SCALABLE DATA, OBSERVATION SYSTEMS AND INDICATORS TO SUPPORT EFFECTIVE MONITORING OF GOALS AND TARGETS FOR THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK: GEO BON SUPPORT FOR IMPLEMENTATION

I. INTRODUCTION

This document profiles how the activities of the Group on Earth Observations Biodiversity Observation Network (GEO BON) can serve to support effective implementation of the post-2020 Global Biodiversity Framework (GBF), namely regarding scalable tracking of progress towards goals, targets and monitoring elements in the draft Monitoring Framework -- CBD/SBSTTA/24/3 (18 November 2020 version) and CBD/SBSTTA/24/3Add.1 (25 November 2020 version). This information document draws from and reflects recent submissions from the GEO BON network in response to reviews of the initial post-2020 GBF discussion documents and draft Monitoring Framework. Given the long-standing engagement of GEO BON in supporting the Parties of the CBD, this document also builds on relevant GEO BON inputs to previous SBSTTA and SBI meetings (i.e., CBD/SBSTTA/21/INF/17, CBD/SBSTTA/21/INF/1, CBD/SBI/1/INF/49, CBD/SBI/1/INF/16, CBD/SBSTTA/19/INF/8 and CBD/SBSTTA/17/INF/7).

Specifically, this document provides an overview of how:

- GEO BON can support implementation of **national biodiversity observation systems** to underpin effective and sustained goal and target tracking for CBD and other national and international planning and reporting requirements.
- Effective biodiversity goal and target tracking is under-pinned by **systematically monitored biodiversity data** that augments environmental data for the purpose of monitoring changes in the status and trends of groups of species, ecosystem functions, and ecosystem services characteristic to any area; and,
- The use of **essential variables on biodiversity, ecosystems, and ecosystem services** provides an efficient, consistent, and integrated means for tracking the proposed targets from national to global scales. The Essential Biodiversity Variables (EBVs) and Essential Ecosystem Services Variables (EESVs) are an integral complement to the UN Essential Ocean Variables (EOVs) and Essential Climate Variables (ECVs), and indicators will be based on complements of these.

II. STANDARDIZED ESSENTIAL VARIABLES (EBVs, EESVs) DRIVEN APPROACH TO EFFECTIVE GOAL AND TARGET TRACKING SUPPORTED BY BIODIVERSITY OBSERVATION NETWORKS (BONs)

The Challenge: There is currently great heterogeneity in the development and the use of indicators by Parties to the United Nations (UN) Convention on Biological Diversity (CBD), with most indicators derived from nationally sourced data and methodologies and therefore often lacking global applicability[1] [2]. This variety of indicators and evidence underpinning them strongly limits potential synergies between national and global target tracking and constrains the ability to quantify and compare national progress towards meeting global goals as well as inform the cumulative contribution of national commitments. Further, many of the Aichi Biodiversity Targets were not well measured by indicators at national or global scales[3], lacking spatially explicit information, such as maps, that are critical for strategic planning and implementation. The

[1] Han, X., Gill, M., Hamilton, H., Vergara, S., and Young, B. (2019). Progress on National Biodiversity Indicator Reporting and Prospects for Filling Indicator Gaps in Southeast Asia. Environmental and Sustainability Indicators. In Press.

[2] Bhatt. R., Gill, M., Hamilton, H., Han, X., Linden, H., and Young, B. (2019). Uneven Use of Biodiversity Indicators in Fifth National Reports to the Convention on Biological Diversity. Environmental Conservation, 1-7. Doi: 10.1017/S0376892919000365

[3] CBD Secretariat. USE OF INDICATORS FOR TRACKING PROGRESS. Post 2020 Thematic Consultation on Transparent Implementation, Monitoring, Reporting and Review. 20-22 February 2020, Rome.

timing is right for a new phase of monitoring approaches due to technology improvements like satellites, affordable genome sequencing, citizen science, autonomous vehicles, and others. To ensure that the new post-2020 Global Biodiversity Framework is adequately supported, reviewed and monitored, innovative approaches are needed that facilitate the powerful synergies possible between national and global planning, monitoring and review and between the various action and state-based targets[4].

Meeting the Challenge: GEO BON operates as a global community of practice seeking to ensure best practices, interoperability and convergence of methods to address essential biodiversity and ecosystem services in an operational manner. It aims to improve the acquisition, coordination and delivery of enhanced biodiversity information for timely and effective conservation policy-making. Essential Biodiversity Variables (EBVs) and Essential Ecosystem Services Variables (EESVs), when used in combination with environmental and biological observations (e.g., EOV, ECV), provide a standard yet flexible framework that allows for the production of scalable indicators that can facilitate a more coherent means to support the implementation of the biodiversity monitoring framework from national to global scales[5]. GEO BON guides the design and implementation of national, regional and thematic Biodiversity Observation Networks (BONs) worldwide. Integrating EBVs and EESVs within well-designed BONs can directly underpin national implementation of the post-2020 Global Biodiversity Framework, and transform the capacity to detect, understand and predict biodiversity status and trends. The scalable nature of EBVs and EESVs and their derived indicators lend themselves well to the flexible implementation of a set of Headline, Component and Complementary Indicators that Parties can adopt and apply for national reporting and target tracking. Such an approach allows for the utilization of nationally held and/or globally disaggregated data and can facilitate more reliable aggregation to determine the contributions of national implementation to global targets. The open standards and methodology employed also reduce barriers to national implementation.

[4] CBD Secretariat. NATIONAL REPORTING. Post 2020 Thematic Consultation on Transparent Implementation, Monitoring, Reporting and Review. 20-22 February 2020, Rome.
[5] Pereira, H. M. et al. (2013). Essential Biodiversity Variables. Science 339, 277–278.

A. Institutional connectivity of GEO BON in biodiversity governance and data providers

1. GEO BON connects biodiversity observation networks, monitoring organizations, and research institutes, including field and Earth observation (EO) scientists, to local, national, regional, and intergovernmental policy and assessment processes, such as CBD, Multilateral Environment Agreements (MEAs) and Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). This is accomplished through a *user-driven design process for biodiversity observation networks*, with many established BONs operational at national, regional, and global scales. These BON's employ the EBV and EESV framework to ensure a *consistent, inter-operable and scalable approach to data and indicator production*.

2. The EBV and EESV frameworks brings datasets into an *open hierarchical methodology* that facilitates calculation of indicators to track progress against biodiversity goals and targets and *support decision-making at multiple scales*, from a range of underlying biodiversity and environmental datasets that follow globally adopted operating practices and standards (Figure 1).

3. The indicators supported by EBVs and EESVs are a part of and can *contribute to existing policy support initiatives and platforms* such as the Biodiversity Indicators Partnership (BIP), UN Biodiversity Lab, NBSAP Forum, and UN System of Environmental Economic Accounting (SEEA). Their fundamental attributes allow them to be *spatially scaled without introducing bias* – which is a key requirement for a more cohesive and comprehensive approach to the monitoring and reporting of national and global targets.

4. EBVs, EESVs and indicators based on them are developed at regional to global scales and are being operationalized as pilots at national scales (e.g., Ghana, Colombia, Uganda, Ecuador, Bolivia, Peru, Bahamas, Costa Rica, etc.). They are a complement to Essential Ocean Variables and Essential Climate Variables and use *flexible workflows that connect and integrate core primary data* to produce multiple decision-support outputs.

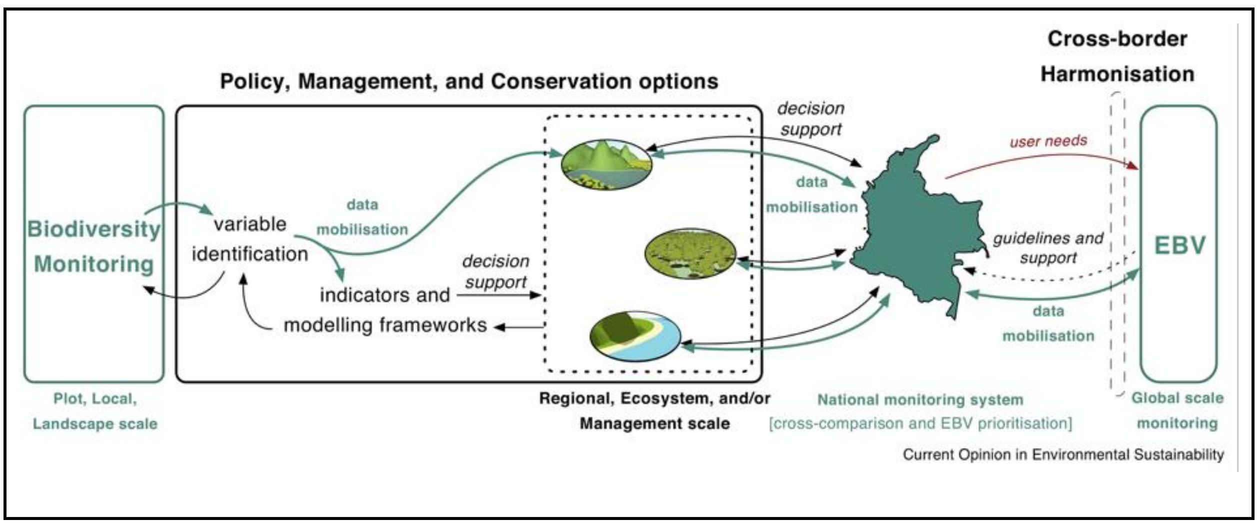

Figure 1. A cross-scale approach to global biodiversity monitoring with EBVs (Source: Navarro et al. 2017[6])

[6] Navarro, L. M. et al. (2017). Monitoring biodiversity change through effective global coordination. Current opinion in environmental sustainability, 29, 158-169.

B. Added-value of EBV and EESV-based indicators for Post-2020 Global Biodiversity Framework

1. *Data and indicators for CBD national and global strategic planning and reporting*

EBVs and EESVs can be part of the backbone for integrating CBD national planning and reporting mechanisms for many global goals and targets that require biological and socio-economic information as well as environmental observations already collected as physical, chemical, and geological Essential Climate Variables and Essential Ocean Variables. EBVs and EESVs can be easily aligned with stated goals and targets in the National Biodiversity Strategies and Action Plans (NBSAPs) to help track them. National Reports (NRs) could report the changing state and trend of different EBVs and EESVs used to set strategies and goals in the NBSAPs**.** National datasets for EBVs and EESVs reporting could be further used in global EBVs, EESVs and derived indicators to harmonize data and standards, improve the rigor of global models, and fill in the data gap through continuous cross-scale and cross-country exchange and validation (Figure 1). *EBV- and EESV-based indicators will facilitate more coherent and comparable national reporting and facilitate the ability for more reliable calculation and measurement of the contribution of national commitments to global targets (Figure 2).*

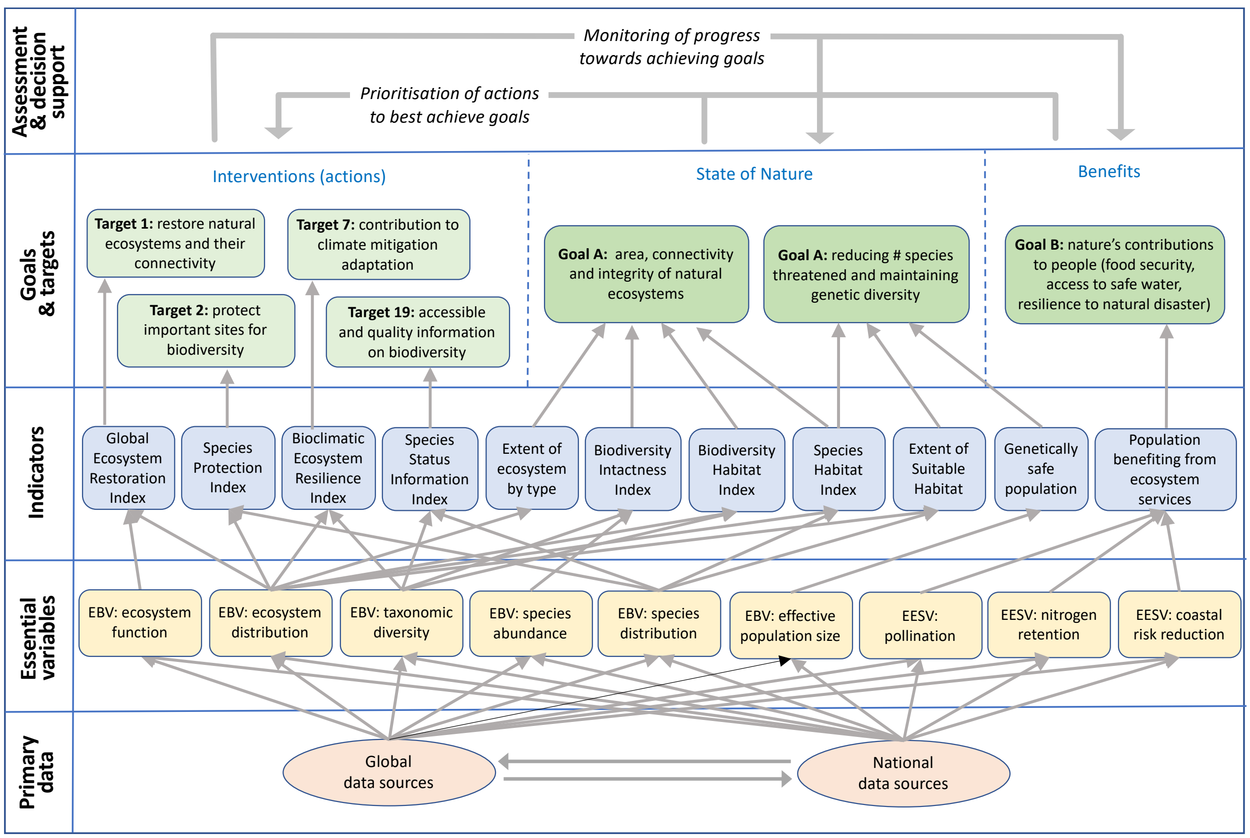

Figure 2. Workflow of example EBV and EESV-based approach to developing indicators from primary data via standardized essential biodiversity variables in supporting the implementation of the CBD Global Biodiversity Framework by prioritizing actions and monitoring progress towards achieving goals and targets (Source: Kim et al. *in prep.*[7]).

[7] Kim, H.J. et al. *In preparation.* Essential Biodiversity Variables and Essential Ecosystem Services Variables for Conservation Post-2020.

2. Spatial comprehensiveness for actionable guidance on prioritization and monitoring

Integrating remotely sensed and field-based data, modelling-based EBVs and EESVs can be spatially complete, which allows for the generation of indicators with global coverage. With a more accurate and comparable accounting of biodiversity and ecosystem changes at any given location, *EBVs and EESVs can support spatially explicit prioritisation of potential actions to best achieve goals, as well as monitoring of actual progress towards achieving goals resulting from implemented actions (Figure 2).*

3. Complementary datasets for monitoring multiple goals and targets

EBVs represent diverse levels and facets of organisms from genes to ecosystems and they can be used to derive indicators that inform multiple goals and targets consistently in a unified framework. The EBVs are a critical complement to monitoring data that focus on physical, chemical, and geological status and trends of the environment, and which are often used as a proxy to infer or forecast biological changes. The EESVs, being developed as a complementary extension to the EBVs, represent core variables for assessing key changes in ecosystem services -- the benefits nature provides to people. The employment of common underpinning EBV and EESV datasets across multiple indicators also allows assessment of interactions and dependencies between targets and goals beyond merely monitoring their progress. *Deployment of EBVs and EESVs as a structural component to national biodiversity and ecosystem services observation systems and for the generation of indicators greatly simplifies data collation and indicator production, leading to efficiencies in data reporting and analytics (Figure 2).*

4. Scalability of indicators for use from sub-national to global scale

EBVs and EESVs are spatially explicit and, by definition, scalable from sub-national to national to regional and global scales, thereby allowing for consistent target tracking at all scales. In situ (field-based) data at more local scales can also be used to progressively validate and calibrate predictions derived from global-scale modelling (Figure 1).

C. List of CBD-endorsed indicators developed via GEO BON based on the EBV concept[8]. These indicators incorporate data on biodiversity, and should be used in the context of concurrent environmental observations, specifically Essential Climate Variables and Essential Ocean Variables, as appropriate. (Additionally available EBV-based indicators submitted to SBSTTA24 peer review in **Annex 1**).

1. Bioclimatic Ecosystem Resilience Index
2. Biodiversity Habitat Index
3. Biodiversity Intactness Index
4. Protected Area Connectedness Index
5. Protected Area Representativeness Index
6. Species Habitat Index
7. Species Protection Index
8. Species Status Information Index

[8] GEO BON (2015) Global Biodiversity Change Indicators. Version 1.2. Group on Earth Observations Biodiversity Observation Network Secretariat. Leipzig, 20 pages. doi: 10.978.39817938/19

III. PROPOSED GEO BON SUPPORT FOR IMPLEMENTATION OF THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

Effective tracking of global and national targets is dependent on information and indicators that are fit-for-purpose, nationally and globally representative and comparable, and scalable. The measurement of global biodiversity status and trends has largely remained spatially, temporally and taxonomically limited, constraining the effective tracking of target progress and the timely and effective support for conservation decisions. Through connecting and convening scientists and organizations involved in biodiversity observation and prediction worldwide around the shared goal of effective biodiversity information, GEO BON will provide support for the Framework implementation in four major ways:

A. Establishment and support of a global network of biodiversity observation systems

GEO BON is deploying a flexible but systematic approach to increasing the capacity of biodiversity observations[9] through the establishment of user-driven national (i.e., Colombia, China, France, Bahamas, etc.), regional (i.e. Arctic, Tropical-Andes, Asia-Pacific, Americas) and thematic (e.g. marine, freshwater, soil, etc.) BONs. The continued deployment of operational Biodiversity Observation Networks, particularly at national scales, will serve to underpin and sustain effective target tracking through the provision of credible biodiversity data for fit-for-purpose indicators. GEO BON is ready to support Parties to the CBD in establishment of new national BONs through the provision of expert technical and scientific guidance, the sharing of experiences from existing BONs, the structuring of observation network design via a BON Design Manual and the provision of best-use tools and technologies for more efficient and powerful biodiversity monitoring.

B. Production, delivery and guidance around existing CBD-endorsed GEO BON indicators

Several indicators that leverage Essential Biodiversity Variables (EBVs) and Essential Ecosystem Services Variables (EESVs) have been developed under the auspices of GEO BON and are proposed as headline or component indicators are recognized as key information sources by the CBD. In partnership with the indicator-providing partner institutions GEO BON will help support the ongoing access to indicator information and associated workflows and provide guidance around the interpretation and national updating of indicators. GEO BON is ready to provide assistance to all parties for their effective use of GEO BON indicators.

C. Support the advancement of currently not yet fully developed or operational headline indicators

Headline indicators for several goals and targets are currently considered not fully developed or operational. These are possible indicators which could be used to measure the goal or target that require additional research to fully operationalize the indicator. Examples proposed headline indicators include “A.0.5 The proportion of populations maintained within species”[10], “B.0.2 Value of all final ecosystem services (Gross Ecosystem Product)”, “19.0.1 Biodiversity information index”. Other indicators such as “A.0.1 Extent of selected natural ecosystems” may benefit from further refinement regarding the remote sensing- and model-

[9] Pereira, H.M., Navarro, L.M, and Martins, I.S. (2012). Global Biodiversity Change: The Bad, the Good and the Unknown. Annual Review of Environment and Resources 2012 37:1, 25-50

[10] UNEP/CBD/SBSTTA/24/3/INF/XX “Genetic diversity in the post-2020 Global Biodiversity Framework: scientific and technical support for revised genetic diversity goals, targets and indicators for all species (wild and domestic)

based capture of select ecosystems. Through its global expert community GEO BON is committed to aid the further development of these indicators, in support of the proposed CBD technical expert group.

D. Capacity building webinars to guide effective implementation of the post-2020 Global Biodiversity Framework

Analysis of the failure to achieve the Aichi Biodiversity Targets has identified a number of deficiencies. Parties to the CBD have struggled, in many cases, to easily and effectively track and guide progress to national targets due to their limited access to user-friendly indicator methodologies and the reliable data needed for these indicators[11]. The current monitoring framework proposal for the post-2020 Global Biodiversity Framework addresses some of these challenges by providing guidance so that Parties can easily identify appropriate indicators (i.e., Headline, Component and Detailed Indicators) for the different targets. However, further guidance will be needed for the production, delivery and use of biodiversity indicators[12].

Perhaps the most significant failing has been regarding the lack of implementation support and enabling conditions at the national scale, particularly the implementation of data-to-indicator workflows that help monitor the impact of conservation actions in target achievements. The GEO BON network, comprising over 200 organizations and over 1500 experts on the delivery of effective biodiversity observations, will work with the CBD to support Parties with this need[13].

GEO BON, in partnership with the Secretariat of the Convention on Biological Diversity, is offering a series of webinars that focus on technical aspects of implementation of the post-2020 monitoring framework on interrelated themes including:

- Support the interpretation and use of existing GEO BON indicator products;
- Utilize existing indicator methodologies and underlying data for the sustained production of national scale indicators;
- Co-design how to scale indicators for seamless tracking of national to global targets;
- Leverage the outputs of the UN System of Economic and Environmental Accounting's Experimental Ecosystem Accounts for tracking ecosystem-based targets;
- Use indicators in conjunction with simple decision support tools to develop and prioritize actions needed to achieve targets effectively and efficiently; and,
- Design new or enhance existing biodiversity observation systems to ensure continual production of relevant data for detecting, understanding and predicting biodiversity status and trends.

[11] Xu, H., Cao, Y., Yu, D., Cao, M., He, Y., Gill, M., and Pereira, H. (2021). Ensuring effective implementation of the post-2020 global biodiversity targets. Nature Ecology & Evolution. DOI: 10.1038/s41559-020-01375-y
[12] UNEP/CBD/SBSTTA/24/3/INF/16
[13] UNEP/CBD/SBI/3/Add2

Annex 1. EBVs, EESVs and their derived indicators for monitoring elements of the draft goals. EBVs and EESVs can be underlying datasets for deriving a range of indicators to inform the Global Biodiversity Framework. This list includes those EBVs, EESVs and their derived indicators that currently exist or are in active development. The indicators range from relatively simple derivations of EBVs and EESVs to composite indices that combine one or more EBVs and EESVs with a range of ancillary information including the EOVs and ECVs (submitted in response to SBSTTA24 Peer Review).

Components of the draft Goals	**Goal Monitoring Elements**	**Indicator name**	**Responsible Institution for the indicator**	**Time series and frequency of updates**	**Key literature**
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)	Trends in area of forest ecosystems Trends in area of other terrestrial ecosystems Trends in area of mangroves Trends in area of other marine and coastal ecosystems Trends in wetlands	Extents/areas of 59 standardized ecosystem types globally	iDiv Carsten Meyer (casten.meyer @idiv.de)	1992-2018, annually	Remelgado & Meyer (in review) (https://portal.geobon.org/ebv-detail?id=10)
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)	Trends in area of forest ecosystems Trends in area of other terrestrial ecosystems	Biodiversity Habitat Index (BHI)	CSIRO	2005-2015, every 5 years	Hoskins et al 2020 (https://doi.org/10.1016/j.envsoft.2020.104806)
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)	Trends in area of other marine and coastal systems	Kelp canopy extent. Spatial coverage primarily US west coast, gradually expanding, eventually to global	SBC-LTER, KEEP, Zooniverse, & Kyle Cavanaugh (kcavanaugh@geog.ucla.edu)	1984-present	Bell, T. W. et al. 2020 (https://doi.org/10.1016/j.rse.2018.06.039) Cavanaugh et al. 2010 (https://www.kelpecosystems.org/)
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)	Trends in area of other marine and coastal systems	Seascape Ecosystem Distribution	Oregon State University Maria Kavanaugh (maria.kavanaugh@oregonstate.edu)	2002-present	Kavanaugh et al. 2014 (http://dx.doi.org/10.1016/j.pocean.2013.10.013) Kavanaugh et al. 2016 (doi:10.1093/icesjms/fsw086)

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
					Kavanaugh et al. 2018 (https://doi.org/10.3389/fmars.2018.00130)
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)		Live Cover via Vegetation Continuous Fields	NASA	2000-present annually	https://lpdaac.usgs.gov/products/mod44bv006/
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)	Trends in area of forest ecosystem	Forest distribution (presence and absence; fragmentation)	Temple University Victor Gutierrez (tug61163@temple.edu)	2000-2018	R-package to derive EBV on forest distribution using data from Hansen et al 2013 (DOI: 10.1126/science.1244693)
GA1. Increased extent of natural ecosystems (terrestrial, freshwater and marine ecosystems)		Ecosystem live cover	Temple University Victor Gutierrez (tug61163@temple.edu)	2000-2015	R-package to derive EBV on tree cover using data from Sexton et al. (https://doi.org/10.1080/17538947.2013.786146)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trend in the area of degraded terrestrial ecosystems restored Trends in habitat connectivity Trend in the area of degraded wetlands restored Trend in the area of converted agricultural lands restored	GERI - Global Ecosystem Restoration Index	iDiv - German Centre for Integrative Biodiversity Research (nestor.fernandez@idiv.de)	Every 5 years	Torres et al. 2018 (https://doi.org/10.109/rstb.2017.0433) Fernández et al. 2020 (DOI: https://dx.doi.org/10.978.39817938/57)

Components of the draft Goals	**Goal Monitoring Elements**	**Indicator name**	**Responsible Institution for the indicator**	**Time series and frequency of updates**	**Key literature**
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trends in fragmentation and quality of forest ecosystems Trends in fragmentation and quality of dry and sub-humid lands, grasslands and other terrestrial ecosystems Trends in integrity for all ecosystems	Biodiversity Habitat Index (BHI)	CSIRO	2005-2015, every 5 years	Hoskins et al 2020 (https://doi.org/10.1016/j.envsoft.2020.104806)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trends in fragmentation and quality of forest ecosystems Trends in fragmentation and quality of dry and sub-humid lands, grasslands and other terrestrial ecosystems Trends in integrity for all ecosystems	Bioclimatic Ecosystem Resilience Index (BERI)	CSIRO	2005-2015, every 5 years	Ferrier et al 2020 (https://doi.org/10.1016/j.ecolind.2020.106554)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trends in fragmentation and quality of other marine and coastal systems	Phytoplankton functional types and size distribution	Oregon State University Maria Kavanaugh (maria.kavanaugh@oregonstate.edu)		Kostadinov et al 2009 (https://doi.org/10.1029/2009JC005303)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trends in fragmentation and quality of inland waters	Algal Blooms	PBL Jan Janse (Jan.Janse@pbl.nl)	(1900-)1970-2015(-2070)	Beusen et al. 2015 (http://www.geosci-model-dev.net/8/4045/2015/) Janssen et al. 2019 (https://doi.org/10.1016/j.cosust.2018.09.001)

Components of the draft Goals	**Goal Monitoring Elements**	**Indicator name**	**Responsible Institution for the indicator**	**Time series and frequency of updates**	**Key literature**
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)		Productivity Seasonality	Clark University Florencia Sangermano (fsangermano @clarku.edu)	2001-2019 annually	Eastman et al. 2013 (https://doi.org/10.3390/rs5104799) Eastman et al. 2009 (https://doi.org/10.1080/01431160902755338)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)		Net primary production	UBC William Cheung (w.cheung@oceans.ubc.ca)	1981-2100	
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)		Distribution of Ecosystem Functional Types; Ecosystem Functional Diversity [richness, rarity, Shannon Index]	Virginia University Howard Epstein (hee2b@virginia.edu)	2001-2020 (operational)	Alcaraz-Segura et al. 2013 (https://doi.org/10.3390/rs5010127) Paruelo et al. 2001 (https://doi.org/10.1007/s10021-001-0037-9)
GA2. Ecosystem Integrity and connectivity (terrestrial, freshwater and marine ecosystems)	Trends in fragmentation and quality of forest ecosystems Trends in fragmentation and quality of dry and sub-humid lands, grasslands, and other terrestrial ecosystems	Relative Magnitude of Fragmentation (forest) (RMF)	University of Amsterdam W. Daniel Kissling (wdkissling@gmail.com)	1992-2018	Naimi & Kissling 2020 (https://portal.geobon.org/ebv-detail?id=4) Naimi et al. 2019 (https://doi.org/10.1016/j.spasta.2018.10.001)
GA2. Reduce the number of species that are threatened by X%	Trends in the area of suitable habitat for threatened species	Area of habitat by species	Sapienza University Carlo Rondinini (carlo.rondinini@uniroma1.it)	1992-2018	Rondinini et al. 2011 PTRSB (https://doi.org/10.1098/rstb.2011.0113) Brooks et al. 2019 (https://doi.org/10.1016/j.tree.2019.06.009)

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
GA5. Maintain Genetic diversity	Trends in the genetic diversity of wild species	Number of populations within species with effective population size (Ne) above 500 versus those with Ne below 500.	GEO BON Genetic Composition Working Group, IUCN Conservation Genetic Specialist Group, GBIKE shoban@mortonarb.org	annually	Hoban et al 2020 (https://doi.org/10.1016/j.biocon.2020.108654) Laikre et al 2020 (https://doi.org/10.1126/science.abb2748)
GA5. Maintain Genetic diversity	Trends in the genetic diversity of wild species	The proportion of distinct populations maintained within species	GEO BON Genetic Composition Working Group, IUCN Conservation Genetic Specialist Group, GBIKE shoban@mortonarb.org	annually	Hoban et al 2020 (https://doi.org/10.1016/j.biocon.2020.108654) Laikre et al 2020 (https://doi.org/10.1126/science.abb2748)
GA5. Maintain Genetic diversity	Trends in the genetic diversity of wild species	Number of species and populations in which genetic diversity is being monitored using DNA based methods	GEO BON Genetic Composition Working Group, IUCN Conservation Genetic Specialist Group, GBIKE shoban@mortonarb.org	annually	Hoban et al 2020 (https://doi.org/10.1016/j.biocon.2020.108654) Laikre et al 2020 (https://doi.org/10.1126/science.abb2748)
Ax		Terrestrial Mean species abundance	PBL Aafke Schipper (Aafke.Schipper@pbl.nl)	1850 - 2050	Schipper et al. 2020 (https://doi.org/10.1111/gcb.14848)
Ax		Species richness / Changes in local terrestrial	NHM Andy Purvis (Andy.Purvis@nhm.ac.uk)	01.1000-12.2015	Newbold et al. 2015 (https://doi.org/10.1038/nature14324)

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
		diversity (PREDICTS)			Hill et al. 2018 (https://doi.org/10.1101/311787) Kim et al. 2018 (https://doi.org/10.5194/gmd-11-4537-2018)
Ax		Overall organism abundance	NHM Andy Purvis (Andy.Purvis@nhm.ac.uk)	01.1000-12.2015	Newbold et al. 2015 (https://doi.org/10.1038/nature14324) Hill et al. 2018 (doi: https://doi.org/10.1101/311787) Kim et al. 2018 (https://doi.org/10.5194/gmd-11-4537-2018)
Ax		Current global functional diversity of mammals and birds	Sapienza University Carlo Rondinini (carlo.rondinini@uniroma1.it)	current	Rondinini et al. 2011 PTRSB (https://doi.org/10.1098/rstb.2011.0113) Brooks et al. 2019 (https://doi.org/10.1016/j.tree.2019.06.009)
Ax		Current global phylogenetic diversity of mammals and birds	Sapienza University Carlo Rondinini (carlo.rondinini@uniroma1.it)	current	Rondinini et al. 2011 PTRSB (https://doi.org/10.1098/rstb.2011.0113) Brooks et al. 2019 (https://doi.org/10.1016/j.tree.2019.06.009)
Ax		Freshwater mean species abundance	PBL Jan Janse (Jan.Janse@pbl.nl)	(1900-)1970-2015(-2070)	Janse et al. 2015 (https://doi.org/10.1016/j.envsci.2014.12.007)
Ax		Marine Biomass density by size class	Memorial University of Newfoundland	1950-2005	Tittensor et al. 2018 GMD (https://doi.org/10.51

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
			Tyler Eddy (Tyler.Eddy@mi.mun.ca)		94/gmd-11-1421-2018) Lotze et al. 2019 PNAS (https://doi.org/10.1073/pnas.1900194116)
Ax		Marine Species richness	UBC William Cheung (w.cheung@oceans.ubc.ca)	1950 - 2100	
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in pollination and dispersal of seeds and other propagules	Pollination	PBL Rob Alkemade (Rob.Alkemade@pbl.nl)	1970-2050	Stehfest et al. 2014 (https://www.pbl.nl/en/publications/integrated-assessment-of-global-environmental-change-with-IMAGE-3.0)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in regulation of climate	Carbon storage	PBL Rob Alkemade (Rob.Alkemade@pbl.nl)	1970-2050	Stehfest et al. 2014 (https://www.pbl.nl/en/publications/integrated-assessment-of-global-environmental-change-with-IMAGE-3.0)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in regulation of climate	Carbon storage	Stanford University Becky Chaplin-Kramer (bchaplin@stanford.edu)	2000-2018 (tbc)	
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in pollination and dispersal of seeds and other propagules	Pollination	Stanford University Becky Chaplin-Kramer (bchaplin@stanford.edu)	2015 land cover (but can do annually), crop types are year 2000	Chaplin-Kramer et al. 2019 (https://dx.doi.org/10.1126/science.aaw3372)

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in formation, protection and decontamination of soils and sediments	Sediment retention	Stanford University Becky Chaplin-Kramer (bchaplin@stanford.edu)	2015 land cover (but can do annually), population (every 5 years)	
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in regulation of hazards and extreme events	River flood protection	PBL Jan Janse (Jan.Janse@pbl.nl)		Ward et al. 2015 (https://doi.org/10.1038/nclimate2742)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in formation, protection and decontamination of soils and sediments	Nitrogen retention	Stanford University Becky Chaplin-Kramer (bchaplin@stanford.edu)	2015 land cover (but can do annually), population (every 5 years)	Chaplin-Kramer et al. 2019 (https://dx.doi.org/10.1126/science.aaw3372)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in regulation of hazards and extreme events	Coastal risk reduction	Stanford University Becky Chaplin-Kramer (bchaplin@stanford.edu)	2017 (as far back as UNEP-WCMC maps)	Chaplin-Kramer et al. 2019 (https://dx.doi.org/10.1126/science.aaw3372)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in regulation of freshwater quantity, quality, location and timing	Water quality: Nitrogen, Phosphorous	PBL Jan Janse (Jan.Janse@pbl.nl)	1900-2050	Beusen et al. 2015 (http://www.geosci-model-dev.net/8/4045/2015/) Janssen et al 2019 (https://doi.org/10.1016/j.scitotenv.2019.04.443)|

Components of the draft Goals	Goal Monitoring Elements	Indicator name	Responsible Institution for the indicator	Time series and frequency of updates	Key literature
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other		Pest control	PBL Rob Alkemade (Rob.Alkemade@pbl.nl)	1970-2050	Stehfest et al. 2014 (https://www.pbl.nl/en/publications/integrated-assessment-of-global-environmental-change-with-IMAGE-3.0)
GB1. Nature's regulating contributions including climate regulation, disaster prevention and other	Trends in formation, protection and decontamination of soils and sediments	Erosion Control	PBL Rob Alkemade (Rob.Alkemade@pbl.nl)	1970-2050	Stehfest et al. 2014 (https://www.pbl.nl/en/publications/integrated-assessment-of-global-environmental-change-with-IMAGE-3.0)
GB2.Nature's material contributions including food, water and others		Water provision	PBL Jan Janse (Jan.Janse@pbl.nl)	1900-2050	
GB2.Nature's material contributions including food, water and others	Trends in the provision of food and feed from biodiversity	Maximum catch potential	UBC William Cheung (w.cheung@oceans.ubc.ca)	1950-2100	Cheung et al 2016 (https://doi.org/10.1016/j.ecolmodel.2015.12.018)
GB2.Nature's material contributions including food, water and others	Trends in the provision of food and feed from biodiversity	Food production (plant based)	PBL Rob Alkemade (Rob.Alkemade@pbl.nl)	1970-2050	Stehfest et al. 2014 (https://www.pbl.nl/en/publications/integrated-assessment-of-global-environmental-change-with-IMAGE-3.0)