GEO Task US-09-01a: Critical Earth Observations Priorities

Biodiversity Societal Benefit Area

GROUP ON EARTH OBSERVATIONS

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Group on Earth Observations

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Critical Earth Observation Priorities for Biodiversity SBA

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Group on Earth Observations

GEO Task US-09-01a:
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Summary

This report is part of GEO Task US-09-01a, with the objective of identifying critical Earth observation priorities for nine Societal Benefit Areas (SBAs). This document discusses the Biodiversity SBA, focussing on the environmental realms, i.e., terrestrial, freshwater and marine, as sub-areas. The effort involved 14 expert Advisory Group members recruited by the Analyst, and included members from all continents except Antarctica. The document search effort, including online literature searches, documents used in the previous Biodiversity SBA report and recommendations from Advisory Group members, yielded 234 documents that potentially contained Earth observation priorities for one or more of the sub-areas. Closer perusal revealed that 64 documents contained information relevant to the analysis. Selected documents were searched for keywords related to needs (e.g. need, require, necessary, essential, fundamental, critical, vital) and observations (e.g. observation, monitor, variable, parameter, data, information).

Priority parameters were identified for each of the sub-areas (based on expert opinion/vote) and for biodiversity as a whole (based on expert opinion/vote and relevance to multiple sub-areas). This resulted in the final list of 15 priority parameters for biodiversity categorised as high, medium and low priorities, and listed below:

- **High Priority Parameters**: Ecosystem extent/change
  Habitat extent/change
  Habitat quality/change
  Land cover/change
  Species abundance/change of selected species
  Species distribution/change of selected species

- **Medium Priority Parameters**: Contaminants/Pollutants
  Ecosystem quality/change
  Important biodiversity sites extent/change
  Protected area extent/change
  Species composition of communities or ecosystems

- **Low Priority Parameters**: Biomass
  Land use/change
  Sea temperature (surface and sub-surface)
  Water quality

1. Introduction

This report identifies Earth observation priorities for the Biodiversity SBA, based on an analysis of 64 publicly available documents produced by Group on Earth Observations' Member Countries and Participating Organizations.

1.1. GEO and Societal Benefit Areas

The Group on Earth Observations (GEO)[1] is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS)[2]. GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, in situ, airborne, and space-based instruments.
GEO is focused on enhancing the development and use of Earth observations in nine SBAs:

Agriculture	Biodiversity	Climate
Disasters	Ecosystems	Energy
Human Health	Water	Weather

1.2. Task US-09-01a

The objective of GEO Task US-09-01a is to establish and conduct a process to identify critical Earth observation priorities within each SBA and those common to the nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these existing materials and analyzing across the materials to determine the priority observations.

This task considers ground, in situ, airborne, and space-based observations. The task includes both observed and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions and significant representation from developing countries.

GEO will use the Earth observation priorities resulting from this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

1.3. Purpose of Report

The primary purpose of this report is to identify the critical Earth observation priorities for the Biodiversity SBA. The intent of the report is to describe the overall process and specific

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[1] GEO Website: *http:// www.earthobservations.org*
[2] GEO 10-Year Implementation Plan: *http://www.earthobservations.org/documents.shtml*

methodologies used to identify documents, analyze them, and determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results of this report in combination with reports from the other eight SBAs. The GEO UIC has already performed a meta-analysis across eight out of the nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. The GEO UIC will update those critical Earth observation priorities common to many of the SBAs using the results of this Biodiversity SBA report. Subsequently, the GEO UIC will produce a revised/final overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

The report's authors anticipate that the GEO Secretariat, Committees, Member Countries, Participating Organizations, Observers, Communities of Practice, and the communities associated with the Biodiversity SBA are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Biodiversity SBA, focussing on the sub-areas of Terrestrial, Freshwater and Marine Realms.

The report provides some background and contextual information about the Biodiversity SBA. However, it is not intended as a handbook or primer on the Biodiversity SBA, and a complete description of the Biodiversity SBA is beyond the scope of this document. Please consult the GEO website (referenced above) for more information about the Biodiversity SBA.

The report focuses on the Earth observations within the Biodiversity SBA, independent of any specific technology or collection method. Thus, the report addresses the "demand" side of observation needs and priorities. The report does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

The term "Earth observation" is used here to refer to parameters and variables (e.g., physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term "Earth observation priorities" refers to the parameters deemed of higher significance than others for the given SBA, as determined through the methodologies described within. The report uses the terms "user needs" and "user requirements" interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the cited documents. The term "requirements" is used generally in the

report to reflect users' wants and needs; the use in this report does not imply technical, engineering specifications.

Following this introduction, the report discusses the overall approach and methodologies used in this analysis (Section 2). Section 3 describes the Biodiversity SBA and the specific sub-areas that were part of the analysis. Section 4 articulates the specific Earth observations for each Biodiversity sub-area, and Section 5 presents the priority observations across the Biodiversity SBA. Sections 6 and 7 present additional findings from the analysis of the documents and any recommendations. The appendices include the documents cited and consulted as well as a list of acronyms used throughout the document.

2. Methodology and Process

2.1. Task Process

The basic methodology for identifying critical Earth observation priorities within an SBA relies on an Analyst working in coordination with an Advisory Group to select the scope of the analysis, identify and analyze relevant documents, and finally extract and prioritize relevant Earth observation parameters. The GEO UIC established a general process for each of the SBA Analysts to follow in order to ensure some consistency across the SBAs. This general process for each SBA involves 9 steps, as summarized in the following list:

Step 1: UIC Members identify Advisory Groups and Analysts for each SBA
Step 2: Determine scope of topics for the current priority-setting activity
Step 3: Identify existing documents regarding observation priorities for the SBA
Step 4: Develop analytic methods and priority-setting criteria
Step 5: Review and analyze documents for priority Earth observations needs
Step 6: Combine the information and develop a preliminary report on the priorities
Step 7: Gather feedback on the preliminary report
Step 8: Perform any additional analysis
Step 9: Complete the report on Earth observations for the SBA.

A detailed description of the general US-09-01a process is available at the Task website *http://sbageotask.larc.nasa.gov* or the GEO website. For the Biodiversity SBA analysis, many of these steps were conducted simultaneously. The Analyst identified existing documents (Step 3) concurrently with development of the analytic methods and priority-setting criteria (Step 4), in coordination with the Advisory Group. This allowed the methods to be tailored to the types of documents that were being identified. Also, as input was received from the Advisory Group, the Analyst continued to conduct Step 3 (document identification and analysis) iteratively throughout the process, as Advisory Group members continued to identify relevant documents.

2.2. *Analyst and Advisory Group*

The Biodiversity SBA had an "Analyst" and an "Advisory Group" involved in the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main coordinator to manage the activities.

2.2.1. Analyst

For the Biodiversity SBA, the Analyst was Michele Walters. She holds a masters degree in ecology and is currently employed by the Council for Scientific and Industrial Research (CSIR) in South Africa where she is serving as the Executive Officer for the Group on Earth Observations Biodiversity Observation Network (GEO BON). She is a research associate at the University of Pretoria's Centre for Wildlife Management. She was previously employed by the South African National Biodiversity Institute (SANBI) and lectured at Walter Sisulu University where she was also curator of the zoological museum.

2.2.2. Advisory Group

The Analyst assembled the Advisory Group, which consisted of 14 scientific and technical experts, recognized as credible and respected in the field of Biodiversity. The Advisory Group members are from both developed and developing countries, and encompass all regions of the world, representing GEO Countries and Participating Organizations, as listed in Table 1. The 14 members of the Advisory Group included participants from 11 countries across six continents

Table 1: GEO Task US-09-01a: Advisory Group for Biodiversity SBA

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
Vishwas CHAVAN	Denmark	Global Biodiversity Information Facility (GBIF)	Europe	Bioinformatics, zoology
Daniel FAITH	Australia	Australian Museum	Australia/Oceania	Genetics, Taxonomy
Simon FERRIER	Australia	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australia/Oceania	Biodiversity modelling, conservation assessment
Gary GELLER	USA	National Aeronautics and Space Administration (NASA)	North America	Ecology, Remote Sensing
Mike GILL	Canada	Environment Canada and Circumpolar Biodiversity Monitoring Program (CBMP)	North America	Arctic Ecology, Biodiversity monitoring
Ian HARRISON	USA	Conservation International (CI)	North America	Freshwater Ecology and Conservation
Bill MAGNUSSON	Brazil	Instituto Nacional de Pesquisas da Amazônia (INPA)	South America	Ecology, Biodiversity monitoring

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
Xavier LE ROUX	France	Fondation pour la Recherche sur la Biodiversité (FRB)	Europe	Ecology
Harini NAGENDRA	India	Ashoka Trust for Research in Ecology and the Environment (ATREE)	Asia	Forest Ecology, Remote Sensing
Bradley REED	Switzerland	Group on Earth Observations (GEO) and United States Geological Survey (USGS)	Europe	GEO Secretariat Biodiversity expert
Robert SCHOLES	South Africa	Council for Scientific and Industrial Research (CSIR)	Africa	Systems Ecology, Remote Sensing
Eva SPEHN	Switzerland	Global Mountain Biodiversity Assessment (GMBA) - DIVERSITAS, University of Basel	Europe	Ecology, Mountain Biodiversity
Sheila VERGARA	Philippines	Asean Centre for Biodiversity (ACB)	SE Asia	Marine & Environmental Science
Martin WEGMANN	Germany	Committee on Earth Observation Satellites (CEOS), DLR-DFD	Europe	Remote Sensing

The Analyst developed the pool of candidates for the Advisory Group based on volunteers from the GEO Biodiversity Community of Practice (COP; i.e. GEO BON) as well as specific suggestions from COP members. The Analyst invited each potential candidate to participate and provided each with information on the expectations for Advisory Group members. The role of the Advisory Group was to help identify relevant documents, comment on the analytic methods and priority-setting criteria utilized, and review the Analyst's findings, priorities, and reports. Communication was conducted primarily through emails and electronic document exchange.

2.3. Methodology

2.3.1. Documents

The task required the identification of publicly available documents expressing Earth observation needs for biodiversity. To do this, the Analyst relied on a two-fold methodology: 1) web-based literature searches, and 2) suggestions from Advisory Group members. The Analyst identified documents as follows:

- Requested the Advisory Group to provide or recommend relevant documents
- Conducted web-based literature searches using Google Scholar and relevant peer-reviewed journal websites (to identify journal articles), as well as Google and Organisational Websites (to identify other types of documents). Combinations of search

terms relevant to the task were used (e.g. “biodiversity”, “terrestrial” and “observation”, “monitoring”) to perform the searches.

- Included documents listed in the previous Biodiversity SBA report (limited to those published between the years 2000 – 2009) for this task. *The following methods were used to identify these documents (taken from http://sbageotask.larc.nasa.gov/Biodiversity_US0901a-FINAL.pdf):*
  - Used full text search in peer reviewed journals using several search engines (Google, SpringerLink, ScienceDirect, Wiley InterScience).
  - Used keyword search in WorldCat a worldwide library catalog of books, theses, manuscripts collections, journal articles, etc.
  - Searched for relevant publications generated by all GEO Participating Organizations (http://www.earthobservations.org/ag_partorg.shtml) , the environmental agency websites associated with GEO Member Countries (http://www.earthobservations.org/ag_members.shtml), and the websites of GEO Observers (http://www.earthobservations.org/ag_observers.shtml).
  - Searched for relevant documents on environmental (biodiversity focused) NGO websites.
  - Searched the remote sensing and global monitoring initiatives currently underway and referenced on SEDAC’s website (Remote Sensing and Environmental Treaties: Building More Effective Linkages; http://sedac.ciesin.columbia.edu/rs-treaties/initiatives.html).
  - Searched for relevant documents in the U.S. Library of Congress Science Tracer Bullet Series. The prepared bibliography on biodiversity was compiled in 1997 and was considered outdated for the purpose of this report. However, the prepared bibliography on remote sensing (completed 2005) revealed several relevant biodiversity citations.
  - Several documents were provided to the Analyst through personal communication by Advisory Group members and others involved in the management of this GEO task.

The initial set of potentially relevant documents was assessed by the Analyst to determine their relevance to the task. If deemed potentially relevant they were included in the set to review. Each document, in turn, was then included/excluded in the final selection based on whether it explicitly mentioned an observational need. Selected documents were searched for the keywords related to needs (e.g. “need”, “require”, “necessary”, “essential”, “fundamental”, “critical”, “vital”) and observations (e.g. “observation”, “monitor”, “variable”, “parameter”, “data”, “information”). Since very few documents mentioned needs explicitly, the Analyst also included parameters that are currently and frequently used for biodiversity applications as reported by the documents. A final set of 64 documents was used to determine observation priorities for biodiversity.

2.3.2. Meta-Analysis Methods

The Analyst extracted information from the documents that met the criteria for inclusion in the analysis as related to the three biodiversity sub-areas of analysis (terrestrial, freshwater, marine). This involved skimming the documents for mention of observation needs as well as using the

relevant software search functions to find keywords (see 2.3.1). The Analyst then compiled all of the data into a single spreadsheet for further analysis. For each observation, the extracted information included the applicable biodiversity sub-area (terrestrial, freshwater, marine), biodiversity organizational level (genes, species, ecosystems), the PSR (pressure-state-response) Assessment Framework category, the geographic region of interest of the document (Global, Africa, Europe etc.), and the type of document (organisational document, journal article, book).

Where documents used different terminology for parameters that are identical or nearly identical the Analyst grouped these observation parameters into a broader category of observations resulting in the aggregation of certain parameters that are similar in nature. For example, species extent, species distribution and species occurrence were included in a species distribution/change category. For each of the Biodiversity Realms, the Analyst constructed a table of the observation priorities, as well as sub-variables/qualifiers (where they were specifically mentioned), that were identified in at least one of the document references. An example of a sub-variable would be habitat fragmentation, which is essentially a measure of habitat extent. Other examples would be where particular taxa or habitats were explicitly mentioned, for instance Mangroves in terms of Ecosystem Extent. *It is important to note that this would not mean that mangroves are more important (in terms of biodiversity observation parameters) than other coastal habitats, but merely that those others were not expressly named. Examples and sub-variables are by no means exhaustive.*

2.3.3. Prioritization Methods

The majority of the Advisory Group members felt that the following three methods (in no particular order) were suitable for assessing priorities: 1) prioritizing observations in terms of their relevance to measuring progress towards the CBD Aichi Targets, 2) recommendations of the Advisory Group, or 3) a combination of the two. The Analyst chose method 2 (recommendations) and thus requested the Advisory Group to indicate their top 15 parameters for each realm. Since some of the Advisory Group members felt insufficiently qualified to provide votes for certain realms, the Analyst then obtained specialist input by asking additional experts in those domains to provide votes. The voting process resulted in the Analyst being able to identify 17, 16, and 18 priority observations for the Freshwater, Terrestrial and Marine realms respectively.

The Analyst then pooled these parameters to use as the set from which the top 15 priority observations (as required by the task) were to be selected. The selection was again made by choosing the parameters with the most votes. Where the same parameter was selected for more than one sub-area, it was included only once and the number of sub-areas it was relevant to recorded (e.g. see Ecosystem extent/change in Table 10 below). The votes for these variables were recorded as the average across relevant sub-areas. The voting process resulted in a great many ties as most votes were cast for more-or-less the same parameters. This, in turn, resulted in there being no clear cut-off point between the top 15 and the 16th parameters, as well as there being no clear prioritisation within this top 16.

The task required that a list of 15 top Biodiversity observations be created and that this list be categorised into 3 more-or-less equal groups of high, medium and low priorities (bearing in mind

that all of them are considered important). The analyst then considered observations (in the top 16) with the same number of votes (i.e. ties) and prioritised those according to their relevance (as top priorities) for 1, 2 or all sub-areas. For example, if 3 observations all received a vote of 5 but they were top priorities in 1, 2 and 3 sub-areas respectively, the observation prioritised in all sub-areas was given a higher rank than the one prioritised in only 2, which in turn outranked the one selected in a single sub-area.

To separate the remaining tied votes, the Analyst considered whether the parameters were also listed in other sub-areas despite not being selected as top variables in that sub-area. In other words: was the observation listed as relevant to other sub-areas by any of the 64 documents analysed? Again the Analyst considered the number of sub-areas and also the number of votes received. For instance, if two observations, each found only in one sub-area, were also present in the parameter list of other sub-areas, the parameter relevant to more sub-areas was considered to be of higher ranking. If these observations were tied in respect to number of sub-areas, any votes they may have received were considered. The result of these two weighting processes was a clear ranking from 1-12 and a tie for parameters 13-16. Since the task required only 15 top parameters to be selected, the Analyst had to remove one of the parameters from the 'low' category. In attempting to decide which one to remove, the Analyst reverted to prioritisation method 1 (i.e. relevance to the CBD Aichi Targets) to determine relative importance of parameters 13-16. This was done using documents recently published by the Convention on Biological Diversity (2011a,b).

The task further required that the top 15 variables be grouped into High, Medium, and Low priority parameters. The task leaders advised that the number of parameters in each category (High, Medium and Low) should be *roughly* equal. Without the restriction of equal categories, the Analyst included parameter 6 (habitat extent/change) in the high category and parameter 11 (species composition) in the medium category, because they were more frequently mentioned in the literature than the other parameters in their respective groups (i.e. parameters 6-10 and 11-15). This resulted in 6, 5 and 4 parameters classed as high, medium and low priorities respectively, rather than 5 in each category.

3. BIODIVERSITY SBA

3.1. Description

The GEOSS 10-Year Implementation Plan notes that the Biodiversity SBA is focused on "three major levels of organization (the genetic level, the species level, and the ecosystem level), within each of which there are three aspects of diversity: composition, structure and function". Section 4.1.9 of the 10-Year Implementation Plan describes the Biodiversity SBA as the following:

> <u>Biodiversity: Understanding, monitoring and conserving biodiversity</u>
> Issues in this area include the condition and extent of ecosystems, distribution and status of species, and genetic diversity in key populations. Implementing GEOSS will unify many disparate biodiversity observing systems and create a platform to integrate biodiversity data with other types of information. Taxonomic and spatial

gaps will be filled, and the pace of information collection and dissemination will be increased.

The scope of the GEO Biodiversity SBA includes observations at the genetic, species and ecosystem levels in the Terrestrial, Freshwater and Marine realms.

3.2. Sub-areas

In considering potential sub-areas for Biodiversity, the Analyst made a number of suggestions and asked for feedback from the Advisory Group. The initial suggestion was for sub-areas representing the three major levels of biodiversity organisation, so as to follow the description of the SBA in the 10-Year Implementation Plan. The Advisory Group, however, largely felt that this was an unsuitable grouping method for this task. A further suggestion was for grouping according to the Pressure-State-Response (PSR) Assessment framework. This was not considered suitable either and the Advisory Group converged on the sub-areas of Biodiversity realms (Terrestrial, Freshwater and Marine) and these were therefore selected to provide a truer reflection of organisation within the Biodiversity COP. Each parameter was, however, also classed according to biodiversity organisation and PSR framework.

Biodiversity can be defined as the variety of species, including variation in their genetic make-up, and variation in the ecosystems in which they occur. The sub-areas are:

Terrestrial Biodiversity: Biodiversity found on land. This excludes water bodies such as rivers and lakes.

Freshwater Biodiversity: Biodiversity found in freshwater systems. These systems may include streams and rivers, lakes, wetland- and geothermal systems and underground aquifers.

Marine Biodiversity: Biodiversity found in the sea. For the purposes of this task, coastal systems were included here, rather than creating a 4th sub-area.

3.3. Documents

The document search effort, including online literature searches, documents used in the previous Biodiversity SBA report and recommendations from Advisory Group members, yielded 234 documents that potentially contained Earth observation priorities for one or more of the sub-areas. The Analyst skimmed through the documents to determine if the information provided specific biodiversity-related Earth observation priorities. If the document proved of relevance to the task, the Analyst reviewed the document and extracted the appropriate data into a database. A total of 137 of these documents were reviewed of which 64 documents (See Appendix B) met the criteria for inclusion in the analysis (approximately 27% of the initial set).

Almost half (31) of the documents were of relevance for biodiversity observations anywhere on Earth (see Table 2). The remaining documents (excluding Polar Regions and Oceania/Australia)

were evenly distributed between the developed (North America and Europe – 13 documents) and developing world (Africa, Asia, South/Central America and the Tropics – 14 documents).

Table 2: Geographic relevance of the 64 documents analysed for the Biodiversity SBA.

Geographic Region	Number of Documents*
Africa	3
Asia	5
Europe	6
Global	31
Middle East	1
North America	7
Oceania/Australia	2
Polar Regions	6
South/Central America	3
Sub-global (Tropics)	2

* Two documents were of relevance to the Asia-Pacific Region and were listed under both 'Asia' and 'Oceania/Australia', so the column adds up to 66 documents.

Of the 64 relevant documents, twenty-three were journal articles, one was a book, and the remainder were documents generated by various organisations (reports/ informational documents etc.).

3.4 User Types

Table 3 lists examples of the broad types of user for whom the biodiversity observation needs identified in this report are of potential relevance (adapted from the previous Biodiversity SBA report).

Table 3: Examples of potential user types for the Biodiversity SBA.

Wildlife Biologists/Managers
Forest Managers
Protected Area Managers
Botanists/Zoologists
Taxonomists
Conservationists
Ecologists
Land Use Planners
Land Use Managers
Land Developers
Environmental Consultants
Natural Resource Extraction (Loggers, Miners, Oilman)
Policy Makers (National, State, and Local Governments; NGOs)

Academics/Researchers
Community Based Monitoring Groups
Concerned Citizens (e.g., bird watchers/groups)
Private Land Owners

Broad consideration was given to these user types when selecting documents to be employed in the analysis. Both scholarly references as well as reports generated by organisations (including organisations involved in technical, policy and management issues) relevant to the Biodiversity SBA were considered.

4. Earth Observations for BIODIVERSITY SBA

This task required the identification of observation priorities for the Biodiversity SBA. Documents relevant to both the developed and developing world were used. However, many of the documents from specific regions could apply to other regions of the world or relate to global needs.

The GEO Task US-09-01a called for the identification of parameters related to Earth observation needs with observation parameters defined as "physical, geophysical, chemical, and biological parameters that describe the Earth's land, oceans, and atmosphere as well as factors related to human dimensions". This included Earth observations in the broader sense, i.e. in situ and remotely sensed, as well as observation parameters that can be directly sensed or measured and also indirectly derived from other observations or obtained from model outputs.

4.1. Earth Observations for Terrestrial Biodiversity

The analyst identified many parameters in the documents pertaining to terrestrial biodiversity. The most commonly mentioned were species distribution, species abundance, distribution of ecosystems and habitats, and changes relating to these. In terms of the PSR assessment framework, most parameters related to the state of biodiversity. When considering the level of biodiversity organisation, ecosystem level observations were more frequently mentioned. The list of parameter needs for Terrestrial Biodiversity is given in Table 4 (presented alphabetically according to 'Biodiversity organisation'). Parameters related to the physical/geophysical environment and human dimensions were classed, under biodiversity organisation, as 'Environmental' and 'Human' respectively.

Table 4: Earth Observation Parameters for Terrestrial Biodiversity. Parameters are listed alphabetically for each of the 'Biodiversity organisation' classes.

Biodiversity organisation	**Parameter/Variable**	**Sub-variable/qualifier**	**Pressure/State/ Response**
Genes	Genetic diversity/change of selected species	Threatened species, Cultivated plants, Domestic/exploited animals, Selected crop wild relatives	State
Genes	Metagenomics	Selected environmental samples	State
Species	Extinction risk	Selected/threatened taxa e.g. utilized species (including species in trade);	State

		species that provide ecosystem services	
Species	Harvest rates/change	Selected/threatened taxa; Targeted and non-targeted species	Pressure
Species	Phenology of selected species	Selected/threatened taxa	State
Species	Species abundance/change of selected species	E.g. Invasive alien species (IAS), pollinators, selected crop wild relatives, threatened species, harvested/commercially valuable species, species in threatened/selected ecosystems etc.	State/Pressure
Species	Species composition of communities or ecosystems	Selected/threatened ecosystems e.g. forests	State
Species	Species distribution/change of selected species	E.g. IAS, pollinators, crop wild relatives, threatened/harvested species, species in threatened ecosystems etc.	State/Pressure
Ecosystems	Biomass	Above-ground	State
Ecosystems	Carbon storage	Forest	State
Ecosystems	Conservation/management success	NA*	Response
Ecosystems	Ecosystem extent/change	Selected critical terrestrial ecosystems, e.g. forests, grasslands, desert, Mediterranean ecosystems etc.; within protected areas. Includes connectivity/fragmentation.	State/Pressure
Ecosystems	Ecosystem quality/change	Selected critical terrestrial ecosystems, e.g. forests, grasslands, desert, Mediterranean ecosystems etc. Includes degradation, desertification, and Biodiversity intactness.	State/Pressure
Ecosystems	Forest density	NA	State
Ecosystems	Forest structure	NA	State
Ecosystems	Habitat extent/change	Selected critical terrestrial ecosystems, e.g. forests (Forest cover/change (native and plantation) incl. deforestation/reforestation), grasslands, Mediterranean ecosystems etc.; within protected areas. Includes connectivity/fragmentation.	State
Ecosystems	Habitat quality/change	Selected critical terrestrial ecosystems, e.g. degradation, desertification, biodiversity intactness, overgrazing, fire occurrence and frequency etc.	Pressure
Ecosystems	Important biodiversity sites extent/change	NA	Response
Ecosystems	Land cover/change	NA	State/Pressure
Ecosystems	Land use/change	NA	State/Pressure
Ecosystems	Leaf Area Index (LAI)	NA	State
Ecosystems	Normalized Difference Vegetation Index (NDVI)	NA	State
Ecosystems	Photosynthetically Active Radiation (PAR)	NA	State

Ecosystems	Plant Functional Types	NA	State
Ecosystems	Productivity	NA	State
Ecosystems	Protected area extent/change	NA	Response
Ecosystems	Sustainable production systems extent/change	Forest, agricultural, fishery and aquaculture ecosystems under sustainable management	State
Ecosystems	Vegetation type	NA	State
Environmental	Air temperature	NA	State/Pressure
Environmental	Contaminants/Pollutants	E.g. Nitrogen deposition, nutrient loading etc.	Pressure
Environmental	Precipitation	NA	State/Pressure
Environmental	Sea level	NA	Pressure
Environmental	Snow	Depth/change; duration/change	State
Environmental	Soil chemistry	NA	State
Environmental	Soil moisture	NA	State
Environmental	Soil structure	NA	State
Environmental	Topography	Incl. Altitude and slope	State
Human	Agriculture/ crop production	NA	Pressure
Human	Economic growth	NA	Pressure
Human	Energy generation/consumption	NA	Pressure
Human	Global trade	E.g. Farming practices	Pressure
Human	Human demographics	Population growth; migration; settlement	Pressure
Human	Infrastructure development	NA	Pressure
Human	Mining	NA	Pressure

* NA = Either not applicable or not available in the reviewed literature

4.2. Earth Observations for Freshwater Biodiversity

The Analyst identified comparatively few parameters in the documents pertaining to freshwater biodiversity. Parameters included those describing physical water attributes e.g. water level, quality and extraction, as well as biodiversity measures relating to species distribution and habitat/ecosystem extent. In terms of the PSR assessment framework, most parameters, as with the terrestrial variables, related to the state of biodiversity. When considering the level of biodiversity organisation, most parameters were again related to ecosystem level observations. The list of parameter needs for Freshwater Biodiversity is given in Table 5 (presented alphabetically according to 'Biodiversity organisation').

Table 5: Earth Observation Parameters for Freshwater Biodiversity. Parameters are listed alphabetically for each of the 'Biodiversity organisation' classes.

Biodiversity organisation	**Parameter/Variable**	**Sub-variable/qualifier**	**Pressure/State/ Response**
Genes	Genetic diversity/change of selected species	Threatened species	State
Genes	Genetic structure of selected	Selected fish species	State

	species		
Genes	Metagenomics	Selected environmental samples	State
Species	Population structure	Selected fish species	State
Species	Species abundance/change of selected species	E.g. IAS, utilized fish species	State
Species	Species distribution/change of selected species	E.g. IAS, utilized fish species	State
Ecosystems	Conservation/management success	NA	Response
Ecosystems	Contaminants/Pollutants	E.g. Nitrogen deposition, nutrient loading etc.	Pressure
Ecosystems	Ecosystem extent/change	Selected critical freshwater ecosystems	State
Ecosystems	Ecosystem quality/change	Selected critical freshwater ecosystems	State/Pressure
Ecosystems	Habitat extent/change	Selected critical freshwater ecosystems; inland waters	State
Ecosystems	Habitat quality/change	Selected critical freshwater ecosystems; degradation	State/Pressure
Ecosystems	Important biodiversity sites extent/change	NA	Response
Ecosystems	Protected area extent/change	NA	Response
Ecosystems	Sustainable production systems extent/change	Area of fishery and aquaculture ecosystems under sustainable management	State
Environmental	Sea level	NA	State/Pressure
Environmental	Water level/change	NA	State/Pressure
Environmental	Water quality	NA	State/Pressure
Human	Energy generation/consumption	NA	Pressure
Human	Human demographics	E.g. Settlement	Pressure
Human	Water use/extraction	NA	Pressure
Species	Extinction risk	Selected/threatened taxa e.g. utilized species (including species in trade)	State
Species	Harvest rates/change	Selected/threatened taxa; Targeted and non-targeted species	Pressure

* NA = Either not applicable or not available in the reviewed literature

4.3. Earth Observations for Marine Biodiversity

Many parameters pertaining to marine biodiversity were identified from the various documents. Parameters included those describing the physical environment, e.g. sea ice temperature and ocean salinity, as well as biodiversity measures relating to genetic diversity, species distribution and habitat/ecosystem extent. In terms of the PSR assessment framework, most observations were state observations. When considering the level of biodiversity organisation most parameters, unlike the terrestrial and freshwater variables, were environmental. The list of parameter needs for Marine Biodiversity is given in Table 6 (presented alphabetically according to ‘Biodiversity organisation’). It is important to note that while variables such as Ecosystem/Habitat extent and Ecosystem/Habitat quality are important parameters for the

Marine realm, they will be difficult to measure until the need for consistent classification of marine ecosystem/habitat types has been met.

Table 6: Earth Observation Parameters for Marine Biodiversity. Parameters are listed alphabetically for each of the 'Biodiversity organisation' classes.

Biodiversity organisation	**Parameter/Variable**	**Sub-variable/qualifier**	**Pressure/State/ Response**
Genes	Genetic diversity/change of selected species	E.g. Harmful Algal Bloom (HAB) species, threatened species etc.	State
Genes	Genomics/barcoding of selected species	E.g. Plankton, Microbes, Zooplankton, Selected fish species etc.	State
Genes	Metagenomics	Selected environmental samples	State
Species	Biometric measures of selected species	E.g. Length of harvested fish, zooplankton size etc.	State
Species	Diet	Arctic colonial seabirds	State
Species	Extinction risk	Selected/threatened taxa e.g. utilized species (including species in trade)	State
Species	Harvest rates/change	Selected/threatened taxa; Targeted and non-targeted species, including by-catch/ Illegal, Unreported and Unregulated fishing (IUU)	Pressure
Species	Phenology of selected species	Selected/threatened taxa e.g. Colonial seabirds; Marine mammals; certain fishes	State
Species	Population structure of selected species	E.g. Colonial seabirds, mammals, certain fishes	State
Species	Recruitment of selected species	E.g. Waders/shorebirds, colonial seabirds	State
Species	Species abundance/change of selected species	Benthic fauna and microbes, HAB species, Harvested fish, IAS, Mammals, Phytoplankton, Zooplankton, Microbes, Prey species, Colonial seabirds and waders/shorebirds, Sea-Ice Biota, Selected fish species etc.	State
Species	Species composition	Selected/threatened ecosystems	State
Species	Species distribution/change of selected species	IAS, HAB species, Selected fish species, Mammals, Phytoplankton, Zooplankton, Turtles, Prey species, Colonial seabirds and waders/shorebirds, threatened/harvested species etc. Incl. Population/metapopulation fragmentation and connectivity	State
Species	Survival rates of selected species	E.g. Waders/shorebirds	State
Ecosystems	Biomass	Selected taxa, e.g. Phytoplankton, Zooplankton, Microbes, selected fish species, mangroves, sea-ice biota, benthic fauna and microbes etc.	State
Ecosystems	Biome extent/change	NA	State

Ecosystems	Conservation/management success	NA	Response
Ecosystems	Contaminants/Pollutants	E.g. Nitrogen deposition, oil spills, nutrient loading (e.g. Si, PO4), selected compounds in food chain and environment etc.	Pressure
Ecosystems	Ecosystem extent/change	Selected critical marine ecosystems, e.g. Corals, Mangroves, seagrasses, saltmarshes, kelp, deep sea systems, etc	State
Ecosystems	Ecosystem quality/change	Selected critical marine ecosystems, e.g. Corals (e.g. coral bleaching), Mangroves, seagrasses, saltmarshes, kelp, deep sea systems, etc	State/Pressure
Ecosystems	Habitat extent/change	Habitat of selected/threatened taxa (e.g. marine mammals and birds); Seafloor and substrate; Selected critical marine ecosystems, e.g. Corals, Mangroves, seagrasses, saltmarshes, kelp, deep sea systems, etc. Includes Destruction, Connectivity, Fragmentation	State
Ecosystems	Habitat quality/change	Selected critical marine ecosystems, e.g. Corals, Mangroves, seagrasses, saltmarshes, kelp, deep sea systems, etc. Includes degradation	State/Pressure
Ecosystems	Important biodiversity sites extent/change	NA	Response
Ecosystems	Marine trophic index	NA	State
Ecosystems	Productivity	E.g. Selected marine ecosystems and Primary productivity	State
Ecosystems	Protected area extent/change	NA	Response
Ecosystems	Sustainable production systems extent/change	Area of fishery and aquaculture systems under sustainable management	State
Environmental	Air temperature	NA	State
Environmental	Ocean acidity/carbon	Seasonal	State/Pressure
Environmental	Ocean circulation patterns	NA	State
Environmental	Ocean colour/ fluorescence	NA	State
Environmental	Ocean depth	NA	State
Environmental	Ocean salinity	NA	State
Environmental	Sea ice concentration/change	NA	State/Pressure
Environmental	Sea ice extent/change	NA	State/Pressure
Environmental	Sea ice temperature	NA	State/Pressure
Environmental	Sea ice thickness/change	NA	State/Pressure
Environmental	Sea level	NA	State/Pressure
Environmental	Sea temperature	Surface and sub-surface	State/Pressure
Environmental	Snow depth/change	NA	State/Pressure
Environmental	Wind direction	NA	State
Environmental	Wind speed	NA	State

Human	Energy generation/consumption	NA	Pressure
Human	Harvesting effort/catch per unit effort (CPUE)	By gear type	Pressure
Human	Harvesting methods	Environmentally destructive fishing techniques e.g. bottom trawling	Pressure
Human	Human demographics	Settlement	Pressure
Human	Infrastructure development	Coastal development	Pressure

* NA = Either not applicable or not available in the reviewed literature

5. Priority Observations for Biodiversity

5.1. Priority Observations for Terrestrial Biodiversity

The 16 priority observations for terrestrial biodiversity are given in Table 7 below (listed in alphabetical order for each 'Biodiversity organisation' class). The majority of variables related to ecosystems and indicators of the state of terrestrial biodiversity. Based on the voting, no 'human observations' made it to the priority list.

Table 7: Priority Observation Parameters for Terrestrial Biodiversity.

Biodiversity organisation	**Parameter/Variable**	**Pressure/State/ Response**
Genes	Genetic diversity/change of selected species	State
Species	Extinction risk	State
Species	Species abundance/change of selected species	State/Pressure
Species	Species composition of communities or ecosystems	State
Species	Species distribution/change of selected species	State/Pressure
Ecosystems	Conservation/management success	Response
Ecosystems	Ecosystem extent/change	State/Pressure
Ecosystems	Ecosystem quality/change	State/Pressure
Ecosystems	Habitat extent/change	State
Ecosystems	Habitat quality/change	Pressure
Ecosystems	Land cover/change	State/Pressure
Ecosystems	Land use/change	State/Pressure
Ecosystems	Protected area extent/change	Response
Environmental	Air temperature	State/Pressure
Environmental	Precipitation	Pressure
Environmental	Soil moisture	State

5.2. Priority Observations for Freshwater Biodiversity

The 17 priority observations for freshwater biodiversity are given in Table 8 below (listed in alphabetical order for each 'Biodiversity organisation' class). The majority of variables again

related to ecosystems and indicators of the state of freshwater biodiversity. Based on the outcome of the voting, in this instance two 'human observations' were included in the priority list, but no observations of genetic diversity were included.

Table 8: Priority Observation Parameters for Freshwater Biodiversity.

Biodiversity organisation	Parameter/Variable	Pressure/State/ Response
Species	Extinction risk	State
Species	Harvest rates/change	Pressure
Species	Species abundance/change of selected species	State
Species	Species distribution/change of selected species	State
Ecosystems	Conservation/management success	Response
Ecosystems	Contaminants/Pollutants	Pressure
Ecosystems	Ecosystem extent/change	State
Ecosystems	Ecosystem quality/change	State/Pressure
Ecosystems	Habitat extent/change	State
Ecosystems	Habitat quality/change	State/Pressure
Ecosystems	Important biodiversity sites extent/change	Response
Ecosystems	Protected area extent/change	Response
Ecosystems	Sustainable production systems extent/change	State
Environmental	Water level/change	State/Pressure
Environmental	Water quality	State/Pressure
Human	Human demographics	Pressure
Human	Water use/extraction	Pressure

5.3. Priority Observations for Marine Biodiversity

The 18 priority observations for marine biodiversity are given in Table 9 below (listed in alphabetical order for each 'Biodiversity organisation' class). As with the other sub-areas, the majority of variables related to ecosystems. Observations for the state of marine biodiversity far outnumbered those for pressure or response. Again, based on the voting, no 'human observations' were included in the priority list, but more 'environmental observations' made it to the list of top priorities for this sub-area than for the others.

Table 9: Priority Observation Parameters for Marine Biodiversity.

Biodiversity organisation	Parameter/Variable	Pressure/State/ Response
Genes	Genomics/barcoding of selected species	State
Species	Biometric measures of selected species	State
Species	Harvest rates/change	Pressure
Species	Species abundance/change of selected species	State
Species	Species composition	State
Species	Species distribution/change of selected species	State

Ecosystems	Biomass	State
Ecosystems	Contaminants/Pollutants	Pressure
Ecosystems	Ecosystem extent/change	State
Ecosystems	Habitat extent/change	State
Ecosystems	Habitat quality/change	State/Pressure
Ecosystems	Important biodiversity sites extent/change	Response
Ecosystems	Productivity	State
Ecosystems	Protected area extent/change	Response
Environmental	Ocean acidity/carbon	State/Pressure
Environmental	Ocean circulation patterns	State
Environmental	Sea ice extent/change	State/Pressure
Environmental	Sea temperature (surface and sub-surface)	State/Pressure

5.4. Overall Priority Observations for Biodiversity

The top overall priority observations were selected from the pool of 51 parameters (corresponding to the three tables above) and prioritised using the methods described in section 2.3.3, to create categories of high, medium and low priorities of more-or-less equal size.

The 15 priority observations for biodiversity are given in Table 10 below, listed in the three tiers of priority (and alphabetically within each tier). Ten of the observations were for ecosystems, three for species (distribution, abundance and composition) and two environmental parameters. No genetic or human observations were in the top 15. Only two response variables (Protected areas and Important biodiversity sites) were included but these were expressed, in the literature, as a need for all sub-areas, despite only being identified as a priority in the freshwater domain. The state of biodiversity was represented more (12) in the top 15 than measures of pressure (9). Observations in the high and medium priority categories contained only parameters for measuring ecosystems and species.

Ten of the top 15 parameters were relevant to the Freshwater realm and 12 to each of the Marine and Terrestrial realms. While all of the high priority parameters, with the exception of Land cover/change, were of interest to all realms, only Species abundance/change and Habitat quality/change were considered priorities in all three (based on voting).

Table 10: Overall Priority Observation Parameters for Biodiversity.

Priority	Biodiversity organisation	Parameter/Variable	Realm (identified priorities)	Other realm (not on priority list)	Pressure/ State/ Response
High	Ecosystems	Ecosystem extent/change	Terrestrial/ Marine	Freshwater	State/ Pressure
High	Ecosystems	Habitat extent/change	Marine/ Freshwater	Terrestrial	State
High	Ecosystems	Habitat quality/change	All	NA*	State/ Pressure
High	Ecosystems	Land cover/change	Terrestrial	none	State/

					Pressure
High	Species	Species abundance/ change of selected species	All	NA	State
High	Species	Species distribution/change of selected species	Terrestrial/ Marine	Freshwater	State/ Pressure
Medium	Ecosystems	Contaminants/Pollutants	Marine/ Freshwater	Terrestrial	Pressure
Medium	Ecosystems	Ecosystem quality/change	Terrestrial	Freshwater/ Marine	State/ Pressure
Medium	Ecosystems	Important biodiversity sites extent/change	Freshwater	Marine/ Terrestrial	Response
Medium	Ecosystems	Protected area extent/change	Freshwater	Marine/ Terrestrial	Response
Medium	Species	Species composition of communities or ecosystems	Terrestrial	Marine	State
Low	Ecosystems	Biomass	Marine	Terrestrial	State
Low	Ecosystems	Land use/change	Terrestrial	none	State/ Pressure
Low	Environ-mental	Sea temperature (surface and sub-surface)	Marine	none	State/ Pressure
Low	Environ-mental	Water quality	Freshwater	none	State/ Pressure

* NA = Not applicable

6. Additional Findings

In the course of conducting this analysis, the Analyst identified some common themes and additional findings which are detailed below. This information relates to the Biodiversity SBAand the need for coordinated monitoring efforts, data compatibility issues, data gaps, infrastructure, and funding, amongst others. The Analyst produced a table of 'other needs' which consists of needs not related to specific biodiversity parameters, but still expressed in the reviewed literature. The Analyst also included such needs reported on in the previous Biodiversity SBA report in the table which is attached as Appendix C.

Common themes

The GEO Task US-09-01a Critical Earth Observation Priorities "Summary of Results" provides the priority listing for the other 8 SBAs. It is notable that the list for biodiversity as provided in this report, has low overlap with the 25 highest ranked observations (overlapping for land use and vegetation cover). On the other hand, the other 8 SBAs have high overlap in priority observations. This may highlight the basic fact that "biodiversity" inevitably involves primary biological observations (genes, species, etc), plus key variables for modelling, for inferring loss of intactness, and for inferring conservation actions.

For all three realms (Terrestrial, Freshwater and Marine), most parameters identified from the literature were related to the state of biodiversity rather than to pressures or responses. Through the CBD, world leaders committed in 2002 to significantly reduce the current rate of biodiversity loss (CBD 2003; Butchart et al 2010). This 2010 target is widely acknowledged not to have been met. In fact, indicators showed declines in the state of, and increases in pressures on, biodiversity (Butchart et al 2010), indicating the need for continued information on the state of the world's biological resources, as expressed by the priority variables identified in this task and the suggested indicators for the renewed 2020 targets (CBD 2011a,b).

Identified observation priorities for the state of marine biodiversity in particular, far outnumbered those for pressure or response. This is probably a result of the greater level of uncertainty about the state of marine biodiversity, being reported in the literature (and voted on by the advisory group) as the greatest need. Furthermore, for the Marine domain, most variables were related to the physical environment including parameters related to, for instance, sea level, -temperature and -ice, and ocean acidity and -salinity (see Table 6). This need for information on the state of the physical parameters characterising the marine environment is probably a reflection of marine organisms' vulnerability to changes in their environment, particularly at a global scale, (considering phenomena like ocean acidification and coral bleaching), and the need for these variables in models predicting trends (current and future) in species distributions and abundance.

When looking at the overall top priority parameters across domains, however, and considering the level of biodiversity organisation, ecosystem (e.g. land cover, ecosystem/habitat extent and quality) and species (distribution, abundance and composition) level observations were in the majority, with the high- and medium tier parameters containing only these kinds of variables. These would seem consistent with trends toward integrated measures of biodiversity such as GLOBIO (Alkemade et al. 2009), the Natural Capital Index (NCI; ten Brink and Tekelenburg

2002), the Biodiversity Intactness Index (BII; Scholes and Biggs 2005), the Nature Index (NI; Certain et al. 2010), the Biodiversity Representativeness Indices (Faith et al 2008), and the Biodiversity Change Index (BCI; Normander et al. 2012), and the information needed to develop them.

The lesser attention given to genetics observations may reflect several factors. One is that observation or knowledge gaps at the species/ecosystem level seem to be logically precedent to filling gaps at the level of genes. Another factor may be that protocols and standards determining "good" or "useful" genetics observations are less well-developed.

It is important to note that not all parameters identified are independent of each other, and some variables are needed to derive others. To calculate extinction risk, for example, requires measures of distribution and abundance. And while certain parameters can be directly measured (e.g. temperature) others may be indirect measures derived from models (e.g. trends in species abundance).

For GEOBON an example of this inter-dependency among priority observations is found in the "lens" approach, where species distribution observations combine with key environmental variables to model overall biodiversity, and this combines with remote sensing observations on condition/intactness to provide information about biodiversity change over time.

The importance of indirect measures is reflected in the set of top priorities. Ecosystem extent/change, Habitat extent/change, Habitat quality/change, and Land cover/change all may be used to infer biodiversity losses through modelling.

<u>Additional findings</u>

Several documents noted the need for greater capacity in taxonomy (see Appendix C). Taxonomy underlies many of the priority parameters identified in the various sub-areas and it should be kept in mind that the expertise required in this field for certain areas of biodiversity is insufficient. It is difficult to monitor or protect what we don't know is there. It follows that the high priority given (Table 10) to observations for species distribution and abundance implies high priority also for increased taxonomic information. This accords with the GEOSS 10-Year Implementation Plan description of the Biodiversity SBA as including a goal where "Taxonomic and spatial gaps will be filled, and the pace of information collection and dissemination will be increased." (see section 3.1)

Many of the references reviewed discussed the use of data from satellites, in particular for monitoring changes in net forest cover. One of the advisory group members pointed out that such estimates do not always provide a true reflection of what is happening on the ground. For instance, according to Puyravaud (2010), "estimates usually pool old-growth native forests, secondary re-growth, and exotic plantations, among others". In addition, "more generally, the distinction between native and modified forests is increasingly being blurred. In Peninsular Malaysia, for example, species rich native forests are rapidly being replaced by monocultures of exotic rubberwood trees, yet these still are legally classified as permanent forest reserves. A failure to discern such changes could paint a highly misleading picture of the fate of the world's native forests" (Aziz *et al.* 2010).

Several documents expressed a need for information on habitat degradation which, for the analysis, was included in the parameter habitat quality/change. It was pointed out that "Earth observation methods/platforms need to be developed to identify ecosystem degradation, as conversion is much easier to map but modifications (including degradation) are more cryptic, but often occupy a significant area".

There is a need for information on human activities and how they relate to biodiversity and changes in its status and trends. For example:

- "Problems of valuation have been discussed, including valuating the intrinsic biological characteristics of certain communities and areas. This is needed to bring the study of biodiversity into the realm of socio-economic sciences and is considered important for policy-making, e.g., in spatial planning" (Heip et al. 2009)
- "Quantitative analysis of impacts of different types of human activities (e.g. fuelwood collection, grazing, road construction, agricultural expansion) on hydrologic function, animal movements, and other ecological processes in different climatic settings is needed" (DeFries et al. 2010).
- Need information on "cultural attributes that foster or conflict with conservation goals and how they are changing" (DeFries et al. 2010).

Another need, frequently expressed by members of the Biodiversity Community of Practice, is for consistent satellite observations that can be used to draw comparisons over time. Chambers *et al*. (2007), for instance states: "Despite recent advances in remote sensing of land-cover change, gaps remain in our understanding of forest disturbance in tropical forests and related ecological processes. First, consistent satellite observations are necessary to evaluate the forest response to variable climate conditions." Even though the Landsat-era is over, new sensors, for example RapidEye and the upcoming SENTINELs, will fill the Landsat gap. However, while the consistency of satellite imagery across four or more decades cannot be ensured, it is envisaged for the coming decades.

Other remote sensing needs mentioned in the literature included the need for optical sensors that can detect and assist with diagnoses of changes in ecosystem function (e.g. water and nutrient cycling and species composition (NRC - SSB 2007). However, forthcoming hyper-spectral data sets (EnMAP - launch 2013) might address this issue.

A number of references called for greater *coordination* and *collaboration* in the world of biodiversity monitoring. This included a need for data integration/interoperability (need for "further improvement of the availability and interoperability of biodiversity data and information" (CBD 2008a)), coordinated monitoring systems (need for "an integrated global biodiversity observation network by complementing, expanding, and linking national and regional monitoring systems to provide effective information on ecosystems, species, and genes, and the services they collectively provide" (CBD 2008b)) and standard protocols (need to "develop and assess appropriate, scientifically sound and rigorous monitoring methodologies of biodiversity based on standardized protocols and sampling strategies..." (EPBRS 2002)).

7. Analyst Comments and Recommendations

The process

The Analyst found the nine-step process straight-forward and simple to follow, but, while understanding the need for comparative methodology between SBAs, somewhat prescriptive. It would have been preferable to set the scope for the task (consulting with the COP as appropriate) before selecting the Advisory Group. This could have resulted in a better balance of expertise and possibly greater participation from the Advisory Group.

Furthermore, the process might not have been the best way to achieve the goals of the task. In particular, by being so prescriptive, the pathways to improving the list of priority variables were constrained and some important pathways excluded—specifically, expert opinion, which for various reasons may not be in the literature, or missed in literature searches. Also, the concept that all SBAs should follow the same standard procedure seems flawed—the quality of the final product for each SBA should be more important than the method used to generate it. Therefore the current process might not have led to the highest quality priority list (particularly since it only employs a subset of the possible informational sources).

Additionally, the process seems vulnerable to the way the SBAs are defined. For example, a "larger" SBA and a "smaller" SBA both are required to identify the same number of priority parameters and (if understood correctly) are given equal weight in the final, cross-SBA evaluation.

It would also have been useful if there was a mechanism/step for revising group membership or adding new members to the Advisory Group as needed during the process. Many members of the group, while expressing an interest to be part of the process were unable to contribute.

The task

Very few documents mentioned *needs* explicitly, and as a result the Analyst included parameters that are currently and frequently used for biodiversity applications as reported by the documents. This, however, represented a potentially never-ending exercise since almost every single variable or parameter of interest to the Biodiversity community of practice falls within the broad scope of the Task (i.e. earth observations in the broader sense, including in situ and remotely sensed, as well as observation parameters that can be directly sensed or measured and also indirectly derived from other observations or obtained from model outputs), and the relevant literature is virtually endless. The Analyst had to be somewhat pragmatic about what to include and when to stop looking for and reading documents. Several references were received from Advisory Group members quite late in the process and the analyst, regrettably, could not include them in the analysis due to time constraints.

Having included documents that do not explicitly mention *needs* the resulting parameter sets might not give a fair reflection of the true needs (and gaps) of the Biodiversity COP. As mentioned above, it would have been useful to have a way of including expert opinion in the process.

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Appendix A: Acronyms

ACB: Asean Centre for Biodiversity
AHTEG: Ad-hoc Technical Expert Group
ATREE: Ashoka Trust for Research in Ecology and the Environment
CBD: Convention on Biological Diversity
CBMP: Circumpolar Biodiversity Monitoring Program
CEOS: Committee on Earth Observation Satellites
CI: Conservation International
COP: Community of Practice
CPUE: Catch Per Unit Effort
CSIR: Council for Scientific and Industrial Research
CSIRO: Commonwealth Scientific and Industrial Research Organisation
DLR-DFD: German Aerospace Center - Remote Sensing Data Center
FRB: Fondation pour la Recherche sur la Biodiversité
GBIF: Global Biodiversity Information Facility
GEO BON: Group on Earth Observations Biodiversity Observation Network
GEO: Group on Earth Observations
GEOSS: Global Earth Observation System of Systems
GMBA: Global Mountain Biodiversity Assessment
HAB: Harmful Algal Blooms
IAS: Invasive Alien Species
INPA: Instituto Nacional de Pesquisas da Amazônia
IUU: Illegal, Unreported and Unregulated fishing
LAI: Leaf Area Index
NASA: National Aeronautics and Space Administration
NDVI: Normalized Difference Vegetation Index
NGO: Non-governmental Organisation
PAR: Photosynthetically Active Radiation
PCB: Polychlorinated Biphenyl
PSR: Pressure-State-Response
SANBI: South African National Biodiversity Institute
SBA: Societal Benefit Area
SEDAC: Socioeconomic Data and Applications Center
UIC: User Interface Committee
USGS: United States Geological Survey

Appendix B: References

Documents Cited

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Appendix C: Other needs expressed in reviewed literature and previous Biodiversity report.

The Analyst recorded all needs as related to the Biodiversity SBA, even if they were not actual biodiversity parameters/variables. These are listed in the table below which includes similar needs identified by the previous Biodiversity report. While they are not parameters per se, they are (in most cases) important for a global, comprehensive, and coordinated observation network for biodiversity.

Need	Region	Realm	Year	Reference
Additional monitoring sites are needed to determine whether all Arctic colonies respond in the same manner to annual climate and ice conditions, pressures from harvest or other forms of anthropogenic stress, and whether there are inherent differences in reproductive success, recruitment and survival of seabirds across the Arctic.	Arctic	Marine	2008	Petersen, A., Irons, D., Anker-Nilssen, T., Artukhin, Y., Barrett, R., Boertmann, D., Egevang, C., Gavrilo, M.V., Gilchrist, G., Hario, M., Mallory, M., Mosbech, A., Olsen, B., Osterblom, H., Robertson, G. and Strøm, H. 2008. Framework for a Circumpolar Arctic Seabird Monitoring Network. CAFF CBMP Report No.15. CAFF International Secretariat, Akureyri, Iceland.
There is a need for a rapid increase in marine protected area coverage.	Global	Marine	2008	Wood, L.J., Fish, L., Laughren, J. and Pauly, D. 2008. Assessing progress towards Global marine protection targets: shortfalls in information and action Oryx 42: 340–351.
There is a need to link sampling approaches across scales of space and time. This refers to, for example, methods used in shallow water which can be adapted to deep habitats, and similar sampling approaches could capture pelagic diversity for a range of microbes, as well as metazoans including zooplankton.	Arctic	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Among the needs is an accurate and up-to-date checklist of the US marine biota, along with identification tools.	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Understanding biology is strongly contingent on a knowledge base being built, including fostering of taxonomic expertise and resources (guides, museum collections, databases of molecular sequences and geospatial distributions, sampling and data-	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf

Need	Region	Realm	Year	Reference
management protocols, etc.) at appropriate scales of space, time, and taxonomic resolution. To coordinate and help build these, a central facility is needed that would also function as an archival repository for data and for voucher specimens, and where trained professionals routinely identify specimens.				
In the pelagic realm, drifters and floats might be designed to gather smaller amounts of similar data, but ships will also be needed.	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
But it is essential to the US to help compile global checklists and identification tools so that invasive organisms can be recognized and identified, a task that should involve all taxonomists of marine organisms in the US.	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Assembling and synthesizing the existing programs and data is necessary to identify trends, as well as gaps in taxonomic, spatial, and temporal coverage.	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Because much of the deep sea lies outside national boundaries, international and industry collaborations are essential.	Global	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Requires baseline spatial and taxonomic assessments of US waters, including mobilizing legacy data.	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf
Establish one or more Biodiversity Observation Center(s) to coordinate sample processing, including taxonomic identifications, data management, and training. Workshop participants emphasized that a comprehensive marine BON will not be viable without sustained long-term support for both the personnel to process large volumes of	US	Marine	2011	Amaral-Zettler, L., Duffy, J.E., Fautin, D.G., Paulay, G., Rynearson, T., Sosik, H. and Stachowicz, J. 2011. Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report. http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf

Need	Region	Realm	Year	Reference
samples and observations (molecular data, physical specimens, images, etc.), and the requisite information technology infrastructure.				
The accuracy of global land cover datasets and global land cover change datasets needs to improve.	Global	Terrestrial	2007	Strand, H., Höft, R., Strittholt, J., Miles, L., Horning, N., Fosnight, E. and Turner, W., (eds.) 2007. Sourcebook on Remote Sensing and Biodiversity Indicators. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 32, 203 pp.
The collection and distribution of land cover and land cover change validation (ground truthing) data is necessary to guide the classification process and assess the accuracy of the final product. Unfortunately, there remains a lack of international coordination and standardization in this component	Global	Terrestrial	2007	Strand, H., Höft, R., Strittholt, J., Miles, L., Horning, N., Fosnight, E. and Turner, W., (eds.) 2007. Sourcebook on Remote Sensing and Biodiversity Indicators. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 32, 203 pp.
Quantitative analysis of impacts of different types of human activities (e.g. fuelwood collection, grazing, road construction, agricultural expansion) on hydrologic function, animal movements, and other ecological processes in different climatic settings is needed.	Tropics	Terrestrial	2010	DeFries, R., Karanth, K. and Pareeth, S. 2010. Interactions between protected areas and their surroundings in human-dominated tropical landscapes. Biological Conservation 143: 2870–2880.
Need information on the ability of different land uses to support wildlife to advance on the simplifying assumption used in this paper that forest is a proxy for wildlife habitat.	Tropics	Terrestrial	2010	DeFries, R., Karanth, K. and Pareeth, S. 2010. Interactions between protected areas and their surroundings in human-dominated tropical landscapes. Biological Conservation 143: 2870–2880.
Need information on cultural attributes that foster or conflict with conservation goals and how they are changing.	Tropics	Terrestrial	2010	DeFries, R., Karanth, K. and Pareeth, S. 2010. Interactions between protected areas and their surroundings in human-dominated tropical landscapes. Biological Conservation 143: 2870–2880.
Nuclear markers which are sufficiently polymorphic for population genetics and phylogeography studies, and yet still potentially applicable across various phyla, are crucially needed.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
There is a need for a register of valid names and	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W.,

Need	Region	Realm	Year	Reference
there is some agreement to use WoRMS for their purposes.				Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
As a consequence of the ever-growing anthropogenic pressures on the sea floor, there is an increased need for sustainable management.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
Large-scale marine environment datasets are scarce, so there is a need to integrate and manage local datasets in an alternative way, so that they meet the requirements for data and information on a global scale, and to support decision-making.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
There is a need for data integration and accessibility.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
There is a need to establish a network for observation and early warning of biodiversity changes that covers most of Europe's coast.	Europe	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A.,

Need	Region	Realm	Year	Reference
				Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
Problems of valuation have been discussed, including valuating the intrinsic biological characteristics of certain communities and areas. This is needed to bring the study of biodiversity into the realm of socio-economic sciences and is considered important for policy-making, e.g., in spatial planning.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
Oceanographic vessels are needed to study offshore marine biodiversity and ecosystem functioning.	Global	Marine	2009	Heip, C., Hummel, H., van Avesaath, P., Appeltans, W., Arvanitidis, C., Aspden, R., Austen, M., Boero, F., Bouma, TJ., Boxshall, G., Buchholz, F., Crowe, T., Delaney, A., Deprez, T., Emblow, C., Feral, JP., Gasol, JM., Gooday, A., Harder, J., Ianora, A., Kraberg, A., Mackenzie, B., Ojaveer, H., Paterson, D., Rumohr, H., Schiedek, D., Sokolowski, A., Somerfield, P., Sousa Pinto, I., Vincx, M., Węsławski, JM. and Nash, R. 2009. Marine Biodiversity and Ecosystem Functioning. Printbase, Dublin, Ireland ISSN 2009–2539.
There is a need for internally consistent biome-scale monitoring to accurately depict relative variations in forest clearing dynamics within and between countries.	Tropics	Terrestrial	2008	Hansen, M.C., Stehman, S.V., Potapov, P.V., Loveland, T.R., Townshend, J.R.G., DeFries, R.S., Pittman, K.W., Arunarwati, B., Stolle,F., Steininger, M.K., Carroll, M. and DiMiceli, C. 2008. Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data. PNAS 105: 9439–9444.
There exist critical gaps like the lack of databases on socio-economic driving forces linked to geo-referenced land-use and land-cover changes; the lack of geo-referenced data providing accurate information on the rates of land-use change, or the lack of data which describe and characterize global-scale processes in the land surface (e.g., land degradation and changes in soil properties) and their interactions with global biogeochemical cycles and climate.	Global	Terrestrial	2003	Mastura, S.A. and Skole, D.L. 2003. Initial Synthesis of Land-Use and Land-Cover Change Research in Asia and Pacific: A summary of APN-funded research activities focused on understanding land-use and land –cover change as an agent of Global change in Asia and the Pacific. Asia-Pacific Network for Global Change Research Secretariat. Kobe, Japan. http://www.goes.msu.edu/publications/pdfs_ps/CGCEO%2093.pdf

Need	Region	Realm	Year	Reference
Workshop participants emphasized the need for the development and maintenance of effective local monitoring networks and the collection and integration of traditional ecological knowledge as part of a comprehensive monitoring framework.	Arctic	Marine	2007	Simpkins, M., Kovacs, K.M., Laidre, K., and Lowry, L. 2007. A Framework for Monitoring Arctic Marine Mammals - Findings of a Workshop Sponsored by the U.S. Marine Mammal Commission and U.S. Fish and Wildlife Service, Valencia, March 2007. CAFF International Secretariat, CAFF CBMP Report No. 16.
A broad-based organization, such as the CBMP, is needed to maintain and administer partnerships, promote collaboration and coordination, and provide a conduit for reporting results.	Arctic	Marine	2007	Simpkins, M., Kovacs, K.M., Laidre, K., and Lowry, L. 2007. A Framework for Monitoring Arctic Marine Mammals - Findings of a Workshop Sponsored by the U.S. Marine Mammal Commission and U.S. Fish and Wildlife Service, Valencia, March 2007. CAFF International Secretariat, CAFF CBMP Report No. 16.
The ability to detect and map individual species will be advanced with the integration of high spatial resolution imagery with hyperspectral data, validated against field data. Improved scaling methods from high to moderate resolution imagery are also needed.	Tropics	Terrestrial	2007	Chambers, J.Q., Asner, G.P., Morton, D.C., Anderson, L.O., Saatchi, S.S., Espírito-Santo, F.D., Palace, M. and Souza C. Jr. 2007. Regional ecosystem structure and function: ecological insights from remote sensing of tropical forests. Trends in Ecology and Evolution 22: 414–423.
High-resolution radar or LiDAR data are needed for more detailed understanding of forest structure, especially in continuously cloudy regions of the Amazon Basin.	Tropics	Terrestrial	2007	Chambers, J.Q., Asner, G.P., Morton, D.C., Anderson, L.O., Saatchi, S.S., Espírito-Santo, F.D., Palace, M. and Souza C. Jr. 2007. Regional ecosystem structure and function: ecological insights from remote sensing of tropical forests. Trends in Ecology and Evolution 22: 414–423.
Despite recent advances in remote sensing of land-cover change, gaps remain in our understanding of forest disturbance in tropical forests and related ecological processes. First, consistent satellite observations are necessary to evaluate the forest response to variable climate conditions.	Tropics	Terrestrial	2007	Chambers, J.Q., Asner, G.P., Morton, D.C., Anderson, L.O., Saatchi, S.S., Espírito-Santo, F.D., Palace, M. and Souza C. Jr. 2007. Regional ecosystem structure and function: ecological insights from remote sensing of tropical forests. Trends in Ecology and Evolution 22: 414–423.
We lack robust data on the population status of the vast majority of rare or economically important freshwater species.	Asia	Freshwater	2003	Dudgeon, D. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* 500: 295–314.
The unreliability of estimates of species richness in individual river basins makes it virtually certain that national inventories, collections and taxonomic knowledge in Asia are inadequate to document extinctions.	Asia	Freshwater	2003	Dudgeon, D. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* 500: 295–314.
There are figures showing that the number of	Asia	Freshwater	2003	Dudgeon, D. 2003. The contribution of scientific information

Need	Region	Realm	Year	Reference
scientists and technicians per 1000 people in Southeast Asia (0.2) is one tenth that in Europe and one twentieth of that in the United States. There is an urgent need for capacity building.				to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* 500: 295–314.
For instance, biodiversity research in China is constrained by a lack of funding and trained manpower, limited accessibility of data and some reluctance of institutions within the country to share or exchange information.	Asia	Freshwater	2003	Dudgeon, D. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* 500: 295–314.
Conservation of freshwater biodiversity is hamstrung by a lack of information.	Asia	Freshwater	2003	Dudgeon, D. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* 500: 295–314.
There is a need for marine ecosystem types for classification.	Global	Marine	2001	Glibert, P. and Pitcher, G. (eds). 2001. *Global Ecology and Oceanography of Harmful Algal Blooms, Science Plan*. SCOR and IOC, Baltimore and Paris. 87 pp.
There is a need for an integrated global biodiversity observation network by complementing, expanding, and linking national and regional monitoring systems to provide effective information on ecosystems, species, and genes, and the services they collectively provide.	Global	All	2008	Convention on Biological Diversity (CBD). 2008. Recommendations from the Pre-COP9 Scientific Conference "Biodiversity Research - Safeguarding the Future". Bonn, Germany May 12-16, 2008. UNEP/CBD/COP/9/INF/51 20 May 2008.
There is a need for further guidance on ecosystem-level rapid assessment methods using remote sensing techniques for inland, coastal, and marine waters.	Global	Aquatic	2006	Convention on Biological Diversity (CBD). 2006. Guidelines for the Rapid Ecological Assessment of Biodiversity in Inland Water, Coastal and Marine Waters. Secretariat of the Convention on Biological Diversity, Montreal, Canada, CBD Technical Series no. 22 and the Secretariat of the Ramsar Convention, Gland, Switzerland, Ramsar Technical Report no. 1.
There is a need for further improvement of the availability and interoperability of biodiversity data and information.	Global	All	2008	Convention on Biological Diversity (CBD). 2008. Convention on Biological Diversity. Conference of Parties (COP) 9 Decision IX/15. Follow-up to the Millennium Ecosystem Assessment. Bonn, Germany. May 19-30, 2008.
There is a need for development of overarching conceptual frameworks that identify what is to be monitored.	Arctic	All	2008	Circumpolar Biodiversity Monitoring Program (CBMP). 2008. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.
Need to address issues of proprietary data and	Arctic	All	2008	Circumpolar Biodiversity Monitoring Program (CBMP).

Need	Region	Realm	Year	Reference
existing data portals (i.e., avoid redundancy and capture connectivity of systems in Web portal).				2008. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.
Need to establish links between scientific monitoring results and human systems to better inform adaptation and mitigation strategies.	Arctic	All	2008	Circumpolar Biodiversity Monitoring Program (CBMP). 2008. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.
There is a need for the creation of harmonized monitoring standards and protocols.	Arctic	All	2008	Circumpolar Biodiversity Monitoring Program (CBMP). 2008. CBMP Partnership Workshop Summary Report. March 6-7, 2008. Washington, DC. Supporting Publication to the Circumpolar Biodiversity Monitoring Program Framework Document.
Need interdisciplinary research framework to monitor biodiversity, to understand ecosystem services provided by biodiversity, and to guide decision making and policies regarding biodiversity in agricultural landscapes.	Global	Terrestrial	2005	Jackson, L., Bawa, K., Pascual, I., and Perrings, C. 2005. agroBIODIVERSITY: A New Science Agenda for Biodiversity in Support of Sustainable Agroecosytems. DIVERSITAS Report No 4. 40 pp.
Need to identify areas where biodiversity is particularly vulnerable.	Global	All	2009	Ash, N., Jürgens, N., Leadley, P., Alkemade, R., Araújo, M.B., Asner, G.P., Bachelet, D., Costello, M.J., Finlayson, M., Lavorel, S., Mace, G., Mooney, H.A., Parr, T., Scholes, R., Soberon, J., Turner, W., Prieur-Richard, A-H., Larigauderie, A., and Walther, B.A. 2009. Assessing, Monitoring and Predicting Biodiversity Change: bioDISCOVERY Science Plan and Implementation Strategy. DIVERSITAS Report No 7. 40 pp.
Need to identify drivers of biodiversity change.	Global	All	2009	Ash, N., Jürgens, N., Leadley, P., Alkemade, R., Araújo, M.B., Asner, G.P., Bachelet, D., Costello, M.J., Finlayson, M., Lavorel, S., Mace, G., Mooney, H.A., Parr, T., Scholes, R., Soberon, J., Turner, W., Prieur-Richard, A-H., Larigauderie, A., and Walther, B.A. 2009. Assessing, Monitoring and Predicting Biodiversity Change: bioDISCOVERY Science Plan and Implementation Strategy. DIVERSITAS Report No 7. 40 pp.
There is a need for improving observation and understanding of biodiversity change.	Global	All	2009	Ash, N., Jürgens, N., Leadley, P., Alkemade, R., Araújo, M.B., Asner, G.P., Bachelet, D., Costello, M.J., Finlayson, M., Lavorel, S., Mace, G., Mooney, H.A., Parr, T., Scholes, R., Soberon, J., Turner, W., Prieur-Richard, A-H.,

Need	Region	Realm	Year	Reference
				Larigauderie, A., and Walther, B.A. 2009. Assessing, Monitoring and Predicting Biodiversity Change: bioDISCOVERY Science Plan and Implementation Strategy. DIVERSITAS Report No 7. 40 pp.
Need to develop and assess appropriate, scientifically sound and rigorous monitoring methodologies of biodiversity based on standardized protocols and sampling strategies to maximize synergy, integration and interoperability.	Europe	All	2002	European Platform for Biodiversity Research Strategy (EPBRS). 2002. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.
Need for developing and applying methods to integrate already existing national and regional monitoring schemes into a European monitoring programme, with specific reference to biodiversity relevant environmental legislation.	Europe	All	2002	European Platform for Biodiversity Research Strategy (EPBRS). 2002. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.
Need to promote co-operation between national and regional monitoring programmes information networks.	Europe	All	2002	European Platform for Biodiversity Research Strategy (EPBRS). 2002. Auditing the Ark – Science Based Monitoring for Biodiversity Research Strategy. Silkborg, Denmark, 4-6 October, 2002.
Need to develop better methods for measuring biodiversity status and trends.	Europe	All	2007	European Platform for Biodiversity Research Strategy (EPBRS). 2007. Sustainable use of Biodiversity meeting concerning European Biodiversity Research and the Global Perspective. Leipzig, 5- 7 May, 2007.
Need to support the implementation of the CBD by developing taxonomy, identification, inventories and monitoring of biodiversity and of globally accessible and interoperable databases.	Europe	All	2007	European Platform for Biodiversity Research Strategy (EPBRS). 2007. Sustainable use of Biodiversity meeting concerning European Biodiversity Research and the Global Perspective. Leipzig, 5- 7 May, 2007.
Need to develop and evaluate long-term biodiversity monitoring programmes and indicators.	Europe	All	2005	European Platform for Biodiversity Research Strategy (EPBRS). 2005. Action Plan for Biodiversity Research in Europe. Budapest, Hungary, 31 March - 4 April, 2005. Action Plan (Release 1.1). EPBRS.
Priorities for Biodiversity Action Plan on Agriculture: Assess performance of the reformed CAP in achieving the target of halting biodiversity loss by developing a harmonized framework for evaluation to support development of monitoring systems using agreed indicators.	Europe	All	2005	European Platform for Biodiversity Research Strategy (EPBRS). 2005. Action Plan for Biodiversity Research in Europe. Budapest, Hungary, 31 March - 4 April, 2005. Action Plan (Release 1.1). EPBRS.
Priorities for Biodiversity Action Plan on Agriculture: Improve design, implementation,	Europe	All	2005	European Platform for Biodiversity Research Strategy (EPBRS). 2005. Action Plan for Biodiversity Research in

Need	Region	Realm	Year	Reference
monitoring, and evaluation of agri-environmental instruments at the scales at which they most effectively deliver on the 2010 biodiversity targets.				Europe. Budapest, Hungary, 31 March - 4 April, 2005. Action Plan (Release 1.1). EPBRS.
Need to monitor effects of policies and actions on biodiversity.	Europe	All	2008	Framstad, E., Henle, K., Henry, P-Y., Lengyel, S., Marzano, M., Nowicki, P. and Schmeller, D. 2008. Manual ”Best Practice for Monitoring Species and Habitats of Community Interest” Deliverable 30 of EuMon’s Work Package 6. EU-wide monitoring methods and systems of surveillance for species and habitats of Community interest.
Need to integrate information from single monitoring schemes into indicators that can provide information on broader patterns of biodiversity change	Europe	All	2008	Framstad, E., Henle, K., Henry, P-Y., Lengyel, S., Marzano, M., Nowicki, P. and Schmeller, D. 2008. Manual ”Best Practice for Monitoring Species and Habitats of Community Interest” Deliverable 30 of EuMon’s Work Package 6. EU-wide monitoring methods and systems of surveillance for species and habitats of Community interest.
Need to support the IUCN Global Species Assessments by providing baseline geospatial thematic data and web-based analytical tools.	Global	Terrestrial	2009	Muchoney, D. and Brady, M. (eds). 2009. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Group on Earth Observations (GEO). http://www.dpi.inpe.br/geoforest/
Need to initiate a Data Outreach Program for Forests.	Global	Terrestrial	2009	Muchoney, D. and Brady, M. (eds). 2009. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Group on Earth Observations (GEO). http://www.dpi.inpe.br/geoforest/
Need to initiate a Global Phenology Network.	Global	Terrestrial	2009	Muchoney, D. and Brady, M. (eds). 2009. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Group on Earth Observations (GEO). http://www.dpi.inpe.br/geoforest/
Need to initiate the GEO Protected Areas Assessment and Monitoring program.	Global	Terrestrial	2009	Muchoney, D. and Brady, M. (eds). 2009. Report of the First GEO Forest Monitoring Symposium. November 4-7, 2008, Foz do Iguaçu, Brazil. Group on Earth Observations (GEO). http://www.dpi.inpe.br/geoforest/
Integration and coordination among local, national and other organizations involved in the monitoring process is needed.	US	All	2006	Heinz Centre. 2006. Filling the gaps: priority data needs and key management challenges for national reporting on ecosystem condition. The H. John Heinz III Center for Science, Economics and the Environment. 110 pp.
Improved funding policy is needed to support this ecosystem monitoring program.	US	All	2006	Heinz Centre. 2006. Filling the gaps: priority data needs and key management challenges for national reporting on ecosystem condition. The H. John Heinz III Center for

Need	Region	Realm	Year	Reference
				Science, Economics and the Environment. 110 pp.
Process or institution is needed to make strategic decisions across many monitoring programs.	US	All	2006	Heinz Centre. 2006. Filling the gaps: priority data needs and key management challenges for national reporting on ecosystem condition. The H. John Heinz III Center for Science, Economics and the Environment. 110 pp.
There is a need for a mechanism/way to determine the most appropriate and highest priority investments in monitoring and reporting capacity.	US	All	2006	Heinz Centre. 2006. Filling the gaps: priority data needs and key management challenges for national reporting on ecosystem condition. The H. John Heinz III Center for Science, Economics and the Environment. 110 pp.
Need to adopt a consensus ecosystem classification hierarchy and map product that describes how systems are mapped, how to add detail, and how to extend the classification scheme to all ecosystems (including human dominated systems).	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Need to develop better guidelines for using models that predict species distributions on existing landscapes, to be used by the scientific community and conservation organizations.	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Need to ensure availability and comparability of existing data collections.	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Need improved models for predicting species distributions on existing landscapes.	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Need to organize observational data from in situ research sites in order to develop a validation database for existing products of relevance to biodiversity issues.	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Need to develop a long-term record of critical land-use characteristics, at a spatial scale that is commensurate with the land-cover change product.	Global	Terrestrial	2007	Integrated Global Observation of Land (IGOL). 2007. An Integrated Global Observing Strategy Partnership (IGOS-P) Theme. Integrated Global Observation of Land. Draft, September 6, 2007.
Information on data deficient species (IUCN classification) is needed.	Global	All	2008	Schipper J, Chanson JS, Chiozza F, Cox NA et al. 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. Science 322:225–230.
Need for blending biodiversity assessment and	Global	All	2005	Tucker, G., Bubb P., de Heer M., Miles L., Lawrence A.,

Need	Region	Realm	Year	Reference
monitoring system within a protected area management system to achieve sound and effective management of protected areas.				Bajracharya S. B., Nepal R. C., Sherchan R., Chapagain N.R. 2005. Guidelines for Biodiversity Assessment and Monitoring for Protected Areas. KMTNC, Kathmandu, Nepal.
Need to establish implementing and monitoring agencies. The establishment of subsidiary bodies with authority and resources to undertake specific activities to enhance the implementation of the agreements is vital to ensure continuity, preparation, and follow-up to complex issues.	Global	All	2005	Duraiappah, A.K., Naeem, S., Agardy, T., Ash, N.J., Cooper, H.D. et al. 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. Millennium Ecosystem Assessment. World Resources Institute. Washington, D.C.
Need to address taxonomic training and expertise: investment in taxonomic training is essential to detecting long- term change in species distributions.	Arctic	Marine	2008	Hopcroft, R.R., Bluhm, B.A. and Gradinger, R.R. 2008. Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research. North Pacific Research Board, Anchorage, Alaska. 153 pp.
An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity.	US	All	2007	Space Studies Board (NRC - SSB). 2007. Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. National Research Council of the National Academies Space Studies Board. Panel on Land-Use Change, Ecosystem Dynamics, and Biodiversity.
Data Recommendation: develop national and regional biodiversity databases.	Global	All	2000	Ornithological Society of the Middle East, the Caucasus and Central Asia (OSME). 2000. The First Arabian Ornithological and Conservation Conference. Manama, Bahrain 21-25 October, 2000. Ornithological Society of the Middle East, the Caucasus and Central Asia.
Species and community responses to drivers and pressures: development of methods for monitoring including methods to link satellite derived parameters to on-the ground vegetation assemblages.	South Africa	Terrestrial	2008	South African National Biodiversity Institute (SANBI). 2008. A Research Strategy for the Grasslands Biome. Prepared by The Grasslands Research Team. South African National Biodiversity Institute. November, 2008.
Develop monitoring techniques that can be adapted to work in a dynamic environment taking into account a diverse range of pressures such as climate change.	UK	All?	2005	Rose, P. and Ferris, R. 2005. Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. UK Biodiversity Research Advisory Group (BRAG). Monitoring & Evaluation Sub-Group. 1/10/2005.
In reference to survey techniques and monitoring	UK	All?	2005	Rose, P. and Ferris, R. 2005. Revised Draft Research Strategy

Need	Region	Realm	Year	Reference
systems: Review the potential of all types of remote sensing (e.g., acoustic sensing of the seafloor), as well as other techniques for establishing inventories and monitoring biodiversity.				for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. UK Biodiversity Research Advisory Group (BRAG). Monitoring & Evaluation Sub-Group. 1/10/2005.
Need to address monitoring gap for coastal marine systems.	UK	Marine	2005	Rose, P. and Ferris, R. 2005. Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. UK Biodiversity Research Advisory Group (BRAG). Monitoring & Evaluation Sub-Group. 1/10/2005.
Establish a programme for mapping of seafloor habitats to follow-on from the European MESH project.	Europe	Marine	2005	Rose, P. and Ferris, R. 2005. Revised Draft Research Strategy for Monitoring and Surveillance of Biodiversity and Evaluation of Actions. UK Biodiversity Research Advisory Group (BRAG). Monitoring & Evaluation Sub-Group. 1/10/2005.
Establish an online catalogue of biodiversity monitoring schemes, with links to action plans.	Europe	All	2005	UK Biodiversity Research Advisory Group (BRAG). 2005. Position Statement on Monitoring & Evaluation Research Priorities. UK BRAG Monitoring & Evaluation Sub-Group. 1/13/2005.
Need institutions (federal, state, NGOs) to be stable in order to create, manage, and maintain in situ and remotely sensed long time-series observations.	US	All	2007	US Climate Change Science Program. 2007. The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Public review draft of synthesis and assessment product 4.3. September 11, 2007.