of funding will have to be found to support the work of the network, also considering the limitations (person/months and funding) of the Secretariat.

Justification for acceptance as a GEO Flagship

- *Policy mandate:* GEO BON has received clear policy mandate from the CBD, IPBES, and to a lesser extent the Ramsar Convention, while the national BONs have mandates from their governments.
- *Substantial activity in terms of resources and partners involved*: ± 65 activities listed in the 2017-2020 Implementation Plan. As of February 2019, 658 members, from 81 countries and 451 institutions are registered in the GEO BON members page[22].
- *Information service or product pre- or near-operationally provided*: EBV data portal, EBV catalogue, BON-in-a-Box, as well as EBV products and global biodiversity change indicators nearly operational.
- *User needs satisfied to a significant degree*: see previous sections.
- *Specific user institutions fully engaged*: The executive secretary of IPBES as well as a representative of the CBD secretariat are both members of the GEO BON Advisory Board.
- *Implementation Plan*: Implementation produced in 2017 for the 2017-2020 period available online[23].

4. Relationship to GEO Engagement Priorities and to other Work Programme Activities

Description of which activities or outputs of the Initiative, if any, are expected to inform the achievement of SDG targets and/or the measurement of SDG indicators. Identify which targets and/or indicators are implicated.

The GEO BON policy task force is in the process of mapping the Essential Biodiversity Variables to the different SDGs, targets and indicators. Until now, the mapping was done at the EBV class level (Table 4). Working Groups and BONs are also invited to actively consider the relevance of EBVs to track progress towards the SDGs, as was done for instance for the Species Traits EBVs in a recent publication[24] which identified more specifically the potential contribution of phenology (SDGs 13, 15), morphology (SDGs 2, 14), and reproduction (SDGs 14, 15). The relevance of ecosystem services, and by extensions the variables that allow to monitor them, is also high in regards to the SDGs, particularly for SDG 2 (zero hunger) but also for SDGs 3, 6, 14 and 15, as illustrated in a publication of the Ecosystem Services WG[25]. Note that in some cases, the mapping can be done for SDGs where biodiversity is not explicitly considered in targets and indicators, but where the role of

[22] https://members.geobon.org/pages/index.php
[23] https://geobon.org/downloads/governance-documents/geobon_imp_plan_20172020.pdf
[24] Kissling et al., 2018. Nature Ecology and Evolution 2, 1531-1540 (doi.org/10.1038/s41559-018-0667-3)
[25] Geijzendorffer Ilse R., et al. 2017. *Environmental Science and Policy.* 74: 40-48

biodiversity is nonetheless well understood as is the case for instance for SDG 3 (health). In addition, the working groups and BONs were invited to provide information to the Secretariat on potential synergies between their activities and the SDGs, targets and indicators (Table 4). While GEO BON has put more emphasis on supporting the needs of the CBD and the reporting on the Aichi Targets, the SDGs seem to be gaining more visibility within the network, beyond SDGs 14 and 15, which might be made more apparent in the next Implementation Plan (2020-2023).

Table 4. Relevance of the EBVs, EESVs and specific activities of network for the Sustainable Development Goals (Note: mapping is ongoing and subject to modifications)

#	SDG	Relevant EBVs (class) and EESVs							Example of specific product
		Genetic Composition	Species Populations	Species Traits	Community Composition	Ecosystem Structure	Ecosystem Functions	Ecosystem Services	
2	Zero Hunger	●	●	●		●	●	●	Fishery yields from rivers and lakes (Freshwater BON)
3	Health		●	●				●	Distribution maps of vectors of diseases and early-warning systems (Species Population)
6	Water		●			●	●	●	High spatial and temporal resolution mapping of wetlands (Ecosystem Structure and Freshwater BON)
13	Climate action			●		●		●	
14	Life below water	●	●	●	●	●	●	●	Prototype product being developed by the MBON together with OBIS and the US sanctuary for Target 14.2 that integrates EO (e.g. seascapes, ocean color, sea surface temperature), OBIS data and field surveys.
15	Life on land	●	●	●	●	●	●	●	The set of Global Biodiversity Change Indicators endorsed by the CBD for some of the Aichi targets can inform on, inter alia, the degradation, conservation and restoration of ecosystems.

Description of which activities or outputs of the Initiative, if any, are expected to support the Paris Agreement and identify which pillars are implicated.

N/A but if resource allows, this should be considered in the post-2020 GEO BON Implementation Plans.

Description of which activities or outputs of the Initiative, if any, are expected to support achievement of the targets of the Sendai Framework and which targets are implicated.

N/A but if resource allows, this could be considered in the post-2020 GEO BON Implementation Plans.

List of Flagships, Initiatives and Community Activities in the 2017-2019 GEO Work Programme that are relevant to this Initiative and a brief description of the relationship or plans for future engagement / collaboration.

Being part of the GEO network allows GEO BON the opportunity to connect with the observations and data organized in the other GEO SBAs. These cross-linkages provide an opportunity to produce value-added, integrated tools and products that facilitate more informed and effective

policy - going beyond reporting on status and trends to also identifying the causal mechanisms driving biodiversity change and producing predictive models for examining future scenarios.

The GEO BON Secretariat and members have identified synergies with several of the flagships and initiatives listed in the GEO work programme (Table 5). In some cases, the relationship and collaboration is well established (e.g. MBON and Blue Planet Initiative) while in others the connection needs to be made in the next implementation phase, ideally with the support of the GEO Secretariat.

Table 5. Link between GEO BON, its Working Groups, BONs and Task Forces and the elements of the GEO Work Programme

Name	Connection established?	GEO BON WG or BON / Rationale
GEO Flagships		
Global Forest Observation Initiative	to be discussed	**Ecosystem Structure WG** / Within the Ecosystem Structure EBV class, the extent of forest is considered to be one of the candidate EBV products.
GEO initiatives		
AfriGEOSS	to be discussed	At the moment, there are no national BONs in Africa, or a regional BON for the continent. The existing thematic BONs do by definition also cover the African continent. Regardless, when resources allow, GEO BON would benefit from connecting with AfriGEOSS to build its network in the region.
AmeriGEOSS	established discussed	**MBON** / The NASA funded project for the Pole to Pole MBON in support of the AmeriGEOSS work plan seeks to develop a regional biodiversity network spanning the coastal zone and open ocean and directly contributes to the activities of the BON. MBON is also developing capacity building activities with AmeriGEOSS. **"Americas BON" and Tropical Andes BON** / The former was endorsed by GEO BON and AmeriGEOSS, while the later still is to be established and connected.
Asia-Oceania GEOSS	established	**AP BON** / the Asia Pacific BON is already an active component of AOGEOSS
EO4EA	to be discussed	The EBVs and EBV products could provide relevant information and data for Ecosystem Accounting. Some interest was expressed at the GEO 15 plenary but a follow-up is needed.
EO4SDG	discussed	The **GEO BON Secretariat** was involved in early discussions with the EO4SDG initiative. A follow-up is needed. GEO BON is currently engaging with the Interagency Expert Group for SDG Indicators and providing support for tracking of SDG biodiversity targets.
EuroGEOSS	established	The **GEO BON Secretariat** proposed an pilot application for the EuroGEOSS initiative which was included in their biodiversity and ecosystems activities.
GEO ECO	discussed	**Ecosystem Structure, Ecosystem Functions and Ecosystem Services WGs** / Through the ECOPOTENTIAL and SWOS projects (H2020), GEO BON already collaborated with GEO ECO members. Further engagement could be beneficial both for the development of EBVs at the Ecosystem level, for Ecosystem Services monitoring, and for some of the GEO ECO activities.
GEO Land Degradation Neutrality	discussed	**Soil BON /** The monitoring of soil biodiversity, at the species, and ecosystem level can be useful for the GEO LDN initiative, including for reporting needs of the UNCCD parties (if biodiversity is to be considered in their sets of indicators).
GEO Wetlands Initiative	established to be discussed discussed	**Freshwater BON** / Active members of the GEO Wetland initiative are also involved in the Freshwater BON, either directly within their activities, or as members of their advisory board. **Ecosystem Structure WG /** potential collaboration to be considered regarding the extent of wetlands as an EBV product. **Policy Task Force /** potential collaboration to be considered regarding the GEO BON connection to the Ramsar Convention
Oceans and Society: Blue Planet	established	**MBON /** MBON and its members are actively engaging in collaborative activities with GEO Blue Planet. MBON serves as a link between Blue Planet and several programs of the Intergovernmental Oceanographic Commission of UNESCO, including GOOS, OBP), and OBIS. The Blue Planet thematic node on biodiversity is at this time planned to function as the MBON Secretariat.

Potential collaborations could also be established with the following **Community Activities** (tentative list, to be further discussed within the network): Global Marine Ecosystem Monitoring (with MBON), Arctic GEOSS (with Arctic BON), Land Cover and Land Cover change (with Ecosystem Structure WG), Global Mangrove monitoring (with Ecosystem Structure WG and Freshwater BON and MBON).

GEOSS Foundational Tasks

GEO BON is represented in the GEO Communicators Network by Christian Langer (GEO BON IT Officer) as the communications focal point and engages in several activities of the GEOSS Foundational Task.

GEOSS Data & Information Resources: The GEO BON Secretariat promotes the free, full, open and timely access to Earth observation datasets, products and services. GEO BON supports the uptake and implementation of the GEOSS Data Sharing and Management Principles through the development and construction of the Data Portal for Essential Biodiversity Variables. In addition, all the web applications solutions developed by the GEO BON Secretariat support the use of open-source software, web services and cloud computing to enable low-barrier solutions for the use of open and freely accessible Earth observations datasets, especially for countries of the Global South. The source code of these open source web applications is made publicly available on GitHub[26]

GEOSS Infrastructure Development: A first test use of the GEO DAB API as an interface to the GEOSS platform was successfully installed in 2018[27]. Furthermore, the GEO BON and GBIF Secretariats have been discussing with the GEO Secretariat the organization of a workshop to discuss the development of the infrastructure for a "Biodiversity Engine" as a component of the GEO Knowledge Hub.

[26] https://github.com/ChristianLanger
[27] https://rawgit.com/ChristianLanger/WMS-Search-GEO-DAB-API/master/index.html

5. Stakeholder Engagement and Capacity Building

Description of key organizations and stakeholders, particularly at the international level, which are relevant to this Initiative (operating environment of the Initiative).

The German Centre for Integrative, Biodiversity Research (iDiv), Halle-Jena-Leipzig. iDiv is one of four research centers funded by the German Research Foundation (DFG) with an average annual budget of 8 million EUR (9 million USD) since October 2012. In addition to the topical research groups, iDiv has strong central services (outreach office, biodiversity informatics, bioinformatics), a Synthesis Centre (sDiv) fostering theoretical and synthetic thinking as well as a PhD school (yDiv). iDiv and its founding institutions are already involved in vegetation-related databases, including the global vegetation database sPlot, the global trait database TRY and the German vegetation-plot database GVRD. iDiv hosts the GEO BON Secretariat since 2014 and supports GEO BON activities financially as well as by providing space, logistics and scientific support.

US National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Bureau of Ocean Energy Management (BOEM), US Geological Survey. These agencies conduct and sponsors research, collect observations, develop technologies, and extend science and technology education to learners of all ages. NASA and NOAA have supported GEO BON from the beginning and support GEO BON in a variety of ways. These agencies are major funding sources for MBON in the USA and to GEO BON internationally. The Program Scientist for Biological Diversity and Program Manager for Ecological Forecasting in the NASA Headquarters Science Mission Directorate is a member of the GEO BON Advisory Board.

United Nations Educational, Scientific and Cultural Organisation's Intergovern-mental Oceanographic Com-mission (IOC-UNESCO). IOC-UNESCO coordinates the Global Ocean Observing System (GOOS) and runs the Ocean Biogeographic Information System (OBIS) database. The OBIS Project Manager is a member of the MBON and is provided as an in-kind contribution from the Intergovernmental Oceanographic Commission of the UNESCO. Both GOOS and OBIS are key participants in MBON.

Global Biodiversity Information Facility (GBIF). GBIF is a global network of data providers that builds biodiversity information infrastructure and promotes the growth of biodiversity information. The GBIF Executive Director is a member of the GEO BON Advisory Board and GBIF provides in-kind funding and expertise on several topics, mostly but not limited to those related to data management.

ASEAN Centre for Biodiversity (ACB). ACB is an intergovernmental centre of excellence that facilitates cooperation among the members of the Association of Southeast Asian Nations (ASEAN). ACB is an active member of the Asia-Pacific Biodiversity Observation Network (AP-BON) of GEO BON. The Director for Biodiversity Information Management of ACB is a member of the GEO BON Implementation Committee.

Map of Life (MOL). MOL is an online resource for mapping, monitoring and analysing biodiversity worldwide and is assisting in the implementation of EBVs. The Map of Life lead is the co-lead of the Species Populations WG and a member of the GEO BON Implementation Committee.

Instituto Alexander von Humboldt (Colombia). It is a major partner organisation in the development of BON in a Box. Since 2015, GEO BON directly works with the Alexander von Humboldt Institute to design a Colombian national BON, in part, through the application of the BON in a Box: Latin American toolkit. The Alexander von Humboldt Institute hosts the Colombia BON. The lead of the BON is also a member of the GEO BON Implementation Committee.

Strategy for engaging stakeholders in the co-development / co-production of the Initiative, including determining user needs, and for building individual, organizational, and institutional capacity to use the outputs of the Initiative.

Representatives and members of the organizations and stakeholders listed in the previous section engage directly with GEO BON, either within the Advisory Board (e.g. NASA, GBIF), or Implementation Committee (e.g. Map of Life, ACB). Furthermore, members of these organizations can also be members of the different working groups and/or BONs which further allows the stakeholder engagement in the co-production and co-development of activities, services and products (including for organizational and institutional capacity building). The organization of the GEO BON All Hands meetings and Open Science Conferences, alternatively every two years, also provide a forum for the co-design of the activities of the network with the different members, stakeholders and partner organizations.

Regarding individual, organizational and to some extent institutional capacity building, BON in a Box is the main platform. BON in a Box is a capacity building and technology transfer mechanism, functioning as an online, continually updated toolkit for lowering the threshold for a country or region to develop or enhance a biodiversity observation system. Once fully operational, BON in a Box will allow users to access the latest biodiversity observation design tools, monitoring protocols, data standards and management systems and analysis and reporting tools to facilitate more integrated and interoperable biodiversity observations. BON in a Box is being designed to directly support national biodiversity and sustainable development mandates and is particularly designed to improve capacity for nations to contribute to both the CBD and IPBES. Good examples of implementation of BON in a Box at the national level, in Colombia, including with training sessions, webinars, and the development of training materials are two NASA funded projects under the Rose A.50 funding scheme[28]. The first project (16-GEP-0052, led by Victor Gutierrez-Velez at Temple University, USA) aims at developing a Decision Support System to integrate Earth Observations for decision making on biodiversity management and conservation. The second project (16-GEO16-0027, led by Mary Blair at the American Museum of Natural History) expand the Wallace biodiversity modeling software in order to support the calculation of national indicators of biodiversity change.

The establishment of new BONs by GEO BON is another strategy for stakeholder engagement and co-production, at the national, regional and global scales. The GEO BON Implementation Committee has put in place a process for BON application and endorsement that functions as follows: (1) interested groups are invited to contact the secretariat and submit their application following the guidelines made available on the GEO BON website[29]; Note that depending on the scope of the BON, i.e. thematic, national or regional, the requirements might vary; (2) the application is then shared with the Implementation Committee that is invited to comment on it and, if needed, a first recommendation with suggestions of edits is made to the proponents of the BON; (4) the Implementation Committee votes on the endorsement of the BON. When a BON is endorsed, its coordinators/leads are invited to join the Implementation Committee and the BON becomes open for membership to the GEO BON network. The BON is also invited to submit a list of activities, milestones and expected deliverables to the GEO BON Secretariat within the first year of its endorsement, for integration in the GEO BON Implementation Plan.

The GEO BON Secretariat also communicates, via the website and other communication platforms, on the relevant webinars (e.g. MBON webinar series), training courses and open workshops organized by both the members of the network and the partner organizations. In the case of the webinars, those remain, when possible, available directly via the GEO BON website[30].

[28] See a description of the projects and hyperlinks here: https://geobon.org/about/projects/
[29] https://geobon.org/downloads/governance-documents/Draft_Criteria_for_BONs.pdf
[30] https://geobon.org/about/events/web-conferences/

Finally, the engagement with GEO Stakeholders is another essential point, particularly the Initiatives, Community Activities and Flagships with which communication, co-development of activities and other synergies is already assumed to likely be beneficial (Table 5). This could for instance allow reciprocal capacity building between GEO BON and those initiatives. Until now, this engagement has been initiated to some extent via the participation of the GEO BON Secretariat and GEO BON members in the GEO Week, GEO Data Tech Workshop and GEO Symposium, albeit not on a regular basis. While we recognize the importance of these interactions, resources have until now constantly limited the availability of GEO BON representatives for these meetings and might continue to do so.

Current and/or planned activities to engage stakeholders and/or strengthen individual, organizational and/or institutional capacity and the expected outputs and outcomes of these activities.

See previous section.

Current and/or planned activities to strengthen the capacity of the participants in the Initiative for successful implementation of the Initiative.

See previous section.

6. Governance

Description of the governance structure

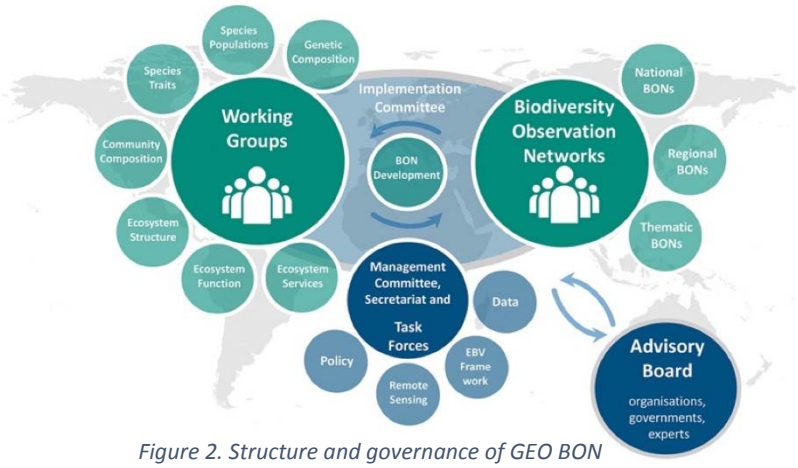


Figure 2. Structure and governance of GEO BON

Working Groups

Working Groups (WG) are structured around particular classes of Essential Biodiversity Variables or other integrating activities. Working groups have one or multiple coordinators and organize their work around activities, most being dedicated to the development of EBVs, which may have their own leads. Activities and outputs of working groups may also include the identification of Research and Development gaps and needs, the establishment of Technical Readiness Levels to help track progress towards the development of EBVs, research papers, books, white papers, web apps, data collection and analysis (e.g. modelling) tools. The BON Development WG is responsible, in part, for creating a direct link between the WGs and the BONs. ***Composition***: Any expert may participate in a working group based on declaration of interest. WG leads can be suggested by the MC, but ultimately are elected by the members of the WG and confirmed by the Implementation Committee.

Task forces

Task Forces are co-led by members of the GEO BON network and by a least one member of the Secretariat. The first were launched in 2017: **EBV development**; **EBV Data**; **Remote Sensing**; **Policy support**. A fifth Task Force on **Funding** should be set up in late 2019 or early 2020. ***Composition***: due to their nature, the task forces are limited to fewer members, invited by the leads.

Biodiversity Observation Networks (BONs)

BONs that are endorsed and hence formally connected to GEO BON can be national, regional or thematic in scope. The role of the BONs is to develop, apply and test the concepts, methods and tools to implement and enhance operational networks; collecting observations and providing data to the community and users. BONs can have one or multiple coordinators and are a key component to GEO BON as they both produce, test and apply tools and applications and produce EBV relevant data that can be upscaled and downscaled to underpin more informed sustainable development and conservation decisions. Activities and outputs of BONs may also include the identification of Research and Development gaps and needs, the establishment of Technical Readiness Levels to help track progress towards the development of EBVs (particularly within thematic/biome scales), research papers, books, white papers, web apps, data collection and analysis (e.g. modelling) tools. ***Composition***: Any expert may participate in a BON based on declaration of interest. BON leads can be suggested by the MC, but ultimately are elected by the members of the BON and confirmed by the Implementation Committee.

Implementation Committee and Advisory Board

The **Implementation Committee** is the organ that implements the deliverables and implementation plan of GEO BON. It is also in charge of approving the annual budget, and nominating and electing the Chair(s) of GEO BON. The IC has an executive function, although much of the daily operation tasks are delegated to the Management Committee and to the Secretariat. The Implementation Committee meets by conference call quarterly and in person once a year. ***Composition:*** Those actively engaged in implementing GEO BON including all members of the Management Committee, the Working Group Leads, the Task Forces leads, and BONs coordinators. The coordinators of large scale projects in which GEO BON is actively involved (e.g. work package lead, partner organisation) are invited to the IC as observers. The (co-)Chair(s) is/are elected by the Implementation Committee for 3 years terms, renewable once.

The **Advisory Board** of GEO BON is composed by representatives of key partner organisations. The AB meets once a year to provide strategic direction and feedback on GEO BON and provides help in the search of funding. ***Composition***: Representatives of NGOs, governments, commercial companies, and experts, in a geographically balanced composition.

Description of the roles of key leadership positions.

The GEO BON **Secretariat** is hosted by the German Centre for Integrative Biodiversity Research (iDiv) – Halle, Jena, Leipzig and is composed by: (1) The *Executive Secretary* who is tasked with, *inter alia*, engaging WG's and activity leads, overseeing product delivery; coordinating technical development (website, etc.), fundraising, representing GEO BON at key meetings, (2) The *GEO BON IT Officer* in charge of the coordination of the Web Page and IT infrastructure; (3) The *Secretary* (part-time) who provides assistance with all administrative and management duties; and (4) the *GEO BON Scientists* working at the Secretariat to provide scientific outputs and support regarding subjects directly related to GEO BON.

The **Management Committee** of GEO BON is responsible for the daily GEO BON operations and meets at least bimonthly to discuss more technical and substantive issues regarding the implementation and coordination of the network. It is composed by all the members of the GEO BON Secretariat, the (co-)*Chair(s)* and the *GEO Science Officer*, who manages the link between GEO BON activities and the GEO secretariat.

Strategy for communication with participants and stakeholders, including the main communications channels used.

In 2015, the GEO BON Secretariat launched the GEO BON website[31] as well as the Newsletter, published every 3-4 months. Members of the network are invited to communicate relevant news and information year round, which are then published as news items on the website and aggregated in the following newsletter. The website is also designed to present what are the EBVs and BONs, and which are the different working groups and their activities. GEO BON is also present on Twitter (@GEOBON_org >1000 followers) and Facebook[32]. The Freshwater BON created a group on ResearchGate[33] to facilitate communication and collaboration between its members. In addition, the GEO BON Secretariat launched in 2017 a "members page[34]" where people can sign up to join the network and the different working groups and BONs. This page also provides basic information on the different WGs and BONs (e.g. geographical distribution of the members, gender balance, realm studied). By registering, new members are automatically added to the GEO BON mailing list which is used by the secretariat to communicate information to the network. Each WG and BON also has a

[31] https://geobon.org/
[32] https://www.facebook.com/BiodiversityObservationNetworkGEOBON/
[33] https://www.researchgate.net/project/Freshwater-Biodiversity-Observation-Network-FW-BON
[34] https://members.geobon.org/pages/index.php

dedicated mailing list administered by the leads/coordinators. New members are added when they ask to join a WG or BON via their profile in the members' page.

The GEO BON Secretariat is working on the integration of its different platforms (geobon.org, members page, data portal, BON in a Box) to simplify access to information for users. Nonetheless, the communication strategy is overall still limited since the resources of the Secretariat do not allow to have a dedicated staff for communication and outreach (aside from the IT officer/web designer).

Monitoring and evaluation activities

GEO BON through its formal governance structure (Advisory Board and Implementation and Management Committees) and periodic All-Hands meetings and Open Science Conferences put in place a structure that allows continual feedback, evaluation, monitoring and assessment of strategies, tasks and deliverables. The **Implementation Committee calls** occur quarterly and involve reporting from the Secretariat, WGs, BONs and TFs as well as detailed technical review and advice for key components of GEO BON. At the **in-person Implementation Committee meetings** (once a year for ± 3 days), all tasks and deliverables are assessed, challenges discussed and advice is given. **Advisory Board meetings** are organised back to back with the in-person IC meetings and review the overall strategic direction for the initiative and opportunities for funding. The **Management Committee calls**, organised every two weeks, address day-to-day issues and technical aspects of the program and its implementation. The **All-Hands meetings and Open Science Conference** (organised alternatively every two years[35]) allow for the entire community to come together to discuss, assess and evaluate achievements and determine new strategic plans. The GEO BON Secretariat plans to publish a report on the activities of the network every other year[36].

Risk management: description of the key risks that could prevent the full realization of the intended outcomes of the Initiative and the strategy for managing and/or mitigating the identified risks.

The GEO BON chairs, the members of the Implementation Committee and the members of the Advisory Board will monitor the identified risks (see below) and apply any necessary means to mitigate them as early as possible. In case of problems, a solution will be reached by a collective decision process within the Implementation Committee. The main risks, as well as their mitigation strategies and management requirements identified for the 2017-2020 implementation plan are the following:

1. **Uncertainty regarding the continuous funding after 2020 for the operation of the GEO BON secretariat and/or the maintaining of a permanent GEO BON infrastructure:** GEO BON will actively raise new funds by communicating and working with funding agencies and donors and by supporting the preparation of new project proposals. This requires man-power which will be provided by the GEO BON MC and Secretariat with targeted help from the Implementation Committee and Advisory Board members. As of the summer of 2019, the GEO BON Secretariat and Management Committees are exploring options for the medium and long-term funding (including hosting) of the secretariat and its web infrastructures after 2020.
2. **Partners disengaging from GEO BON:** Since all involved partners share the common goal of developing GEO BON it is not to be expected that partners will disengage completely. Regardless, new and engaged members regularly join the network, whom could to take over some responsibilities.

[35] In 2016, joint OSC and All Hands meeting in Leipzig, Germany; in 2018, All Hands meeting in Beijing, China; in 2020 OSC in Leipzig, Germany.

[36] Due to changes in the structure and resource limitation, the second edition (2016-2017) is overdue and will be combined with the 2018-2019 edition.

3. **Limited or no funding to develop products and deliverables planned:** While the limitation in funding delays the development of activities and outputs, the GEO BON team has a proven track record for raising substantial funds (e.g. See Resources section and Table B). The MC identified the need to establish a Funding Task Force that would take the lead on the fund raising and scoping activities in 2017, but the TF is still to be established.

7. Resources

Summary of the estimated resources required to implement the proposed activities for the 2020-2022 period, including financial, in-kind participation, and other in-kind resources (e.g. data, equipment, computing capacity, office space).

Although the GEO BON Implementation Plan for the next time period (post 2020) is not yet produced (and will not be until 2021), we can anticipate the need for resources that are at least equivalent to the current level of resources of the network, i.e. financial resources for the Secretariat (Table 6); continuous in-kind participation of the members, particularly that of the 45 Working Groups, BONs, and Task Force co-leads which are also involved in the Implementation Committee; financial resources to maintain the current infrastructure (GEO BON Website, BON-in-a-Box, EBV portal); and funding via projects[37] (e.g. ESA, NASA, H2020 funded) to support the various activities of the network. Note that in general, calculating in-kind contribution as well as projects dedicated to GEO BON by the many partners is a challenge, as most partners don't specifically calculate their time allocated to GEO BON activities. As a result, the following paragraphs detail the lower estimate of the current (and hence minimum required) resources.

The current resources of the **GEO BON Secretariat** represent, annually, ±150 K€ for salaries and 50 K€ for running costs (e.g. travels, publications) to which another 6 Person-Month Equivalent (PME) should be added in in-kind contribution from iDiv, as well as 1 PME from NASA and 2 PME from NatureServe for the Management Committee. The office space is also provided by iDiv for the Secretariat (one office with two desks).

Most of the projects that are currently funding the **activities of GEO BON** have ended or will end in 2019. Nonetheless, listing those projects and their budget can give an idea of the level of funding needed to maintain the implementation of the GEO BON activities:

- GlobDiversity – rs-enabled EBVs for terrestrial ecosystems (PI: Michael Schaepmann – University of Zurich): **750 000 €** funded by ESA from June 2017 to September 2019 (www.globdiversity.net).
- sTWIST working group (W6.30) - Theory and Workflows for Alien and Invasive Species Tracking (PIs: Melodie McGeoch and Martin Winter) funded by the Synthesis Centre of iDiv (sDiv) for the organization of **three international workshops of ±20 participants** at iDiv between 2018 and 2020 (https://www.idiv.de/de/sdiv/arbeitsgruppen/wg_pool/stwist.html)
- Eight projects funded by NASA to advance the work of GEO BON within the GEO Work Programme, i.e. development of EBVs and/or BONs, with an average budget of **500 000 US$** per project between 2017 and 2019.
  - 16-GEO16-0027 (Mary Blair - The American Museum of Natural History) Expanding Wallace Biodiversity Modeling Software to Support National Biodiversity Change Indicator Calculations for GEO BON Assessment and Reporting
  - 16-GEO16-0078 (Walter Jetz - Yale University) Activities to Advance, Build, and Deliver Remote-Sensing Supported Species Distribution and Species Abundance EBVs

[37] https://geobon.org/about/projects/

- 16-GEO16-0031 (Gretchen Daily - Stanford University) Improving Linkages Between Earth Observations and Ecosystem Service Models with Essential Biodiversity Variables
- 16-GEO16-0113 (Maria Kavanaugh - Oregon State University) Dynamic Seascapes to Support a Biogeographic Framework for a Global Marine Biodiversity Observing Network
- 16-GEO16-0052 (Victor Gutierrez-Velez - Temple University) Integration of Earth Observations for Decision Making on Biodiversity Management and Conservation in Colombia: Consolidation of the Colombian Biodiversity Observation Network
- 16-GEO16-0020 (Howard Epstein - University of Virginia) Ecosystem Functional Diversity of the Circumpolar Arctic Tundra
- 16-GEO16-0066 (Patrick Jantz - Northern Arizona University) Quantifying Forest Vertical Structure Using Spaceborne Lidar: A GEO BON Essential Biodiversity Variable Application in Colombia
- 16-GEO16-0073 (Enrique Montes - University of South Florida) Laying the Foundations of the Pole-To-Pole Marine Biodiversity Observation Network (MBON) of the Americas [also AmeriGEOSS]

In addition, budget would be required to sustain the implementation of the activities of the BONs, particularly the regional and thematic BONs. For instance, a lot of the work of the Marine BON has been funded under the National Ocean Partnership Program (NOPP RFP NOAA-NOS-IOOS-2014-2003803) in partnership between NOAA, BOEM, and NASA. Similarly, the Ministry of Environment of Japan has been supporting the activities of the AP BON with **± 12 K€ annually**. The financial support of the China BON is exemplar, as it has received a wide support from the Central Government, Ministry of Environmental Protection (MEP), Ministry of Finance (MF) and approximates an annual financial allocation of **US$ 5.8 million**. An annual budget of **25-50 K€ per BON** would greatly support the management and development of the BONs.

Description of the extent to which confirmed contributions to the Initiative meet the identified requirements. Please note that the details of the contributions will be entered in Table B below.

Until now, the funding that has been secured by the GEO BON Secretariat comes from:

The E-Shape project (EuroGEOSS Showcases: Applications powered by Europe) funded by the European Union H2020 programme (#820852) between 2019 and 2022. The budget allocated to GEO BON related activities for the "myVariables" pilot within the "myEcosystem" showcase is **±500 000€**, most of which will be allocated to the development of the functionalities of the GEO BON Data portal.

The TAO project (From Data to Decision: Collecting, Mobilizing, and Harmonizing Tropical Andes Observatory Data for Improved Conservation Planning) funded by the ERANet LAC funding scheme (ERANet17/BDS-0249) with a budget of **±400 000€** (between 2019 and 2022). This project with partners in Germany, Spain, Peru, Ecuador and Bolivia will collaborate towards the establishment of a sustainable regional BON in the Tropical Andes.

A third project, **iBON** (Integrating Biodiversity Observations and Networks; PIs: Pereira, Navarro, Chase, Winter & König-Ries) has been submitted to the German Center for Integrative Biodiversity Research (iDiv) to fund, *inter alia*, the development and maintenance of the infrastructures (BON-in-a-Box, EBV portal) that have been developed by the GEO BON Secretariat. This funding (pending approval) is of **±500 K€** (although half will be allocated to build a biodiversity data bank) for the 2020-2024 time period. This funding has not yet been confirmed.

This total budget is far from the level of funding needed to maintain the activities of the network. Part of this is due to the fact that the future funding of the secretariat is still being discussed at the time of writing of this document. Concerning the funding needed for the implementation of the activities of the network, we can expect a similar level of in kind contribution to that of the current implementation period (see previous section). In particular, the working group co-leads have committed to continue the conceptualization and development of the Essential Biodiversity Variables

(and Essential Ecosystem Services Variables), including with the delivery of EBV data products by 2020. Similarly the BON leads have committed to continue their operationalization. This will be supported by **in-kind contributions** from the host institutions of the different GEO BON members involved in those activities. Activity leads will also continue their efforts to secure the funding needed to develop and maintain both EBVs products and BONs.

Strategy for mobilizing additional resources, either to meet gaps in confirmed contributions or to support future requirements.

One priority at the moment for the mobilization of resources is to guarantee the funding of the GEO BON Secretariat in the short and long term. The members of the Implementation Committee started to discuss potential strategies for the sustainability of the secretariat which will need a "new home organisation" by the end of 2020, following the election of the future (co-)chair(s). In parallel, the GEO BON Secretariat and Management Committee will continue their efforts to scope relevant calls for proposals and map them to the list of activities of the Implementation Plan, as well as more directly supporting the members of the network applying to those projects. The Management Committee has discussed and agreed that it would not support at the moment the establishment of a membership fee, whether for the members of the network or for the endorsed Biodiversity Observation Networks. However, support from GEO members, in the form of secondments or direct funding, could support the establishment of a central and stable Secretariat.

Summary of existing commercial sector engagement in the Initiative, if any, and the strategy for engaging commercial sector organizations in future.

There is at the moment no existing nor planned engagement with the commercial sector.

Technical Synopsis

Essential Biodiversity Variables development

Essential Biodiversity Variables (EBVs) are a limited set of fundamental harmonized variables that are necessary to analyze and report on biodiversity states over time. EBV datasets can be understood as data layer that contains harmonized biodiversity measurements with consistent space-time information ready for the production of higher level indicators, such as indicators of biodiversity change needed for national reporting or for assessments of IPBES (figure 3). The EBVs are being developed within the different GEO BON Working Groups, and organized across levels of organization of biodiversity: Genetic Composition, Species Populations, Species Traits, Community Composition, Ecosystem Structure and Ecosystem Functions. In addition, within GEO BON, the Essential Ecosystem Services Variables, which will have the EBVs as their building blocks, are being conceptualized by the Ecosystem Services WG, with a first publication to be submitted by the end of 2019. The following sections describe the key data types used to generate EBV data products, examples of workflows for data integration and EBV productions, as well as current limitations and planned strategy by GEO BON.

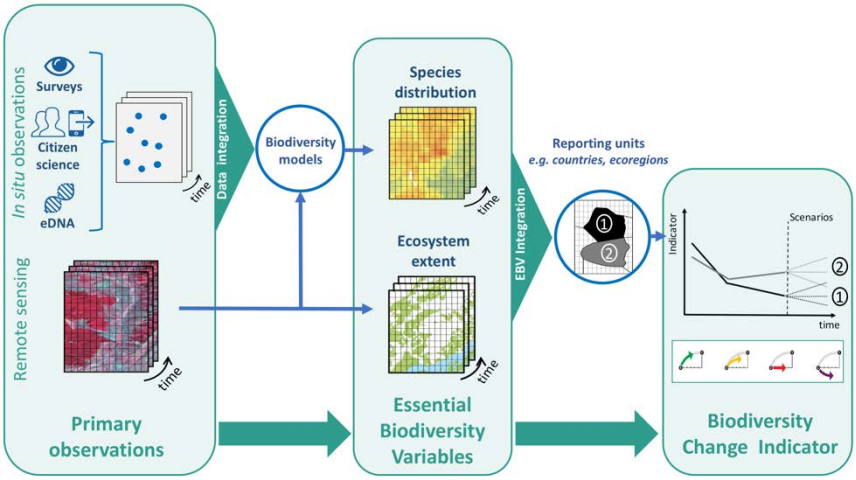


Figure 3. Path from primary observations to the productions of EBVs and indicators (From Navarro et al., 2017).

Key primary observations for EBV production

In-situ data

While the role of genetic data to produce EBVs is agreed on but not yet fully evaluated and documented, we can already assumed that the information made available via genetic data banks such as GenBank will be critical, although most of it is not georeferenced (but see Miraldo et al., 2016[38]). The constant increase in the use of Next Generation Sequencing as well as an increased use of the biological material stored in museum collections are promising developments. These data will be relevant to produce EBVs particularly in the Genetic Composition (e.g. inbreeding, effective population size), Species Populations (e.g. species distributions) and Community Composition (e.g. taxonomic diversity) EBV classes.

The type of datasets used to produce EBVs in the Species Population class can be accessed from incidental records (e.g. citizen science), inventories over small (e.g. plots, camera traps) or large areas (e.g. regional checklists) and expert synthesis maps (Jetz et al., 2019). Essential occurrence data needed to develop the species distribution EBV is made available through GBIF and OBIS, including

[38] Miraldo, A., Li, S., Borregaard, M.K., Flórez-Rodríguez, A., Gopalakrishnan, S., Rizvanovic, M., Wang, Z., Rahbek, C., Marske, K.A., Nogués-Bravo, D., 2016. An Anthropocene map of genetic diversity. Science 353, 1532–1535.

the citizen science data generated via iNaturalist. Inventory data is also made available, for instance the US Breeding Bird Survey (USGS), eBIRD data, the data of the Tropical Ecology Assessment and Monitoring (TEAM) network, the Living Planet Index (LPI) data (WWF – ZSL)[39].

Trait data from the published literature (e.g. COMPADRE, COMADRE, PolyTraits) and specimen collections (e.g. VertNet) have been aggregated into trait databases (e.g. TRY, EMODnet, TraitBank) but their use is still limited since the data is often averaged to provide a mean value per species, and the availability of time series is very low. There are currently few monitoring network that provide in situ trait data such as NEON, USA-NPN, PhenoCam, and Pan European Phenology (Kissling et al., 2018).

The BONs are mandated with facilitating the mobilization of the data that is being acquired within their country, region or realm, into open repositories and using common standards such as the Darwin Even Core.

Remote sensing data

Remote sensing data is essential in the process of EBV production (Pettorelli et al., 2016; Skidmore et al., 2015). RS data serves as the primary observation from which to derive EBVs at the Ecosystem level, in the ecosystem structure (e.g. ecosystem extent) and ecosystem function EBV (e.g. Net Primary Productivity) classes. RS data can also be integrated with the in-situ observations into biodiversity models to produce "wall-to-wall" products for EBVs at the species level.

These remote sensing data can be provided via the data generated by NASA's Landsat and MODIS and ESA's Sentinel programs. The GlobDiversity project for instance is using Sentinel data to produce "RS-enabled EBVs": land surface phenology, fragmentation, canopy chlorophyll concentration and vegetation canopy height. All the A.50 NASA projects (see p. 24-25) also make use of RS products such as vegetation classes, NDVI, percent forest cover, GLAS and Hyperion generated data to only name a few. LiDAR and imaging spectroscopy can also be used to directly produce EBV data for the Species Traits (e.g. phenology) and Community Composition (e.g. richness) classes.

Example of workflows

GEO BON working groups as still in the process of documenting and publishing workflows for the production of Essential Biodiversity Variables. Progress have been made for EBVs at the species level, for instance for the Species Traits (Kissling et al., 2018) and Species Populations (Kissling et al., 2017; Jetz et al., 2019 and Fig.4) EBV classes. The documentation of those workflows is meant to (1) ensure that the EBV production process is open and reproducible; (2) allow BONs to produce EBVs, independently at the national and sub-national levels; and (3) streamline the EBV production process once appropriate e-infrastructures are available (Fernández et al. 2019).

Limitations and planned strategy

The technical synopsis presented here remains for the most part conceptual since most of the GEO BON Working Groups are still working on the documentation of workflows to produce EBVs within their respective classes, as well as the identification of key input data, models, etc. Developing equivalent "technical synopsis" is thus the mandate of each individual Working Group for the current GEO BON Implementation Plan (2017-2020). For this reason, it is at the moment too soon to document a concrete technical synopsis for EBV production. Several limitations, as well as technical and scientific challenges have nonetheless already been identified.

Clearly, the lack of large scale and long term monitoring programs, particularly for some primary observations such as those relating for instance to species traits, species interactions, and allelic diversity is a limitation for the development of EBVs. In the context of the discussion on the post-

[39] See Kissling et al., 2017 for a detailed description of those datasets as primary EO for EBVs.

2020 biodiversity framework of the CBD, GEO BON released the "Beijing call[40]" which calls on Parties of the CBD to step up their efforts in biodiversity monitoring, and suggests to set the establishment of national Biodiversity Observation Networks as one of the future conservation targets. The Beijing call was read in the plenary of the CBD COP 14 in 2018 and has been submitted during the global consultation on the post-2020 framework. The Policy Task Force will follow-up on those efforts and the BON Development WG will continue its work to document the BON Development process (including via BON-in-a-Box) in order to facilitate the establishment of new BONs.

The lack of widespread data sharing philosophy in the biodiversity community also remains a limitation for the production of EBVs. GEO BON and partners have been advocating the FAIR principles for species occurrence and population abundance data, particularly for their mobilization into GBIF using the Darwin Event Core[41]. Here the BONs also have an important role to play to mobilizing the current and future data produced by their members.

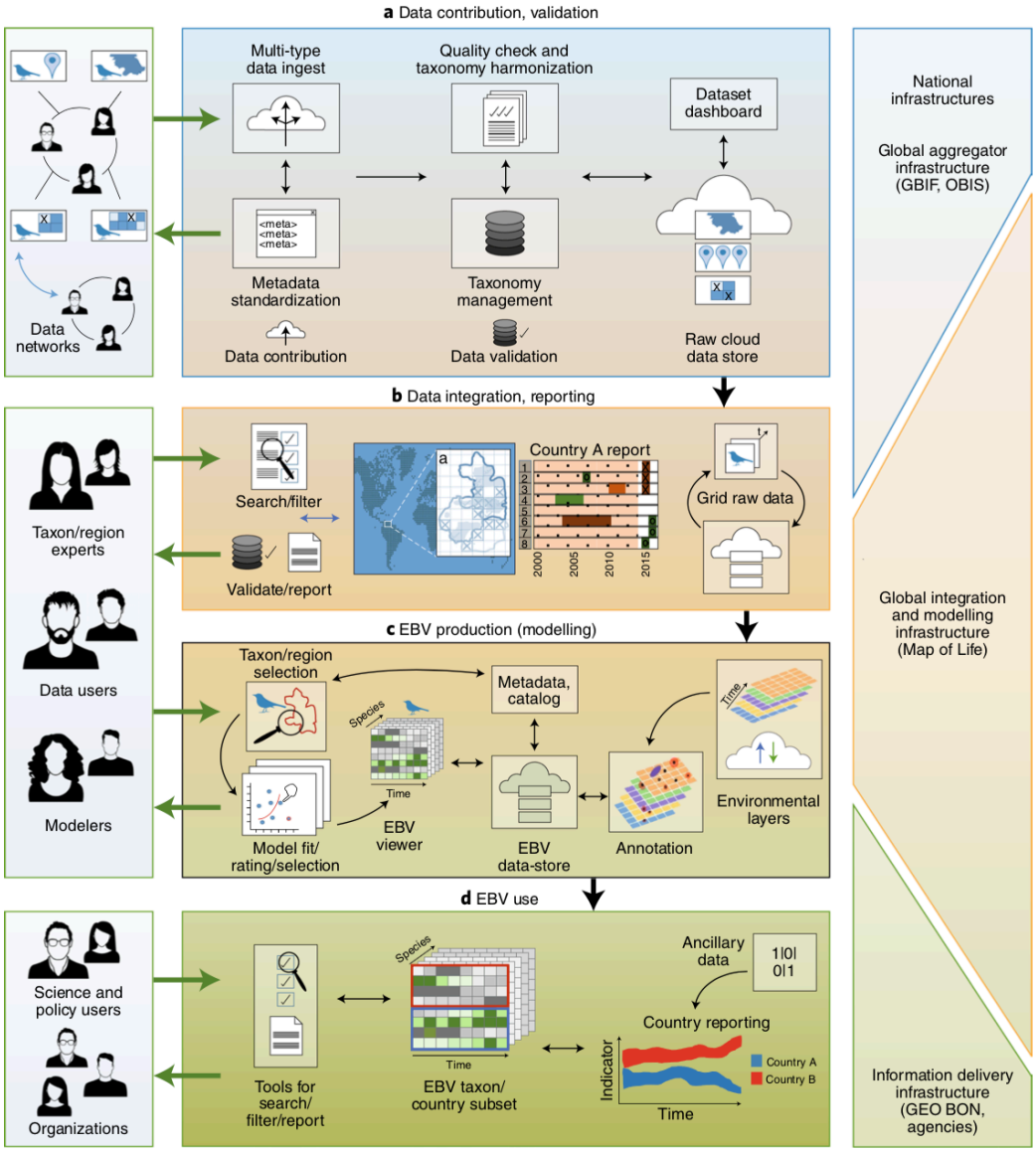


Figure 4. Key actors, workflows and informatics infrastructure for the production and use of essential species population information and Species Populations EBVs. From Jetz et al. (2019) Nature Ecology and Evolution.

[40] https://geobon.org/the-beijing-2018-call-on-biodiversity-observations-for-post-2020-decision-making/
[41] https://geobon.org/downloads/biodiversity-monitoring/brochures/2016/the-eventCore-brochure-2016.pdf

8. Data Policy

Policy of the Initiative regarding data availability, including degree of adherence to the GEOSS Data Sharing Principles and GEOSS Data Management Principles.

The guiding principles that GEO BON follows are based strictly on the GEOSS principles, and consider issues such as information sharing, interoperability, OGC standards, user-orientation and scientific rigor. GEO BON adds value to existing data by working with other organizations to derive higher-level analytical products which are currently not available (e.g. through the calculation and modelling of Essential Biodiversity Variables (EBVs) and derived indicators). GEO BON aim at providing a global, scientifically robust framework for observations that:

- Provide access to observations, models, assessments and forecast information
- Help to build a global system of systems based on the integration of in situ and remote observation systems
- Coordinate aspects of data gathering and the delivery of biodiversity change information
- Ensure long-term continuity of data supply
- Provide a set of innovative and relevant products based on the integration of datasets following the EBV framework (Fernández et al. 2019)

If key datasets are managed by the Initiative, a description of how the data are/will be managed

The EBV data products *per se* are being produced and managed by individual teams, within the GEO BON network, but not exclusively. To support the delivery of these products to users, the GEO BON Secretariat and Data Task Force are developing the EBV Data Portal, which aims to serve as a platform to catalog, visualize and deliver EBV datasets and derived indicators. The portal consists mainly of three components, the **EBV metadata catalogue** for searching and finding EBV datasets using metadata description, the **EBV visualizer** to display the data, and the **EBV analyzer** with basic tools for reporting changes and trends (see following section for a more detailed description of those components).

The input of metadata records into the catalog also includes manual input based on the EBV metadata standard[42]. There, the user can describe information using the online metadata editing tools which will be available through the web interface of the catalogue. The metadata editor will support the EBV Metadata Standard but also common standards such as ISO19115/119/110 used for spatial resources as well as the Dublin Core format used for an open data portal.

This will allow the subsequent modification and maintenance of this internal metadata and the creation of new versions by the user. Based on user profiles (eg. reviewer, editor), a dashboard will provide easy access to information and tasks. Online editing of metadata will be based on a template system and directories of information. The editor will support uploading of EBV metadata, graphics, documents, pdf files and other content types. It will support among other validation system, suggestion to improve metadata quality and geopublication of layers to publish geodata layers in OGC services (eg. WCS/WFS).

Description of how the outputs of the Initiative, and the methods used to produce them, may be accessed, including relevant URLs or permanent identifiers

The **EBV visualizer**[43], an interactive map viewer based on OpenLayers 3 provides access to OGC services (WFS, WCS) and standards (KML, OWS). Connected to the metadata catalog, users can easily find new services, layers and even dynamic maps to combine them together. The **EBV analyzer**

[42] A current version of the EBV metadata standard is available here: https://github.com/ChristianLanger/eml-profile
[43] A first version of the EBV visualizer/analyzer is available online at http://portal.geobon.org.

then allows to plot summary of changes in EBV data over time and by reporting units specified by the user.

The **EBV metadata catalog**[44] acts as a broker and supports metadata harvesting **FROM** (Input) many sources including OGC-CSW 2.0.2 ISO Profile, OAI-PMH, REST, Z39.50 protocols, Thredds, Webdav and ArcSDE. This broker can collect metadata coming from data providers such as GEOSS, transforms the metadata into a common data model and is then able to provide output interfaces.

The metadata within the EBV catalogue provide their own API which allows exchange **TO** (Output) other providers, data portals and services. Therefore, the EBV metadata records could be harvested by GEOSS main component, GEODAB (www.geodab.net) and its Services Registry (http://geossregistries.info) via the provided API and the protocols OGC-CSW 2.0.2 ISO Profile, OAI-PMH. Figure 3 shows this exchange (Input and Output) within the framework of GEO BON´s technical infrastructure.

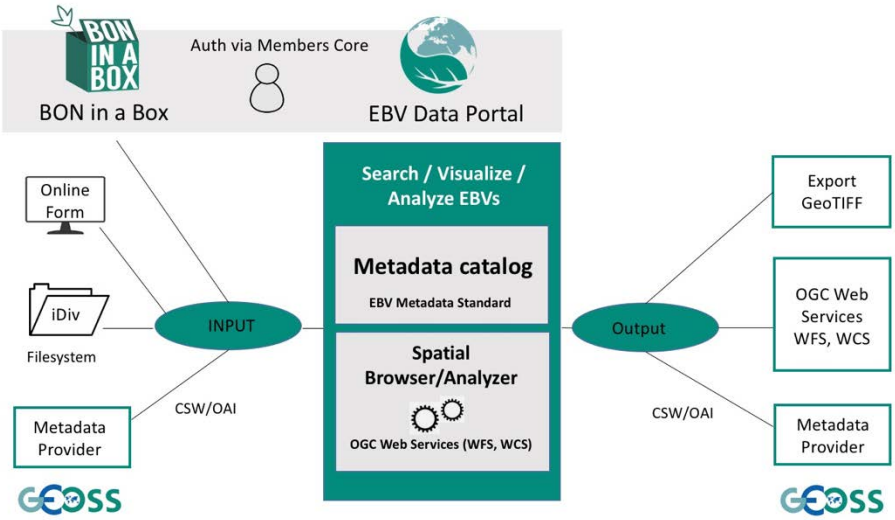


Figure 5. Simplified visualization of the GEO BON technical Infrastructure incl. input/output workflow to GEOSS

Strategy for longer-term preservation of data and information produced by the Initiative.

GEO BON will provide a global, scientifically robust framework for observations that ensures long-term continuity of data supply and data access via an API interface provided by the metadata catalog and GeoServer. These GeoSpatial layers, (GeoTIFF) and web services based on OGC Standards (WFS, WCS) will be available through the web interface for long-term preservation.

[44] A first version of the EBV metadata catalog is available online at https://geonet.geobon.org

Tables

Individual Participants

Table A. The list presented here only represents the members of the GEO BON Implementation Committee (including Secretariat and Management Committee) and Advisory Board. For a full list of members (±800) see: https://members.geobon.org

Note that by law, we are technically not allowed to share the emails of the members, either in Table A or on the GEO BON members page.

First Name	Last Name	Organization	GEO Member / PO Affiliation[45]	Primary Role	Secondary Role
Henrique	Pereira	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Germany	Lead or Co-lead	Component (Task, WG, etc) Lead or Co-Lead
Michael	Gill	NatureServe		Lead or Co-lead	Component (Task, WG, etc) Lead or Co-Lead
Gary	Geller	JPL/NASA		Component (Task, WG, etc) Lead or Co-Lead	
Laetitia	Navarro	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Staff member of the Secretariat to the Flagship or Initiative	Component (Task, WG, etc) Lead or Co-Lead
Christian	Langer	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Staff member of the Secretariat to the Flagship or Initiative	
Nestor	Fernandez	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Staff member of the Secretariat to the Flagship or Initiative	Component (Task, WG, etc) Lead or Co-Lead
HyeJin	Kim	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Staff member of the Secretariat to the Flagship or Initiative	
Karolin	Dietrich	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Staff member of the Secretariat to the Flagship or Initiative	
Tom	Christensen	Aarhus University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Mark	Costello	University of Auckland	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Nicholas	Coops	University of British Colombia	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Jean-Denis	Vigne	French National Museum of Natural History (MNHN)	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Yvan	Le Bras	French National Museum of Natural History (MNHN)	Research institute	Component (Task, WG, etc) Lead or Co-Lead	

[45] There was a problem with this column and the field to fill the different options which is why most cells are empty. We can provide a revised version of the table once a new template is shared.

First Name	Last Name	Organization	GEO Member / PO Affiliation[45]	Primary Role	Secondary Role
Simon	Ferrier	CSIRO		Component (Task, WG, etc) Lead or Co-Lead	
Ilse	Geijzendorffer	Tour du Valat		Component (Task, WG, etc) Lead or Co-Lead	
Carlos	Guerra	German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Sean	Hoban	Morton Arboretum	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Margaret	Hunter	U.S. Geological Survey		Component (Task, WG, etc) Lead or Co-Lead	
Walter	Jetz	Yale University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Jens	Kattge	Max Planck Institute for Biochemistry	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Anna	MacDonald	Australian National University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Melodie	McGeoch	Monash University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Robert	Guralnick	University of Florida	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Frank	Muller-Karger	University of South Florida	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Eun-Shik	Kim	Kookmin University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Daniel	Kissling	University of Amsterdam	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Pedro	Leitão	Technische Universität Braunschweig	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Maria Cecilia	Londoño	Alexander von Humboldt Institute Colombia	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Jeanne	Nel	VU University Amsterdam	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Ilaria	Palumbo	Joint Research Center	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Brian	O'Connor	UNEP-WCMC	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Isabel	Sousa Pinto	University of Porto	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Michael	Schaepman	University of Zurich	Research institute	Component (Task, WG, etc) Lead or Co-	

First Name	Last Name	Organization	GEO Member / PO Affiliation[45]	Primary Role	Secondary Role
				Lead	
Ghada	El Serafy	DELTARES		Component (Task, WG, etc) Lead or Co-Lead	
Odirilwe	Selomane	University of Stockholm	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Andrew	Skidmore	University of Twente	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Wilfried	Thuiller	University of Grenoble	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Eren	Turak	Office of Environment and Heritage (New South Wales)		Component (Task, WG, etc) Lead or Co-Lead	
Maria	Vallejos	University of Buenos Aires	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Sheila	Vergara	ASEAN Center for Biodiversity		Component (Task, WG, etc) Lead or Co-Lead	
Petteri	Vihervaara	Finnish Environment Institute		Component (Task, WG, etc) Lead or Co-Lead	
Diana	Wall	Colorado State University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Aaike	De Wever	Royal Belgian Institute of Natural Sciences		Component (Task, WG, etc) Lead or Co-Lead	
Haigen	Xu	Nanjing Institute of Environmental Sciences		Component (Task, WG, etc) Lead or Co-Lead	
Tesukazu	Yahara	Kyushu University	Research institute	Component (Task, WG, etc) Lead or Co-Lead	
Tim	Hirsh	Global Biodiversity Information Facility		Steering Committee (Board, Advisory Ctte, etc) Member	
Donald	Hobern	International Barcode of Life		Steering Committee (Board, Advisory Ctte, etc) Member	
Anne	Larigauderie	Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)		Steering Committee (Board, Advisory Ctte, etc) Member	
Marc	Paganini	European Space Agency		Steering Committee (Board, Advisory Ctte, etc) Member	
Jon Paul	Rodrigues	IUCN		Steering Committee (Board, Advisory Ctte, etc) Member	
Bob	Scholes	Council for Scientific and Industrial Researh (CSIR - South Africa)		Steering Committee (Board, Advisory Ctte, etc) Member	

First Name	Last Name	Organization	GEO Member / PO Affiliation[45]	Primary Role	Secondary Role
Woody	Turner	NASA		Steering Committee (Board, Advisory Ctte, etc) Member	

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Confirmed Contributions

Due to the lack of synchrony between the GEO and GEO BON Implementation Periods, assessing the confirmed contributions for the next work programme is particularly complicated. In addition, most of the contribution to the GEO BON activities comes from in-kind labor contributions from its members, particularly the 40+ co-leads and coordinators of the different WGs and BONs. For more details on the current, needed and confirmed resources, see section 7.

Table B. Contributions to the GEO Work Programme Activity

Contributing Organization	GEO Member / PO Affiliation	Type of Organization	Type of Contribution	Estimated Value of the Contribution
German Center for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig	Germany	Research institute	Financial	±250 K€ (TBC - 2020 to 2024)
H2020 funding programme	European Commission	Intergovernmental organization	Financial	±500 K€ (2019-2022)
ERANet LAC funding programme	Not affiliated	Intergovernmental organization	Financial	±400 K€ (2019-2022)

Task / Work Package Structure

For the sake of simplicity, the table below focuses on the main activities of the network that are detailed in this document, such as the development of the EBVs and BONs. A detailed list of activities can be found in the 2017-2020 Implementation Plan[46] of GEO BON but note that the activities list of some working groups (e.g. Ecosystem Structure and Ecosystem Functions) should be edited following changes in the leadership of those groups since 2017. In addition, the projects listed pages 24-25 should also be considered by extension as GEO BON activities.

Table C. Task (or Work Packages) Structure of the Work Programme Activity

Task Name	Task Description	Names of Task Leads	Task Starting Year	Year of Planned Task Completion
EBV framework TF	To finalize the development of the EBV framework as well as publish a "final" EBV list.	Henrique Pereira; Nestor Fernandez; Simon Ferrier	2016	2020
Genetic Composition WG	To conceptualize and operationlize the development of the Genetic Composition EBVs and derived indicators	Sean Hoban; Margaret Hunter; Anna MacDonald	2018	Ongoing
Species Populations WG	To conceptualize and operationlize the development of the Species Populations EBVs and derived indicators	Walter Jetz; Melodie McGeoch	2016	Ongoing
Species Traits WG	To conceptualize and operationlize the development of the Species Traits EBVs and derived indicators	Jens Kattge; Marc Costello	2018	Ongoing
Community Composition WG	To conceptualize and operationlize the development of the Community Composition EBVs and derived indicators	Simon Ferrier; Wilfried Thuiller	2018	Ongoing
Ecosystem Structure WG	To conceptualize and operationlize the development of the Ecosystem Structure EBVs and derived indicators	Gary Geller; Ilaria Palumbo; Brian O'Connor	2018	Ongoing
Ecosystem Functions WG	To conceptualize and operationlize the development of the Ecosystem Functions EBVs and derived indicators	Ghada El Serafy; Pedro Leitão	2018	Ongoing
Ecosystem Services WG	To conceptualize and operationlize the development of the Essential Ecosystem Services Variables	Ilse Geijzendorffer; Maria Vallejos; Odirilwe Selomane	2017	Ongoing
EBV Operationalization	Design pilots for EBV operationalization with national Biodiversity Observation Networks	Petteri Vihervaara	2017	Ongoing
EBV Data TF	Development of the EBV data portal and EBV metadata standard	Nestor Fernandez; Robert Guralnick; Daniel Kissling	2017	Ongoing
Remote Sensing TF	Streamline the use of RS to produce EBVs with the working groups; coordinate between users of RS-enabled EBVs and space agencies.	Andrew Skidmore; Nicholas Coop	2017	Ongoing
Policy TF	Support the activities of end users (e.g. CBD, IPBES) with the outputs of GEO BON	Laetitia Navarro; Cornelia Krug	2017	Ongoing
Species Distribution strategic application	Implementing essential variables for invasion monitoring	Melodie McGeoch	2017	Ongoing
Marine BON	Development and Operationalization of the Marine Biodiversity Observation Network	Frank Muller-Karger; Isabel Sousa-Pinto; Mark Costello	2016	Ongoing
Freshwater BON	Development and Operationalization of the Freshwater Biodiversity Observation Network	Eren Turak; Aaike de Wever; Jeanne Nell	2017	Ongoing

[46] https://geobon.org/downloads/governance-documents/geobon_imp_plan_20172020.pdf

soil BON	Development and Operationalization of the soil Biodiversity Observation Network	Carlos Guerra; Diana Wall	2018	Ongoing
BON Design	Development of a flexible framework for BON Design	Michael Gill	2016	2020
BON in a Box	Development of the BON in a Box platfom	Maria Cecilia Londoño	2016	2020
AP BON	Development and Operationalization of the Asia-Pacific Biodiversity Observation Network	Tetsukazu Yahara; Eun-Shik Kim; Sheila Vergara	2008	Ongoing
Arctic BON	Biodiversity monitoring in the Artcic	Tom Christensen	2004	Ongoing
Americas BON	Development and Operationalization of the Americas Biodiversity Observation Network	Miguel Fernandez	2019	Ongoing
Monitoring gaps	Identification of existing biodiversity monitoring systems and of gaps in global observation systems	Michael Gill; Maria Cecilia Londono; Petteri Vihervaara	2018	Ongoing
Colombia BON	Establish a community of practice for biodiversity monitoring in Colombia; guide biodiversity assessments; develop guidelines for biodiversity monitoring	Maria Cecilia Londoño	2015	Ongoing
French BON	Development and Operationalization of the French biodiversity observation network within the "Pole de données biodiversité".	Yvan Le Bras; Jean-Denis Vigne	2016	Ongoing
China BON	Biodiversity monitoring in China - mammals, birds, amphibians and butterflies	Haigen Xu	2014	Ongoing

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Deliverables / Milestones

Table D. Planned Deliverables and Milestones of the GEO Work Programme Activity

Task Name (from Table C)	**Name of Deliverable or Milestone**	**Description of the Deliverable or Milestone**	**Year of Planned Completion**	**Current Status**
EBV framework TF	EBV framework publication	Scientific publication on the EBV framework (Fernandez et al., in prep)	2020	In progress
Genetic Composition WG	Genetic Composition EBV	Delivery of at least one EBV data product for the Genetic Composition EBV class	2020	Not yet started
Species Populations WG	Species Population EBV	Delivery of at least one EBV data product for the Species Population EBV class	2020	In progress
Species Traits WG	Species Traits EBV	Delivery of at least one EBV data product for the Species Traits EBV class	2020	Not yet started
Community Composition WG	Community Composotion EBV	Delivery of at least one EBV data product for the Community Composition EBV class	2020	Not yet started
Ecosystem Structure WG	Ecosystem Structure EBV	Delivery of at least one EBV data product for the Ecosystem Structure EBV class	2020	In progress
Ecosystem Functions WG	Ecosystem Functions EBV	Delivery of at least one EBV data product for the Ecosystem Functions EBV class	2020	In progress
Ecosystem Services WG	EESV framework	Publication of the Essential Ecosystem Services Variables Framework	2020	In progress
EBV Operationalization	EBV Operationalization	Publication on the EBV operationalization pilots with national BONs	2020	In progress
EBV Data TF	EBV Portal	Launch of the EBV Data portal (catalogue/visualizer/analyzer)	2020	In progress
Remote Sensing TF	RS-enabled EBVs	Link RS data to EBV development and workflows	2020	In progress
Policy TF	Post-2020 biodiversity framework	GEO BON contributes to the CBD framework with EBVs and BONs	2020	In progress
Species Distribution strategic application	EBVs for invasion monitoring	Link between primary observations, Species Populations EBVs and indicators for Alien Invasive Species and their impact	2020	In progress
Marine BON	MBON Operational	Operationalization of the Marine BON	2020	In progress
Freshwater BON	FWBON Developed	The Freshwater BON is well established, with clear tasks towards its operationalization	2020	In progress
soil BON	soil BON Developed	The soil BON is well established, with clear tasks towards its operationalization	2021	In progress
BON Design	BON Design Manual	The BON Design Manual is published	2020	In progress
BON in a Box	BON in a Box version 2.	Launch of the new version of BON in a Box with tools added by WGs and BONs and an adopted curation process	2020	In progress
AP BON	AP BON Operational	Operationalization of the AP BON	2020	In progress
Americas BON	Americas BON Developed	The Americas BON is well established, with clear tasks towards its operationalization	2021	In progress

Annexes (additional annexes may be added as required)

Acronyms and abbreviations

AB: Advisory Board
ACB: ASEAN Centre for Biodiversity
AP BON: Asia Pacific Biodiversity Observation Network
ASEAN: Association of Southeast Asian Nations
BON: Biodiversity Observation Networks
CBD: Convention on Biological Diversity
CBMP: Circumpolar Biodiversity Monitoring Program
COP: Conference of the Parties
EBV: Essential Biodiversity Variable
ECOPOTENTIAL: EU H2020 Project "Improving future ecosystem benefits through earth observations"
EO: Earth Observation
ESA: European Space Agency
EU H2020: European Union Horizon 2020
FWBON: Freshwater BON
GBIF: Global Biodiversity Information Facility ();
GCI: GEOSS Common Infrastructure
GEO: Group on Earth Observations
GEO BON: Group on Earth Observations Biodiversity Observation Network
GEOSS: The Global Earth Observation System of Systems
GLOBIS-B: H2020 Project "GLOBal Infrastructures for Supporting Biodiversity research"
GWOS: Global Wetland Observing System
IC: Implementation Committee
iBoL: International Barcode of Life
iDiv: German Centre for Integrative, Biodiversity Research, Halle-Jena-Leipzig
IOC-UNESCO: United Nations Educational, Scientific and Cultural Organisation's Intergovernmental Oceanographic Commission
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
LPI: Living Planet Index
MBON: Marine Biodiversity Observation Network
MC: Management Committee
MoL: Map of Life
NASA: US National Aeronautics and Space Administration
OBIS: Ocean Biogeographic Information System
OGC: Open Geospatial Consortium
PM: Person Month
PREDICTS: Projecting Responses of Ecological Diversity In Changing Terrestrial Systems
SBA: Societal-Benefit-Area
SDG: Sustainable Development Goals
STRP: Scientific and Technical Review Panel of the Ramsar Convention
SWOS: Satellite-based Wetland Observation Service
TF: Task Force
UN: United Nations
UNEP-WCMC: United Nations Environment Programme World Conservation Monitoring Centre
WG: Working Group
ZSL: Zoological Society of London

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Brief CV of Project Leader

Henrique M. Pereira (GEO BON co-Chair)

Henrique Miguel Pereira is the Professor of Biodiversity Conservation at iDiv - German Center for Integrative Biodiversity Research Halle-Jena-Leipzig and Chair of the Catedra REFER Biodiversity at InBio (Portugal). He was the Chair of GEO BON from 2014 to 2017, and is the co-chair since 2017, together with Mike Gill. He was one of the lead authors of the Global Biodiversity Outlook 4 and a Coordinating Lead Author of the IPBES Scenarios Assessment. Prof. Pereira received his PhD in Biological Sciences from Stanford University in 2002. From 2003 to 2005 he coordinated the Portugal Millennium Ecosystem Assessment. From 2006 to 2009 he was the Director of Peneda-Gerês National Park in Northern Portugal. From 2009 to 2014 he was a Research Group Leader at the Center for Environmental Biology of the University of Lisbon. He has published over one hundred scientific papers and reports on biodiversity issues. His research interests revolve around global biodiversity change, with a particular emphasis on the development of monitoring schemes.

Positions

2015-Present	Invited IP Chair	InBio – University of Porto, Portugal
2013-Present	Full Professor	Martin Luther Universität Halle-Wittenberg / iDiv, Germany
2013-2014	Invited Principal Res.	CBA, Faculty of Sciences of the University of Lisbon, Portugal
2012-2013	Invited Assistant Prof.	Faculty of Sciences of the University of Lisbon, Portugal
2009-2013	Research Group Leader	Center for Environmental Biology, University of Lisbon
2006-2012	Invited Assistant Prof.	Instituto Superior Técnico
2007-2009	Director	Dept. of Protected Areas of Northern Portugal, ICNB
2006-2007	Director	Peneda-Gerês National Park, ICNB
2005-2006	Assistant Professor	Instituto Superior Técnico

Publications and Citation Metrics

Web of Science: http://www.researcherid.com/rid/B-3975-2009

Google Scholar: http://scholar.google.pt/citations?user=7rIEh98AAAAJ&hl=en

Other relevant activities and public service

2016-…	Co-Chair of the IPBES Expert Group on Scenarios and Models
2014-2016	Coordinating Lead Author of the Scenarios Assessment of the IPBES
2012-...	Member of the Steering Committee of Map of Life, Yale University
2012-13	Head of the Portuguese delegation to the IPBES
2012-13	Member of the Steering Group of the project on Mapping and Assessing Ecosystem Services in Europe, European Commission
2011-14	Member of the Scientific Committee of bioDISCOVERY, Diversitas
2009-13	Coordinator of the Terrestrial Species Monitoring Working Group of GEO BON
2007-08	Member of the ICSU-UNU-UNESCO Ad Hoc Group to Summarize Scientific Knowledge Gaps Based on the Millennium Ecosystem Assessment.
2005	Member of the Biodiversity Indicators Working Group of the European Academy of Sciences Advisory Council
2006-07	Scientific coordinator of the 3rd National Report of Portugal to the Convention on Biological Diversity (2006-2007).
2003-06	Coordinator of the Portugal Millennium Ecosystem Assessment (http://ecossistemas.org).
2002-05	Member of the Scenarios Working Group of the Millennium Ecosystem Assessment (http://www.maweb.org, 2003-2006).

Michael J. Gill (GEO BON Co-chair)

Mike Gill has been designing and implementing user-driven biodiversity research and monitoring programs for the past 20 years, across the Arctic and within North America, Eurasia, Antarctica and Latin America. His current role as co-Chair of GEO BON has him applying his experience at the global scale, developing integrated and scalable biodiversity observation systems for nations and regions that contribute to a global biodiversity observation system. Mike served previously as Chair of the Circumpolar Biodiversity Monitoring Program – an international network of scientists and local resource users working together to improve detection, understanding and reporting of important trends in the Arctic's biodiversity. Mike, currently with Polar Knowledge Canada, is also leading the development of a new Canadian Arctic science plan. Mike also holds a number of active appointments including serving as an editorial member of Biodiversity: the Journal of Life on Earth. Mike has co-authored over 50 publications and has been a keynote speaker at a number of conferences and events. Mike's career focus is on building user-driven, collaborative networks of scientists and citizens to improve understanding and response to important conservation issues.

Related Experience

Director of the Biodiversity Indicators Program (2018-Present)
NatureServe, Arlington, USA

Co-Chair, GEO BON (July 2017 – present)
Vice-Chair, GEO BON (Jan 2014 to 2017)

- Contribute to the design, development & implementation of a global biodiversity observation system;
- Lead design of capacity building tools for enhanced biodiversity observations;
- Advise governments and institutions on biodiversity observing design;
- Establish and lead international scientific teams; and,
- Chair, present and facilitate at international conferences, workshops and meetings.
- Co-lead of the BON Development Working Group

Senior Science Advisor (September 2014 to 2017)
Polar Knowledge Canada, Wolfville, Nova Scotia

- Lead the design and development of a Canadian pan-Arctic science program;
- Develop and implement a strategic partnership and engagement strategy;
- Develop international, collaborative agreements with key partners (e.g. NASA);
- Establish and lead Arctic scientific teams.

Chair, Circumpolar Biodiversity Monitoring Program (September 2007 to June 2013)
Environment Canada, Canadian Wildlife Service, Whitehorse, Yukon

- Lead and represent international scientific network for coordinating biodiversity monitoring efforts across the entire Arctic (over 80 organizations);
- Lead design and implementation of pan-Arctic biodiversity monitoring plans, biodiversity indicators and community-based monitoring strategies;
- Convene and lead international scientific teams;
- Establish and maintain partnerships and funding arrangements with government, non-government, Aboriginal, and international organizations across the Arctic and globally;
- Advise governments and institutions on biodiversity monitoring and indicator design; and,
- Chair, present (over 150 presentations including keynotes) and facilitate at international conferences, workshops and meetings involving diverse audiences.