D4.3: Final position paper for policy makers

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1. Executive summary

Exploiting primary biodiversity and other data to produce and manage Essential Biodiversity Variables (EBV) data products depends on cooperation, practicality and interoperability among multiple stakeholders, including those collecting and mobilising data with EBV potential (EBV-usable data), those making data 'EBV-ready' and those producing, publishing and preserving EBV data products. Since EBVs feed the construction of different indicators for policy use, also policy makers are important stakeholders to provide guidance on priorities. A policy workshop organised by GEO BON and the GLOBIS-B project brought in May 2018 together the representatives of various (regional and international) policy bodies with senior officials of biodiversity research infrastructures from different continents. The workshop addressed a number of findings:

- While building EBV data products requires a considerable level of data integration from a large number of data providers, it is possible to run comparable, repeatable and quality-based EBV workflows. Policymakers and funders could help move EBVs beyond an academic exercise by expressing their views about the further operationalization of EVBs for their use in biodiversity change assessments and about the role of EBVs in current and future policy developments.
- The research infrastructures contributing to GLOBIS-B have expressed their interest to cooperate on EBV production at the global scale. Policymakers and funders could help promoting coordination around EBV production, including the development of shared and repeatable workflows, and encourage infrastructures to make EBV data products open as well as findable, accessible, interoperable, and reusable (FAIR).
- EBV production is often constrained by legal restrictions on the use, modification and sharing of software and data. Policymakers and funders could help clarify and incentivize requirements for legal interoperability, emphasizing the value of automated and unrestricted data retrieval, and the use of standardized, machine-readable copyright waivers such as CC0, or licenses such as CC-BY.

The workshop discussions resulted in a clear set of recommendations for both the policy sector and the research infrastructures. GEO BON will bring the policy recommendations to the attention of policy bodies, and with clear suggestions for their international meetings. The cooperating research infrastructures in the framework of the GLOBIS-B project will continue on the recommendations relevant for their operations.

2. Contributors

The authors of the present document are Enrique Alonso Garcia (WP4 leader and UAH) and Wouter Los (UvA), while many other members of the GLOBIS-B project team and the participants of the final GLOBIS-B policy workshop provided contributions shaping the outcome of the work. The list of workshop participants is in Annex 1 of this document. We acknowledge the assistance and contributions of the following individuals who contributed significantly throughout the project to the continuing discussions about legal and policy issues related to the development of EBV data products: Donat Agosti, Anne Bowser, Willi Egloff, Laetitia Navarro, and Paul Uhlir.

3. Background

Although reducing the rate biodiversity loss and averting dangerous biodiversity change are accepted international goals, there is no global, harmonized observation system for delivering regular, timely data on biodiversity change[1]. A key mechanism for studying and reporting on biodiversity change is the concept of Essential Biodiversity Variables (EBVs). EBVs are a minimum set of critical variables representing different dimensions of biodiversity from genetic composition, species populations, species traits, community composition, ecosystem function, to ecosystem structure. Processed EBV datasets for each dimension (class) provide the basis for developing high-level indicators of biodiversity. GEO BON[2] is improving the acquisition, coordination and delivery of biodiversity observations and related services to users, including decision makers and the scientific community. A global biodiversity observation network should contribute with data to effective management policies for the world's biodiversity and ecosystem services.

The approach of Essential Biodiversity Variables (EBVs) as developed by GEO BON has been analyzed by the EU-funded GLOBIS-B project[3] in order to propose standardized computational workflows for delivering EBVs. The project has studied how international cooperation of research infrastructures can support standardized EBV development through data sharing and by offering computational workflow tools. Bringing this into effect depends on the willingness of the infrastructures and their governing bodies to contribute with each other's strengths to cooperative efforts in support of EBV production. But it also depends on the ability of national and international policy bodies to provide guidance on priorities, and on removing legal and financial barriers for cooperation.

The GLOBIS-B[4] project "Global Infrastructures for Supporting Biodiversity research" is a Horizon 2020 funded initiative within the coordination and support funding scheme for international research infrastructure cooperation of the European Commission. The project brings together scientists, IT and legal experts, and operators of research infrastructures to address the research needs and infrastructure services required to support EBVs. This cooperation has demonstrated, for a few EBV classes, how the harmonization of data collection and technical data management can contribute to standardized and repeatable EBV data products with common computational workflows. EBVs as produced with data from various sources (e.g. in situ monitoring, remote sensing) are crucial to assess changes in biodiversity through time. They can be used to measure the achievement of policy goals such as the Aichi Biodiversity Targets set by the Convention on Biological Diversity (CBD), or the UN Sustainable Development Goals (SDGs), or the national targets defined in National Biodiversity Strategies and Action Plans (NBSAP) or the like. Finally, they can also serve to define biodiversity management policies from local to global scales.

3.1. Operationalizing the EBV framework

Building EBV data products with heterogeneous types of data in the form of time series requires identification and clear definition of the key dimensions (space, time and taxonomy), attributes and uncertainties of EBV-useable data. Such data must comply with minimum requirements to be defined and be based on reliable data that have been collected and processed following scientifically recognized standards. The data sources and the construction of EBV data products must be traceable and the processing method must be reproducible.

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[1] Pereira, H. M., Ferrier, S., Walters, M., Geller, G., Jongman R. H. G., Scholes, R. J., Bruford, M., Brummitt, N., Butchart, S. H. M., Cardoso, A., Coops, N. C., Dulloo, E., Faith, D. P., Freyhof, J., Gregory, R. D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Karp, D., McGeoch, M. A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B., Sayre, R., Scharlemann, J. P.W., Stuart, S. N., Turak, E., Walpole, M. & Wegmann, M. (2013). Essential biodiversity variables for global earth observation. Science, 339: 277-278. DOI: 10.1126/science.1229931

[2] http://geobon.org

[3] GLOBIS-B: GLOBal Infrastructures for Supporting Biodiversity research. EU-H2020 grant agreement No 654003.

[4] http://www.globis-b.eu

To document biodiversity changes comprehensively, EBVs depend both on existing data, and on new data generated in the future through targeted monitoring. EBVs should be flexible and relevant, and should be possible to calculate:

- For any geographic area,
- At any spatial and temporal scale,
- For any species, assemblage, ecosystem, or biome of interest,
- With data held by any (or across) data repositories, and
- By any expert willing to deploy the conceptual and operational framework of EBVs.

As EBVs will usually be built from multiple sources and research / monitoring activities, combining them requires sufficiently informative metadata about the EBV usable data to allow harmonization and standardization. Building EBV data products further requires dealing with different scales, correcting for imperfections, interpolation and extrapolation; as well as quantifying uncertainties. EBV data products should follow a standardized structure to be defined and the approaches of EBV production should be compatible. The conclusions of the GLOBIS-B project for constructing EBV data products for species distribution and abundance (EBV class species populations) has been published in Biological Reviews 2018 (**https://doi.org/10.1111/brv.12359**).

3.2. Requirements for making EBVs available for policy purposes

If EBV development is to transcend scientific curiosity to become available for policy purposes, it will require clarity and support with respect to:

A. Policy priorities on required EBV products (at the levels of prioritized species, assemblages, ecosystems, biomes, areas, scales);
B. Coordinated monitoring schemes for primary data collection/production on required scales in support of constructing EBV-usable datasets, such as foreseen with Biodiversity Observation Networks (BONs) around the world;
C. Computational workflows to process primary data into various EBV data products;
D. Cooperation of research infrastructures for curating processed (EBV) data and publishing them in required formats;
E. Overcoming legal constraints in relation to accessing data and achieving workflow interoperability.

All workshop participants received prior to the workshop a background document providing considerations with respect to the above issues A to E, together with information about information GEO BON and the GLOBIS-B project (Annex 2).

3.3. Workshop agenda and methodology

The workshop agenda below covered Tuesday afternoon 8 May 2018 and almost the full day of 9 May. After introductory presentations, the workshop participants were divided in four groups to discuss implications of the EBV requirements as mentioned in paragraph 3.2. Afterwards, the group reports allowed to structure suggested recommendations under a few headlines. Next, these structured recommendations were further discussed in one group on policy issues, and another one on issues relevant for research infrastructures. A plenary review of these discussion outcomes resulted in a concise set of recommendations, supported by all participants.

Agenda

8 May 2018

1. 13:30 Welcome & Introduction to the objectives of the Workshop
2. 14:00 Keynote lectures (*Chair: Daniel Kissling*)
   - EBVs as key input for policy objectives (*Laetitia Navarro*).
   - Results from the GLOBIS-B project relevant for the workshop (*Daniel Kissling*).
   - Test case (ALA & GBIF) on invasive species (*Alex Hardisty*).

- EuroGEOSS – Coordinate, combine and cooperate (*Marjan van Meerloo, European Commission*)

15:00 Coffee / Tea

3. 15:30 – 17:30 Table groups of 6 persons each will discuss the proposed recommendations.
    A. Policy priorities on required EBV products (species, assemblage, ecosystem, biome, areas, scales).
    B. Coordinated monitoring schemes for primary data collection or production on of constructing EBV-usable datasets, such as foreseen with Biodiversity Observation Networks (BONs) around the world.
    C. Computational workflows to process primary data into various EBV data products.
    D. Cooperation of research infrastructures for curating processed (EBV) data products and publishing them in required formats.
    E. Overcoming legal constraints in relation to accessing data and achieving workflow interoperability.

    Discuss and agree on each of the recommendations, note any special remarks, and highlighting (if necessary) any significant points of concern.

4. 17:30 – 18:00 Presentations by table group rapporteurs (*Chair: Laetitia Navarro*)

9 May 2018

5. 09:00 Discussion outcomes and proposed conclusions (*Wouter Los*).
6. 09:30 Initial discussion on proposed conclusions from the workshop with a list of recommendations (*Chair: Laetitia Navarro*).

10:30 Coffee / Tea

7. 11:00-13:15 (Continued) Discussion proposed conclusions from the workshop with a list of recommendations (*Chair: Laetitia Navarro*).

13:15 Lunch and end of workshop

8. 14:00 – 15:30 Publicity and next steps.
    Round table discussion about next steps.
    - What possible actions for agreed recommendations?
    - Who will act on each of these?
    - Publicity on workshop outcomes.

4. Workshop outcomes

4.1. EBVs as a fundamental resource for the evaluation of biodiversity trends

Policy questions and needs are varying over countries, regions, continents and globally, and these change over time. Depending on existing and/or emerging policy questions, indicators need to be defined that are informative for answering the expressed questions and needs. As such, preferred indicators will likely also change over time. In order to avoid that new data have to be generated for each new indicator, it is attractive to build upon a body of EBV data sets. Depending on any preferred indicator, it should be possible to construct the indicator from a data selection in a full body of EBV data sets. In this view, a body of EBV data sets should be regarded as a stable intermediate data layer in between *raw data* and varying *indicators*. Examples include EBVs to support infectious disease vectors, invasive species, and effects of biodiversity management. This is needed to guide national-level initiatives among producers and consumers who can then contribute to global-level dialogue. Moreover, sufficiently large EBS data sets would allow for predictive ecology: potentially forecasting trends and assessing the impact of management interventions.

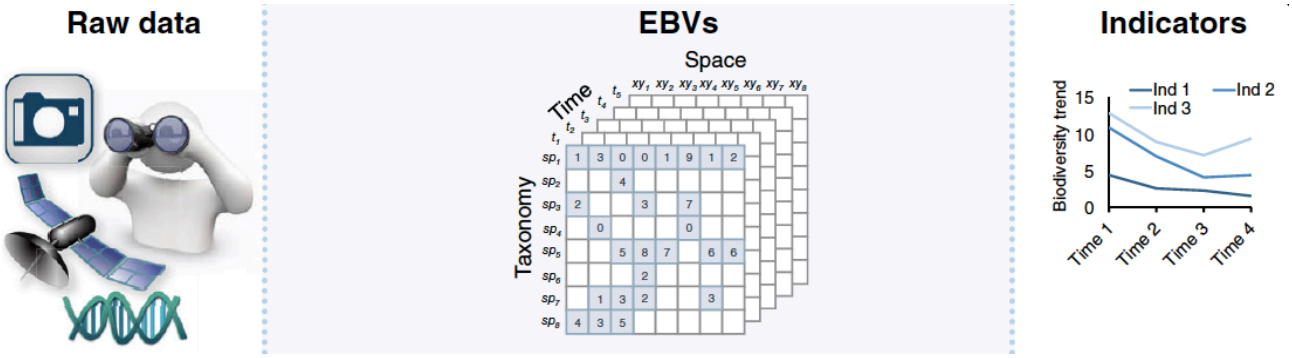

Figure 1 EBVs are calculated from raw data and provide building blocks for indicator development.

To facilitate varying indicators, it is the challenge to agree on building a body of sufficiently large EBV data sets, that are if possible are based upon cooperation, practicality and interoperability among multiple stakeholders, including those collecting and mobilizing data with EBV potential (EBV-usable data), those making data 'EBV-ready' and those producing, publishing and preserving EBV data products. Ten principles offer best current practice guidance to data and infrastructure organizations to enhance their ability to contribute towards production of global EBV data products, whilst retaining autonomy and flexibility to achieve what is needed in ways appropriate to the organizations' own business. The principles as developed in agreement with the cooperating research infrastructures are summarized below.

1. ***Data Management Plan***

   Projects developing EBV data products should have comprehensive data management plans.

2. ***Data Structure***

   EBV data products should adhere to agreed-upon minimum dimensions for each product (i.e., time, space, name/taxonomy (where applicable), etc.). All EBVs should be accommodated in a common framework that conforms (as far as is practically possible) with content and schema standards for representation formats and exchange protocols.

3. ***Metadata***

   EBV data products and the EBV-ready datasets from which they are generated should have associated human- and machine-readable metadata, compliant with accepted community standards and sufficient for purposes of data discovery, access, fitness-for purpose evaluation, citation, interpretation and use.

4. ***Services***

EBV data products, EBV-ready datasets, digital objects and other related services should expose their capabilities and be accessible through common, standardized Application Programming Interfaces (APIs).

5. ***Data Quality (Fitness-for-use)***

   Each EBV data product and EBV-ready dataset should include data quality documentation, sufficient to identify fitness-for-use of the data for specific purposes.

6. ***Workflows***

   It should be possible to execute published, standard workflows for preparing, publishing and preserving EBV data products and the EBV-ready datasets from which they are produced. Ideally, such workflows should be defined and represented in a non-proprietary manner.

7. ***Provenance***

   It should be possible to trace the EBV production process from the product back to the primary data and to reproduce the process. Provenance information must be readable both by humans and by machines.

8. ***Ontologies / Vocabularies***

   EBV data products and EBV-ready datasets should be described by standard, openly accessible and machine-readable key vocabulary terms and conceptual relations (ontologies) presented in a simple way to enable wide usage.

9. ***Data Preservation***

   EBV data products and associated underlying data should be preserved with an associated persistent identifier in a community supported and trusted repository.

10. ***Accessibility***

    EBV data products and EBV-ready datasets must be sensitive, timely and FAIR (Findable, Accessible, Interoperable and Reusable).

4.2. Agreed recommendations

The recommendations below as resulting from the workshop discussions are focussing on four main areas:

1. Secure trust in a stable body of EBV data sets
2. Put in place the conditions for effective EBVs fit-for-use
3. Biodiversity research infrastructures around the world can make this work
4. Advertise the recommendations and request policy support

The recommendations are split in ones addressing policy bodies, and others for research infrastructures.

4.3. Policy recommendations

Policy recommendations are for audiences at the national, regional and international level. Although national policy levels are mainly acting in legislation and management, the bodies based on international agreements and conventions also are suggested to consider the recommendations below.

Secure trust in a stable body of EBV data products

- Policy bodies are recommended to bring into promote that EBV data sets will be based on traceable and quality controlled primary data. Feedback mechanism(s) are needed from uses to providers.

- Building trust and sustainability across entire value chain by ensuring appropriate funding and appropriate governance, also securing appropriate attribution for contributors.

- Likewise, EBV data products must be open and FAIR, and funding bodies are recommended to request this in their funding conditions.
- Trust also requires a professional approach with a competent research community, together with appropriate mechanisms to review EBV development. Here funding bodies can promote such mechanisms.
- The long-term sustainability of stable EBV data products should be implemented by the research infrastructures concerned, and their funding authorities are recommended to explicitly require this.

Put in place the conditions for effective EBVs fit-for-use

- Policy stakeholders are invited to consider improved indicators through the availability of EBV products. They are also suggested to engage with the communities generating the required primary data and the ones constructing EBVs to promote and ensure that the process from primary data to indicators is streamlined.
- Generating primary data relevant for different EBV classes is not yet comprehensively organized with standardized protocols to address data gaps. Funding bodies are recommended to provide funding as incentive to accelerate this.
- Recommend that legislation is effective for opening up and sharing data, and for cross-border data use in the countries and economies where it is still not yet fully implemented.

Advertise the recommendations and request policy support

- GEO BON is invited to take up the heritage of the GLOBIS-B project and to advertise the recommendations in this paragraph.
- A strategy is required for including EBVs in the agenda of the post-2020 biodiversity strategy. The fifteenth meeting of the Conference of the Parties in 2020 is expected to update the Convention's strategic plan. In the context of the 2050 Vision of the current Strategic Plan for Biodiversity 2011-2020 as well the 2030 Agenda for Sustainable Development and other relevant international processes, and in the light of an assessment of progress in achieving the goals and Aichi Biodiversity Targets of the current plan as well as of future scenarios of change. Since the deadline to submit documents or relevant input to the process of preparations for Post-2020 Biodiversity Framework, within the phase of proposals for a comprehensive and participatory process is closed since 16 February 2018, (See https://www.cbd.int/post2020/) and, following the peer review process the document will be revised and made available for consideration by the Subsidiary Body on Implementation SBI) during its second meeting that will take place in Montreal, Canada, 9 - 13 July 2018 and the documents to be analyzed by the SBI seems also closed (see https://www.cbd.int/sbstta22-sbi2/review.shtml#tab=1), the first next step is to analyse how the conclusions and potential additional relevant documents related to GLOBIS-B can be included either info documents or during its celebration through delegates of the countries with which the Research infrastructures have connections as well as the European Commission, or through observers attending its meeting (i.e. GEO BON, IPES or GBIF, if they attend). In any case the process toward the final decision will not be closed in this meeting so the participants assume the commitment to closely follow the process until its final approval.

4.4. Recommendations for research infrastructures

It should be noted that biodiversity research infrastructures have different roles, such as data providers, data aggregators, analytical / computational infrastructure, repositories of EBV data products. In summary

the research infrastructures have to consider their position with respect to the three following generic roles:

1. ***collecting and mobilising data with EBV potential (EBV-usable data),***
2. ***making data 'EBV-ready' and,***
3. ***producing, publishing and preserving EBV data products.***

As for the first role, the workshop expressed that data providers deserve much credit. They have already invested many efforts in securing the availability and accessibility of raw data. For the latter third role nothing yet is in place to perform role at present. A general recommendation for the cooperating research infrastructures is to create something new or to encourage existing research infrastructures to take up this role. Users and other stakeholders must be involved in emergence of that and must incorporate feedback mechanism to first two roles.

Secure trust in a stable body of EBV data products

- Policy bodies are recommended to bring into promote that EBV data sets will be based on traceable and quality controlled primary data. Feedback mechanism(s) are needed from uses to providers to build trust and sustainability across entire value chain. It is recommended that research infrastructures offer such mechanism in their operations.
- EBV data products, workflows and applied tools must be open and FAIR. The research infrastructures are recommended to put in place a number of streamlining activities as proposed in the so-called Bari Manifesto (see at the end of Annex 2). These include harmonization around metadata standards, ontologies, and on the level of data records and data quality.
- Engage with relevant standards bodies (such as TDWG, OGC, W3C, RDA, etc.)
- Turn synthesis centres worldwide on to producing the EBV data products they might need to answer the questions they tackle. Engage institutions capable to for example, the 'synthesis centres' to tackle some specific challenges.
- All steps in workflows from primary data to enriched EBV data sets should be recorded, allowing the documentation of everyone's contributions in workflow steps. This assists in tracing successive steps, and so becomes auditable.
- Trust also requires a professional approach with a competent research community, together with appropriate mechanisms to review EBV development.

Put in place the conditions for effective EBVs fit-for-use

- Engage the stakeholders and communities along the EBV value chain in the exercise to construct/compute EBVs data products. These are the experts, for assessing existing data sources, for protocols to generate new data, and for reaching standards.
- Consider a centralized or distributed service with a tool and workflow catalogue (BON-in-a-Box).
- This also should include services to assist in understanding and deploying such services. Generic workflow components of an EBV need to be easily explainable.
- Give special attention to the training of data scientists capable of operating in this field, from data custodians up to data analytics experts and data executive officers.
- Attention that legislation is effective for opening up and sharing data, and for cross-border data use.

Biodiversity research infrastructures around the world can make this work

- Biodiversity research infrastructures around the world started working together to serve a variety of user audiences. It is potentially possible to construct EBV data products at an industrial scale, and thus build a body of EBV data sets.
- The GLOBIS-B recommendations are addressing a further development from the initial EBV concept, and are suggesting building a body of EBV data sets at an industrial scale allowing for underpinning diverse indicators in support to changing policy and management needs. The research infrastructures are recommended to agree on a common policy for building such EBV data sets at the national and regional levels. This includes an architecture for storing and finding the EBV data sets with options to bring these into use for constructing emerging indicators relevant for policy needs.
- Of course this will start with a few tests, and expanding EBV data sets needs careful joint planning with the coordinating GEO BON.
- A number of data and research infrastructures with the lead of GBIF are discussing the implementation of a shared pipeline for supporting/delivering EBV-ready datasets for the species distribution EBV.
- The LifeWatch research infrastructure discusses developing (with the cooperating Research Infrastructures and the wider scientific community) a shared pipeline with workflows on a dedicated hardware platform to analyze and model the EBV-data.
- These latter processes should be encouraged and the involved research infrastructures are encouraged to promote further collaboration with the involved other research infrastructures and their user communities.

Advertise the recommendations and request policy support

- All recommendations above should be reported to CBD, IPBES and similar conventions in order to promote adoption of this approach.
- Communication needs to be tailored toward audiences. Real life examples may underpin and explain the benefits of the promoted approach. Examples are invasive species, pollinators, algal blooms, and infectious diseases.
- It is important that stakeholders, at national, regional and global scales will recognize the importance of promoting and investing in their areas of capabilities and interests.
- GEO BON is invited to take up the heritage of the GLOBIS-B project and to advertise the recommendations in this paragraph.

5. Conclusions

The GLOBIS-B resulted in considerable progress in understanding the EBV concept, on how research infrastructures can work together to implement computational workflows for EBV construction, and how both policy authorities and scientific communities may benefit from a resource of EBV data products. A coordinated test on biodiversity change related to invasive species showed that the GLOBIS-B results are feasible in practice. The GLOBIS-B project coordination hereby is expressing gratitude for these efforts by GBIF, the Atlas of Australia and the BioVEL initiative. It is crucial to keep together the scientific, infrastructure, technical, and legal communities that cooperated in GLOBIS-B. More concrete efforts are required to build a body of EBV data products, so that better and scientific based indicators - such as for detecting pollinator change - can be based on these data products.

GEO BON will continue on the momentum created by GLOBIS-B, with publicity and by promoting awareness in the relevant policy and other communities. But also by involving the experts from the GLOBIS-B workshops in its GEO BON working groups. A concrete GEO BON action is to advise (national and international) policy bodies about next steps for EBV implementation, following their earlier support for the EBV approach. The involved research infrastructures will build on this with further tests, and to get a better picture of each one role in the chain from generating raw data, data processing, storing EBV data products, and the provision of services to users including policy. By building on existing efforts, successful examples and explanatory documents/publications will assist the GEO BON community to bring the EBV concept on a next operational level in the next few years.

It is reassuring that GBIF is already discussing the implementation of a shared pipeline for supporting/delivering EBV-ready datasets for the species distribution EBV, and that the LifeWatch research infrastructure is discussing the development of a similar for computational workflows to analyze and model the EBV-data.

6. References

[Kissling 2015] Kissling, W.D., Hardisty, A., García, E.A., Santamaria, M., De Leo, F., Pesole, G., Freyhof, J., Manset, D., Wissel, S., Konijn, J. & Los, W. (2015) Towards global interoperability for supporting biodiversity research on essential biodiversity variables (EBVs). Biodiversity. 2015 Jul 3;16(2-3):99-107. doi: 10.1080/14888386.2015.1068709.

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7. Annex 1: Participants of the policy workshop (8 - 9 May 2018)

Person last name	First name	Organisation
Agosti	Donat	PLAZI
Alkemade	Rob	IPBES TSU Scenarios and Models
Alonso	Enrique	State Council of Spain
Bubb	Philip	Biodiversity Indicators Partnership
Canhos	Vanderlei	Brazilian Reference Centre on Environmental Information
Egloff	Willi	PLAZI
Hardisty	Alex	Cardiff University
Hirsch	Tim	Global Biodiversity Information Facility
Holewa	Hamish	Atlas of Living Australia
Huis, van	Edwin	Group of global large Natural History Museums
Ji	Liqiang	Chinese Academy of Sciences
Johansson	Anna-Maria	European Commission - Unit Research Infrastructures
Kissling	Daniel	University of Amsterdam
Konijn	Jacco	University of Amsterdam
Koureas	Dimitris	Distributed Systems of Scientific Collections
Krug	Cornelia	Future Earth
Le Bras	Yvan	FR-BON / ECOSCOPE
Leo, de	Francesca	CNR Italy
Londoño	Maria Cecilia	Humboldt Institute Colombia & CO-BON
Los	Wouter	University of Amsterdam
Manset	David	CEO GNUBILA/MAAT
Meerloo, van	Marjan	European Commission - Unit Earth Observation
Michener	Bill	DataONE data observation network
Navarro	Laetitia	GEO BON
Tienderen	Peter H.	LifeWatch research infrastructure

8. Annex 2: Information package as sent to workshop participants

The text below presents considerations related to EBV requirements A-E (see page 8). The considerations are directed to political, policy, and funding bodies and to research infrastructures. This is indicated in each sub-section below.

B. Policy priorities on required EBV products (species, assemblage, ecosystem, biome, areas, scales)

The GLOBIS-B project investigated the feasibility of producing EBV data products on biodiversity change, and this provided valuable proof of concept for the EBV framework. To advance the EBV framework from this proof of concept to broader development and uptake, there is a need for top-down policy direction to help researchers and supporting infrastructures understand where to focus subsequent efforts within the variety of possible EBV implementations. Guidance by policy bodies could include information on:

1. The prioritized high level challenges, such as the Aichi Biodiversity Targets or new ones that could be supported by related indicators and relevant EBVs.
2. Any other policy targets that might trigger to take up new dimensions of biodiversity not yet covered in existing indicators.
3. Promoted provision of resources on (sub)national and regional scales for meeting the policy priorities with targeted and large-scale EBV efforts.

B. Coordinated monitoring schemes for primary data collection or production on required scales

The production of EBV data products depends on suitable and accessible data. Historically, before the EBV concept was in place, biodiversity observation and monitoring practices were directed at different objectives, either for research purposes or for other reporting obligations. Parts of such legacy biodiversity data can be used for the construction of EBV data products. But new data collection should follow standardized and structured protocols to serve for EBVs and derived indicators, and international policy guidance can serve national efforts in this regard.

1. the CBD may want to consider how its resolutions on global and national obligations on reporting on biodiversity trends may benefit from the new opportunities for building policies on standardized and scientifically recognized EBV data products[5];
2. likewise, to establish links with other related conventions;
3. national authorities charged with setting monitoring priorities may want to promote the inclusion of EBV relevant data in adequately resourced monitoring schemes, allowing for harmonized EBV data processing, for which Biodiversity Observation Networks (BONs) are appropriate vehicles;
4. involved stakeholders may exchange information and agree on best practice approaches in this regard. The BON in a box online catalogue could be considered as an adequate platform for capacity building and knowledge exchange (https://boninabox.geobon.org/).

C. Computational workflows to process primary data into various EBV data products

It is possible to run comparable, repeatable and quality-based EBV workflows with support from cooperating infrastructures. Ideally, widely accepted and adopted sets of generic workflows could lead to substantial EBV production in support of a range of indicators on biodiversity change. But building EBV data products requires a considerable level of data integration from a large number of dispersed data providers, as well as complex preparation and processing steps. This is possible to implement, but research infrastructures and their funders can only provide cost-effective technical actions when policy expectations

[5] This relates to Aichi Target 19: "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied."

will provide them with guidance upon which they can base the development of appropriate computational architecture. Considerations are the following:

1. Policy bodies are suggested to consider the relevance of the production of EBV data products. This could be (a) for scientific interests, (b) for national interests, or (c) for wider regional, continental or global comparability and analysis.
2. Similarly, policy bodies may consider whether only ad hoc EBV development is sufficient, or alternatively a factory-scale EBV production should be preferred to support the policy needs. The latter would imply a generic level to re-use approaches globally, rather than a restriction to domestic solutions serving local interests.
3. Stakeholders are suggested to discuss and make recommendations on the responsibilities for each of the steps in the range from priority setting, data collection up to EBV production and maintenance. What should be organized bottom-up and what top-down; what are the implications for governance and finance?
4. What would be the role of GEO BON and its (national regional, thematic) BONs, or any other coordinating body? How should this be facilitated?

D. Cooperation of research infrastructures for curating processed (EBV) data products and publishing them in required formats

The research infrastructures contributing to the deliberations in the GLOBIS-B project have expressed their interest to cooperate at the global scale on interoperability to advance scientific progress in understanding and predicting the complexity of natural systems. By working together, the complementary data and capabilities of the cooperating infrastructures are thus better accelerated towards addressing the grand challenges on biodiversity and ecosystems. For example, the development and exploitation of cutting-edge IT technologies can contribute to data processing, supported by “machine-machine” interactions. Research infrastructures willing to cooperate in this regard are recommended to consider together the following:

1. Depending on policy guidance as outlined in the previous discussion items, joint efforts should be considered on developing better infrastructure support for EBV production with common support for running generic EBV computational workflows.
2. Become involved in the development and preservation of data, in access, integration and processing steps as an open-source and freely available service in a workflow-oriented e-infrastructure that supports curation, sharing and collaboration.
3. Promote standardized metadata and mechanisms to make EBV datasets ‘findable, accessible, interoperable and reusable’ (FAIR).

E. Overcoming legal constraints in relation to accessing data and achieving workflow interoperability

Constraints on legal interoperability emerge from restrictions on the use, modification and sharing of data and software. They have severe consequences for building EBV data products as they can impede the use of essential datasets and software tools, limit quality control, impede data aggregation and restrict re-usability. To overcome such constraints, datasets and software tools used for building EBV data products must be openly accessible and legally interoperable. More specifically, considerations for the research infrastructures are the following:

7. Legal interoperability can only be achieved if the legal use conditions are clearly and readily determined for each dataset and software tool, allowing for both creation and use of combined and/or derived products.
7. Users should have the right to legally access and use datasets and software tools without seeking authorization from data right holders on a case-by-case basis.
7. EBV data products should be built from openly accessible data in open platforms, indicating for every dataset the legal use conditions.

7. As far as copyright or EU database protection apply to material used in EBV data products, they need to be expressly waived (by CC0-waiver) or mitigated (by CC-BY license or similar common-use-license).
7. EBVs, as well as underlying datasets, are developed in the public interest for scientific and policy purposes and for the sake of the conservation of biodiversity. They must be considered as belonging to the public domain.

Background information

GEO BON

The Group on Earth Observations Biodiversity Observation Network, or GEO BON, was established in 2008 as the biodiversity arm of GEO (Group on Earth Observations). Its mission is improving the acquisition, coordination, and delivery of biodiversity observations, and related ecosystem services, to both the scientific community, and decision-makers. GEO BON organizes its structure and its activities around two key components: the Essential Biodiversity Variables (EBVs), and the Biodiversity Observation Networks (BONs). GEO BON was approved as one of the four GEO Flagships at the GEO XIII Plenary in November 2016.

Essential Biodiversity Variables

The Essential Biodiversity Variables are a minimum set of measurements covering all dimensions of biodiversity, complementary to one another, that are required to study, report, and manage biodiversity change. The EBVs are produced by integrating primary biodiversity observations (e.g. in situ observations or remote-sensing products) and they constitute the building blocks of indicators of biodiversity change. The Essential Biodiversity Variables are organized in six EBV classes: Genetic Composition, Species Populations, Species Traits, Community Composition, Ecosystem Structure, and Ecosystem Function. Regardless of the class, these EBVs should be (1) able to capture critical scales and dimensions of biodiversity; (2) biological; (3) state variables (in general); (4) sensitive to change; (5) ecosystem agnostic (to the largest degree possible); and (6) technically feasible, economically viable and sustainable in time.

On this front, GEO BON and its partners have been developing a set of Global Indicators of Biodiversity Change that have been endorsed by the CBD to report on progress towards the Aichi Targets, as well as by the IPBES, in support of the Global Assessment. The indicators produced using the EBVs can also be used at the national and sub-national scales, for instance for National Biodiversity Strategies and Action Plans (NBSAPs), Environmental Impact Assessments, land and sea use planning, and biodiversity offsets. The EBVs can be understood as the level of integration between the raw biodiversity observations (derived either from in-situ observations or remote sensing), and the high-level indicators that are needed by stakeholders for reporting and decision-making. Several pilot applications of the EBV framework have either occurred or are being planned at national and regional scales in order to develop and test guidance on how the EBVs can be applied at various scales for improving biodiversity observation systems.

The GLOBIS-B project

GLOBIS-B (GLOBal Infrastructures for Supporting Biodiversity research) is a global cooperation funded by the Horizon 2020 research and innovation framework programme of the European Commission[6]. The main aim of GLOBIS-B is to bring together biodiversity scientists, global research infrastructure operators and legal interoperability experts to identify the research needs and infrastructure services underpinning the concept of EBVs. The project is facilitating the multi-lateral cooperation of biodiversity research

[6] The GLOBIS-B project received funding from the European Union's Horizon 2020 research and innovation

infrastructures worldwide[7] and identifies the required primary data, analysis tools, methodologies and legal and technical bottlenecks to develop an agenda for research and infrastructure development to compute EBVs. This requires development of standards, protocols and workflows that are 'self-documenting' and openly shared to allow the discovery and analysis of data across large spatial extents and different temporal resolutions. The interoperability of existing biodiversity research infrastructures is crucial for integrating the necessary biodiversity data to calculate EBVs, and to advance the ability to assess progress towards the Aichi targets for 2020 of the Convention on Biological Diversity (CBD).

The GLOBIS-B project addressed these challenges by bringing together scientific, technical, and legal experts with infrastructure operators in a couple workshops to study possible approaches for EBVs on species distributions and abundances, on traits, and on species interactions. The majority of currently available data derives from incidentally reported observations or from surveys with standardized protocols. Enormous complexity exists in integrating these heterogeneous, multi-source data sets across space, time, taxa and different sampling methods. Integration of such data into global EBV data products requires correcting biases introduced by imperfect detection and varying sampling effort, dealing with different spatial resolution and extents, harmonizing measurement units from different data sources or sampling methods, applying statistical tools and models for spatial inter- or extrapolation, and quantifying sources of uncertainty and errors in data and models. The GLOBIS-B workshops resulted in the identification of generic workflow steps with multiple sequential activities, for example the identification and aggregation of various raw data sources, data quality control, taxonomic name matching and statistical modeling of integrated data.

Figure 1 summarizes key workflow steps for (species distribution) EBVs as part of the information supply chain, conceptually positioned between at the left side raw data and at the right side outcomes as indicators for reporting biodiversity change to policy and management. Three successive groups of workflow steps deal with (a) gathering EBV-usable data sets, (b) the production of harmonized EBV-ready data sets, and (c) the interpolation or extrapolation of these latter data sets with further analysis tools to result in derived and modelled data products. An example of a simple data product is shown for an EBV with the dimensions of taxonomy (e.g. species), time and space.

[7] Atlas of Living Australia
Biodiversity Committee of the Chinese Academy of Sciences
Brazilian Reference Centre on Environmental Information
DataONE Data Observation Network for Earth
Global Biodiversity Information Facility
GEO Biodiversity Observation Network
Germplasm Bank of Wild Species at Kunming Institute of Botany
LifeWatch European Infrastructure for Biodiversity and Ecosystem Research
USA National Ecological Observatory Network
South African National Biodiversity Institute.

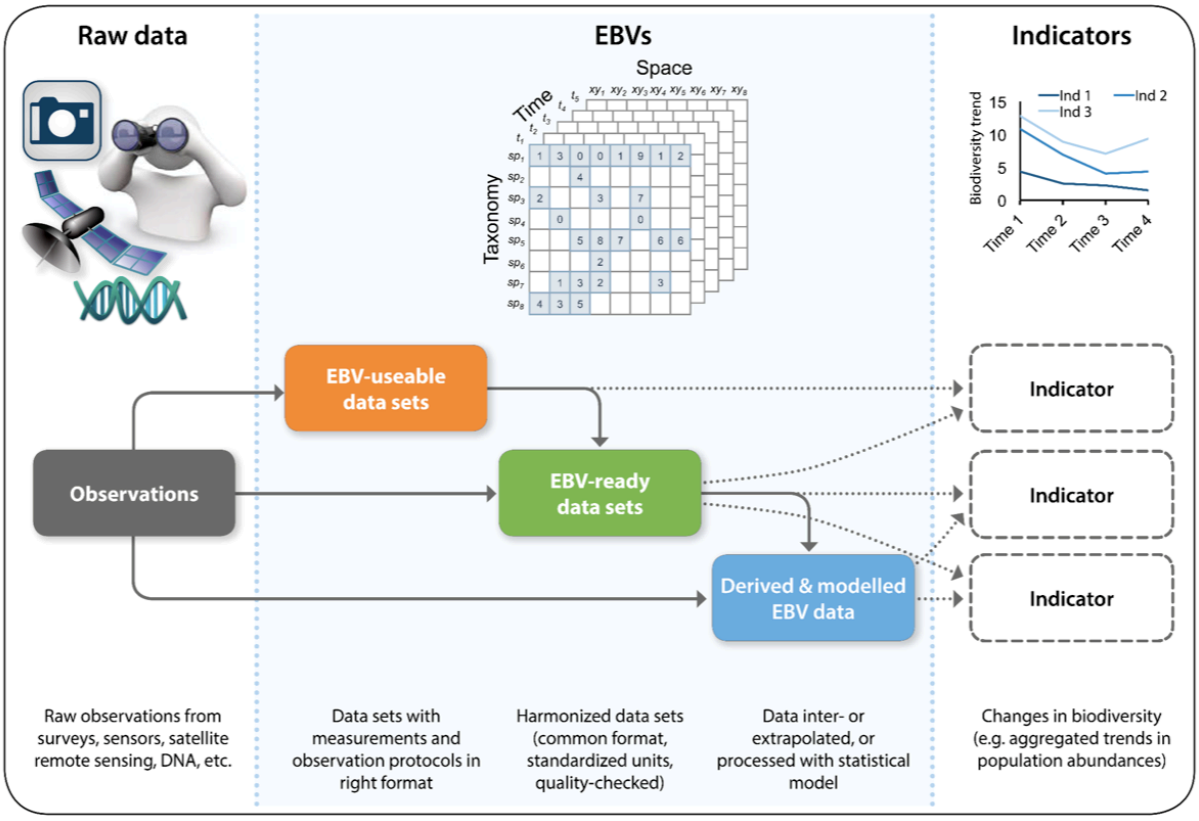

Figure 2 Essential Biodiversity Variables as positioned between raw data and indicators.

Apart from scientific and technical challenges to implement and run such workflows as standardized method for producing EBVs for biodiversity indicators, also constraints related to legal interoperability must be solved. Such constraints emerge from restrictions on data use, modification and sharing, as well similarly for applied software. One of the most efficient approaches that help to assure legal interoperability are common-use licenses such as Creative Commons (CC) licenses. The ideal data sets for building EBV products are those in the public domain, with no restrictions on re-use and attribution (i.e. no need to specify source and license).

The identification of key workflow steps is highly relevant for building global EBV data products. This helps to establish analytical protocols that are robust, transparent and reusable, thereby improving reproducibility of ecological research. Existing projects, research infrastructures and citizen science efforts already operationalize many specific and generic workflow steps. Building reliable and representative global EBV data products requires filling of data gaps in geographic, temporal and taxonomic coverage. This necessitates a renewed effort in data mobilization and expanding existing biodiversity-monitoring initiatives worldwide, including citizen science projects. Producing EBVs in such way requires global cooperation based on common principles of best practices. To this end an international GLOBIS-B workshop in Bari drafted the following manifesto (February 2018).

The Bari Manifesto for Essential Biodiversity Variables (EBV) data products (summary)

(Prepared by a collective representation of the global biodiversity informatics research and data infrastructures community as an outcome of the GLOBIS-B project).

Exploiting primary data to produce and manage Essential Biodiversity Variables (EBV) data products depends on cooperation, practicality and interoperability among multiple stakeholders, including those collecting and mobilizing data with EBV potential (EBV-usable data), those making data ‘EBV-ready’ and

those producing, publishing and preserving EBV data products. Ten principles offer best current practice guidance to data and infrastructure organizations to enhance their ability to contribute towards production of global EBV data products, whilst retaining autonomy and flexibility to achieve what is needed in ways appropriate to the organizations' own business. These principles are presented in the following "Bari Manifesto" as developed in an earlier GLOBIS-B workshop in Bari, Italy.

1. *Data Management Plan*

   Projects developing EBV data products should have comprehensive data management plans.

2. *Data Structure*

   EBV data products should adhere to agreed-upon minimum dimensions for each product (i.e., time, space, name/taxonomy (where applicable), etc.). All EBVs should be accommodated in a common framework that conforms (as far as is practically possible) with content and schema standards for representation formats and exchange protocols.

3. *Metadata*

   EBV data products and the EBV-ready datasets from which they are generated should have associated human- and machine-readable metadata, compliant with accepted community standards and sufficient for purposes of data discovery, access, fitness-for purpose evaluation, citation, interpretation and use.

4. *Services*

   EBV data products, EBV-ready datasets, digital objects and other related services should expose their capabilities and be accessible through common, standardized Application Programming Interfaces (APIs).

5. *Data Quality (Fitness-for-use)*

   Each EBV data product and EBV-ready dataset should include data quality documentation, sufficient to identify fitness-for-use of the data for specific purposes.

6. *Workflows*

   It should be possible to execute published, standard workflows for preparing, publishing and preserving EBV data products and the EBV-ready datasets from which they are produced. Ideally, such workflows should be defined and represented in a non-proprietary manner.

7. *Provenance*

   It should be possible to trace the EBV production process from the product back to the primary data and to reproduce the process. Provenance information must be readable both by humans and by machines.

8. *Ontologies / Vocabularies*

   EBV data products and EBV-ready datasets should be described by standard, openly accessible and machine-readable key vocabulary terms and conceptual relations (ontologies) presented in a simple way to enable wide usage.

9. *Data Preservation*

   EBV data products and associated underlying data should be preserved with an associated persistent identifier in a community supported and trusted repository.

10. *Accessibility*

EBV data products and EBV-ready datasets must be sensitive, timely and FAIR (Findable, Accessible, Interoperable and Reusable).