

**Group on Earth Observations  
Biodiversity Observation Network  
(GEO BON)**

**Technical Summary  
of the  
Detailed Implementation Plan  
With List of Contributors**

**May 2010**

## Technical Summary

### **Purpose, origin and scope of this document**

This summary of the GEO BON 2010 Detailed Implementation Plan draws, in addition, on material in the GEO BON Concept Document and the Implementation Overview, both dated 2008. The latter two foundation documents were drafted through a broad, consultative process, involving increasing numbers of stakeholders as GEO BON progressed from an idea to a reality. The Detailed Implementation Plan was drafted in the first quarter of 2010 by over a hundred experts, organised into eight working groups. This Technical Summary reflects the key ideas and proposed actions in the three underlying documents in a brief and integrated form. Its purpose is to provide an overview of the GEO BON Implementation Plan, in sufficient detail so that readers with a working knowledge of the fields of biodiversity and Earth observation can easily understand the objectives and plans of the network. For further details the full Implementation Plan can be consulted. GEO BON is an evolving concept, responsive to user needs and changing technologies. The Implementation Plan will adapt accordingly, and should thus be considered as a living document.

### **The Vision, Mission and Goals of GEO BON**

The Vision of GEO BON is for a coordinated, global network that gathers and shares information on biodiversity, provides tools for data integration and analysis, and contributes to improving environmental management and human well-being.

GEO BON has as its mission the improved delivery of biodiversity information and services to users, particularly decision-makers. GEO BON focuses on observing and analysing changes in biodiversity over time. [CD 3]<sup>1</sup>

GEO BON is intended to facilitate linkages among the many countries, organisations and individuals contributing to the collection, management, sharing and analysis of observations on the status and trends of the world's biodiversity. It will also identify gaps in and between existing biodiversity observation systems and promote mechanisms to fill them. [IO]

The scope of GEO BON includes primary observations and observation-based inferences on changes in:

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<sup>1</sup> Bracketed references are to pages or sections of the Concept Document [CD], Implementation Overview [IO] or Detailed Implementation Plan [DIP]. See reference list and [http://www.earthobservations.org/GEOBON\\_docs.shtml](http://www.earthobservations.org/GEOBON_docs.shtml).

- Biodiversity composition, structure and function;
- At the ecosystem, species and genetic levels of biological organisation;
- Plus the associated ecosystem services;
- In the terrestrial, freshwater, coastal and open ocean marine domains;
- Worldwide;
- Particularly over the past few hundred years and into the foreseeable future

In addition to collating time series of observations on the presence, abundance and condition of elements of biodiversity, GEO BON intends in future implementation plans to also collate information on interactions between organisms, their functional attributes and their use by people. It will link to supporting data on the abiotic environment, the current taxonomic status of the organisms, the classification of ecosystems, drivers of biodiversity change and measures taken to protect biodiversity. GEO BON will conduct limited observation-based analyses itself, such as change detection, trend recognition, range interpolation, forward projections, and model-based estimations of the supply of ecosystem services. GEO BON will support more detailed analyses undertaken by biodiversity and ecosystem assessment bodies. [CD 3]

The guiding principles on which GEO BON is based are listed in the Concept Document [CD 1.4.1]. They derive from the GEOSS (Global Earth Observation System of Systems) principles, and include issues such as information sharing, interoperability, standards, user-orientation and scientific rigor. The “value proposition” of GEO BON is to build on, coordinate and link existing major initiatives working with biodiversity data and information, in order to derive higher-level “value-added” analytical products not currently available through the existing activities when considered separately. It aims to provide a global, scientifically-robust framework for observations that can detect biodiversity change; provide access to observations, models, assessments and forecast information; help build a global system of systems based on the integration of *in situ* and remote observation systems; coordinate aspects of data gathering and the delivery of biodiversity change information; ensure long-term continuity of data supply; and provide a set of innovative and relevant products based on the integration of datasets. [DIP 1.1]

### **How GEO BON is organised**

GEO BON is a specific example of a “community of practice”, within the Global Earth Observation System of Systems (GEOSS). It is the main implementation platform of the Biodiversity “Societal Benefit Area”. As such, it is a “network of networks”, a structure with minimal parts of its own, designed to help strengthen and coordinate the activities of a diverse set of partners towards a common goal—improved biodiversity information for a wide range of users. The only GEO BON standing body is its Steering Committee, consisting of both

biodiversity information users and providers. The Steering Committee members<sup>2</sup> serve for a period of three years, renewable once. The Steering Committee meets as needed, and consults electronically between meetings. It reports to the Group on Earth Observations (GEO) plenary. The coordination actions of GEO BON are conducted by working groups, established by the Steering Committee, with a defined purpose and for a limited period. The members of the working groups are experts, appointed on a voluntary basis and in their own capacities, selected to provide the necessary skills, experience and connections to achieve the task.

Eight working groups were ratified at the first meeting of the Steering Committee in June 2009. This Technical Summary largely reflects their efforts in drafting implementation plans within their domains, culminating in an all-working group meeting in February 2010. The working groups are pragmatically constituted, reflecting the way the biodiversity community is organised and interacts rather than an abstract logical structure. Thus, for instance, collations of observations at the species level—and especially of land-based species—are in a more advanced state than, for instance, those for freshwater species or for biodiversity-oriented observations at gene level, and are therefore separated out as a working group on their own. The number and focus of working groups will evolve over time as needs dictate. The underlying Detailed Implementation Plan is organised by Working Group—because that arrangement facilitates implementation—but this Technical Summary is arranged by the three main “levels” of biodiversity (genes, species and ecosystems), subdivided into land, freshwater and marine systems, to provide a more integrated view.

GEO BON is a “network of networks”. Two types of constituent networks are especially important to achieve its mission: the Regional BONs and the Topical BONs. Regional BONs are autonomous networks that form—largely spontaneously—to serve the biodiversity observation needs of a group of neighbouring countries. If the Regional BON subscribes to the GEO BON mission and guiding principles, it is welcome to become part of the GEO BON brand and thus gain improved access to the networked GEO datasets that follows from the adoption of agreed standards. Topical BONs are similar, but are typically global in geographical scope and focussed on a particular range of biodiversity issues—for instance, one taxonomic group, or one type of data.

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## **Who are the users?**

The main users of GEO BON will be countries (especially in relation to their obligations under biodiversity-related conventions); national natural resource and biodiversity conservation agencies; international organisations and the biodiversity-relevant treaty bodies; non-governmental organisations (both national and international) in the fields of biodiversity protection and natural resource management; and scientific research organisations and individuals both in and out of academia. [CD 3, IO 3.1]

## **Integrating and enhancing observations using models**

GEO BON recognises that primary observations and models are often not easily separated. Together, they are complementary and synergistic. Modelling will be the main tool in GEO BON for integrating observations across space and time; filling taxonomic gaps through the use of proxies and inferences; filling geographical gaps by linking remotely sensed, *in situ* and collection-based observations; predicting the consequence of biodiversity change for ecosystem function and the delivery of ecosystem services; and making observation-based projections of future change. [CD 2.5]

The needs for, and capabilities of, models in the biodiversity observation domain will first be comprehensively reviewed to inform and guide future modelling initiatives aimed at filling critical gaps. Early attention will also be directed to facilitating establishment of a collaborative framework for inferring global change in compositional diversity, by linking both species distribution (ecological niche) models and community-level distribution models to remotely sensed changes in ecosystem intactness. [DIP 7]

Initial challenges in establishing this framework will be to derive measures of terrestrial ecosystem intactness from remote sensing and to use networks of *in situ* sites to develop, calibrate and validate models of biodiversity change. Trial applications of the framework in the terrestrial, freshwater, marine and microbial metagenomics domains will be demonstrated. [DIP 7]

## **Interoperability and data integration**

GEO BON sets out to help coordinate, harmonise, standardise and manage the *in situ* biodiversity data that are collected by disparate organisations, institutions and individuals for differing purposes, to the degree necessary to achieve collective objectives. It will work with existing networks and initiatives to help develop an efficient and effective informatics network for biodiversity data, adding components and links as necessary. Key design principles will include:

- Spatial elements will need to cover the full range of possibilities from point locations, through linear features, areas and volumes, and be compatible with the *OGC Observations and Measurements specification*;
- Both centralised and service oriented architectures must be catered for in linked networks;
- Discovery services and registers will make use of the GEOSS clearinghouse mechanism, and exploit existing metadata catalogues;
- As far as possible, a unified approach to the construction and deployment of ontologies (specialised vocabularies) will be followed;
- Organism names and habitat classifications need to be compatible with the names used by various networks making up GEO BON, noting important rationalising initiatives such as ITIS, Species 2000, the Catalogue of Life, World Register of Marine Species and Global Names Index and the EBONE General Habitat classification;
- GEO BON must be able to support workflows for services and integration of applications;
- GEO BON must be compatible with the GEO Portal and other web-based interfaces;
- GEO BON must be committed to open data access, while recognising and promoting the need to acknowledge sources [DIP 8]

In order to put these principles into effect, GEO BON proposes to establish a technical coordination capability which will review existing data provider networks, establish partnerships, review the data processing needs of the GEO BON working groups, design an information architecture, build the necessary components, register data and services, and provide helpdesk facilities, training and outreach. [DIP 8]

### **Observations of biodiversity at the genetic level**

The most fundamental unit of biological diversity is variation in the nucleic acid sequences that make up the genetic code of life. This is the basis for variation between species (and thus of ecosystems comprised of different species), but also of variation among individuals and populations within species. It is important in three main ways: as the source and record of evolutionary potential that provides useful new features, some of which help support human well-being now and in the future; as a necessary condition for the viability of species, especially when their populations are reduced to low numbers; and as the basis of functional traits that ultimately determine ecosystem function and ecosystem services. The focus in genetic diversity observations to date has been disproportionately on genetic variation in economically important species, for instance crop plants, domesticated animals and disease organisms. GEO BON

covers those issues, but also genetic variation in wild organisms. The concepts to be implemented by the observation system at the gene level include:

- Repeated measurements, over time, of specific genetic components of interest, in selected target species and clades;
- Linking (in both directions) genetic diversity to the species and ecosystem levels of biodiversity;
- Model-based inferences on change in genetic diversity and its consequences, based on observations of patterns of biodiversity [DIP 1]

Although the technology for observing genetic diversity is rapidly becoming cheaper and more powerful, it will be some time before it is feasible to observe genetic diversity change in all species. GEO BON will focus on three main groups:

- 1) Rapidly declining species, e.g., IUCN “red list” species and Evolutionarily Distinct Globally Endangered (EDGE) species—those with few close relatives on the tree of life, and whose loss would thus prune entire branches;
- 2) Rapidly increasing species, such as invasive alien species and novel pests and diseases;
- 3) Species selected for largely scientific reasons, as reference groups (“controls”) ecological keystone, economically important or flagship species; wild model organisms (e.g., *Arabidopsis*, *Mus* and *Drosophila* ), or species with good historical records. [DIP 1]

Initially, while the protocols are under development, the collection of new genetic observations will be associated with core sites, often co-located with Long Term Ecological Research (LTER) sites. [DIP 1]

A novel GEO BON product will be maps of phylogenetic diversity. These are a fundamental basis for conservation planning, which will complement the currently-used species richness maps in helping to identify areas to prioritise for protection. [DIP 1]

Genetic diversity provides a good tool for understanding patterns and changes in microbial biodiversity, where many species are either undescribed or poorly defined. Specifically, a set of ribosomal sequences known as 16S will be used to map the distribution and turnover of microbial diversity and relate it to macro-ecological features, through a procedure known as metagenomics. Metagenomics will be an important platform in the marine environment, both in sediments and for phytoplankton diversity. [DIP 1, DIP 5]

The embedding of sequence data in a spatial, temporal, taxonomic and ecosystem context is an important step that will be championed by GEO BON. This will be achieved by advocating that sequence data entering the several large databases created for their storage and exchange (e.g.,

GENEBANK) be associated with the appropriate metadata regarding the organism from which the sequence was obtained and the time and place where it was collected. A metadata standard called MIENS (Minimum Information about an Environmental Sequence) will be adopted. [DIP 1]

### **Species-level biodiversity observations**

The variety of species is perhaps the most intuitive aspect of biodiversity, and the best-developed in terms of information systems. Established organisations such as the Global Biodiversity Information Facility (GBIF), and the International Union for Conservation of Nature (IUCN), themselves multi-partner international networks as well as being linked to GEO BON, have laid the foundation for sophisticated biodiversity information systems in this domain, already populated with hundreds of millions of records. The basic data record is an observation that a certain species was present at a given location and time, and has two main origins: specimens in collections in museums and herbaria; and observation lists by field biologists and lay specialists.

These information sources allow maps of distribution ranges to be developed (usually filled-in using “environmental niche models”), and changes in the range over time to be detected. The total number of species recorded at a location is the species richness, a widely-used biodiversity measure. But changes in presence or absence give little advance warning of biodiversity change and are not very helpful for resource management. For these purposes they need to be supplemented with measures of the abundance of organisms of a given species.

### **Species on land**

The species for which time-series data on abundance and distribution will be advocated by and made accessible through GEO BON will be selected according to two broad criteria: feasibility and functional importance. The first includes organisms where monitoring already exists and is conducted by current or potential GEO BON contributors. This includes information from conservation agencies, NGOs and many citizen science networks organised around particular taxonomic groups. The second includes species with economic or ecological importance, such as game species or timber species. The resulting priority groups are terrestrial vertebrates (initially birds, then mammals, amphibians and reptiles), invertebrates (initially butterflies), and vascular plants. Within each group both common and rare species will be monitored, requiring different approaches. In general extensive rather than intensive monitoring is favoured (i.e., less detail at many sites rather than more effort at a few sites). [DIP 2]

There are about 10,000 known bird species. Observations for the annual wild bird indicators (WBI), based on standardised counts of breeding birds, will be extended from those regions where they are already established, with the intent to cover the entire globe by 2020. An observation programme focusing on birds identified by the IUCN as critically endangered (currently 192 species) will be developed, along with a Critically Endangered Bird Indicator

(CEBI). The CEBI will act in support of the Red List Indicator (RLI), one of the indicators in the 2010 targets, in much the same way as the Water Bird Indicator is currently used.

There are currently approximately 5500 known mammal species. For some mammal groups standardised monitoring schemes have been established at the regional level (e.g., iBats for Europe). The aim is to extend these to other regions and taxa, using appropriate sampling methods. These data will extend and improve the Living Planet Index (LPI). For the about 6200 amphibian and 9000 reptile species, existing protocols are even rarer, and development work is needed. [DIP 2]

Insects are the most species-rich group of animals. Among them, butterflies are well documented and are a popular and relatively easily-identified group. They are also sensitive indicators of habitat loss and climate change. Reasonably standard monitoring protocols for butterflies are established in Europe and can be extended to new regions, often using citizen observers. No widely-used standard protocols yet exist for other terrestrial invertebrate groups. [DIP 2]

There are about 400 000 known vascular plant species, and about 2000 per year are still being described. Herbaria records form a large (but spatially patchy) existing data source for historical presence mapping, but do not generally provide good information on abundance or change. The GEO BON aim is to survey, by 2015, as many threatened species as possible from a globally-representative sample, and repeat this analysis thereafter at 5-year intervals. The strategy to achieve this is to prioritise geographical “hotspots” of threatened plants. [DIP 3]

### **Species associated with freshwater ecosystems**

A comprehensive, accurate and regular update of the ecology, distribution, abundance and conservation status of freshwater species is the goal of this part of GEO BON. Working through the IUCN’s Species Information System and prioritising *Red List* is planned. This will be carried out in collaboration with regional and specialist BONs and partners from specialist organisations such as the IUCN Species Survival Commission. Some freshwater taxa, for example, freshwater crabs, amphibians, the Odonata (dragonflies and damselflies) and freshwater fishes already have reasonably comprehensive databases regionally if not globally. Most other freshwater taxa remain poorly known, especially in the tropics. Improving the coverage and standardisation of observation efforts is a GEO BON priority. [DIP 4]

### **Species of coasts, continental shelves and deep oceans**

Several recent efforts, including the Census of Marine Life and the Ocean Biogeographic Information System, have advanced the information on marine species diversity substantially, and will form a basis for GEO BON activities. GEO BON priorities include facilitation of:

- Mobilisation and accessibility of online primary biodiversity data;

- Consensus on data collection protocols;
- Rescue of historical datasets and making them accessible;
- Coordination of the marine biodiversity observation efforts of independent institutes and countries to help ensure more systematic coverage. [DIP 5]

Ships of convenience will form the basis of marine basin-scale monitoring efforts. An example is the Continuous Plankton Recorder programme in the North Atlantic. New routes will need to be set up to achieve global coverage, especially in climatically-sensitive areas such as the Arctic. [DIP 5]

Long-term abundance and distribution changes in large marine organisms (cetaceans, seals, birds, turtles, sharks and fish, for example) can be monitored using a range of techniques, including acoustic tracking arrays and tagging programmes. Some of these species are of commercial fisheries importance, and are also of relevance in the context of Ecosystem Services, noted below. The role of GEO BON here is to stimulate the observations and help to link or provide the databases for them. [DIP 5]

### **Ecosystem-level biodiversity**

Many biodiversity protection organisations have adopted “the ecosystem approach”. For this to be effective, consistent and accurate information on ecosystem location, composition and status must be readily available. GEO BON’s goal is to harmonise the mapping and monitoring of ecosystems worldwide, including terrestrial, freshwater and marine ecosystems. The key metrics of ecosystem change are extent (including the size and connectivity of fragments), condition, and change in functional parameters.

### **Ecosystem services**

Ecosystem services are the benefits that people derive from nature. Such services are based, in complex and not fully-understood ways, on biodiversity, and are one important reason to prevent biodiversity loss. Ecosystem services are often related to the functional aspects of biodiversity at the ecosystem level. Information on changes in the capacity of ecosystems to deliver services is of great importance to many users, and is one way to define “ecosystem condition”.

The ecosystem services activities in GEO BON are not primary observations, but information derived from the integration of observations taken for a variety of purposes. [DIP 6]

GEO BON is planning a biennial accounting of ecosystem service delivery at national resolution. The key GEO BON activity is the development of databases and tools in support of such efforts. An initial set of services are proposed as the elements of these accounts, based on their economic or social importance, rate of change and availability of data. They include provisioning services such as crops, forest products, wild-harvested fish and fresh water, for which most countries

have monitoring systems. Models, based for instance on remotely-sensed net primary productivity and ecosystem disturbance, will help to extend this basic set of services into those for which national statistics are not widely kept—for example, the services of carbon sequestration and erosion control. “Bundling” of related services will help in the communication of changes, since changes in the relative proportions of services is usually less important than that the sum of services does not decline. [DIP 6]

At a subnational level, the GEO BON ecosystem services activity will focus mainly on the provision of standards and recommended protocols for the estimation of service flows. [DIP 6]

### **Terrestrial ecosystems**

The Ecosystem Mapping Task of the GEOSS Ecosystems Societal Benefit Area (SBA) is an important element of the GEO BON strategy. The hierarchical stratification and classification of terrestrial ecosystems is a first step, followed by their spatial mapping. Monitoring changes in ecosystem extent (and related measures, such as fragmentation and connectivity) will be based on the combination of *in situ* observations and remote sensing techniques. GEO BON will be an advocate for such coverage and will help to standardise GEO BON methods and reporting from a biodiversity perspective. A GEO BON activity is to extend and elaborate the FAO Land Cover Classification System to satisfy the needs of biodiversity monitoring. Close collaboration with the Global Observations of Forests Cover-Global Observations of Land Dynamics (GOFCC-GOLD) GEOSS task is a key part of the strategy. [DIP 3]

A global network of *in situ* field stations (“GEO BON Observation Nodes”) is needed for ecosystem condition and function monitoring, and the development of harmonised field protocols is an important element of that endeavour. Some regional examples are extant or under development (e.g., ILTER, NEON and BIOTA), and can serve as prototypes. GEO BON will integrate key ecosystem functional parameters, many monitored from space with *in situ* calibration, into a Terrestrial Ecosystem Function Index (TEFI). TEFI will be based on a data assimilation model of measurements of the energy, carbon and nutrient balance, and will require research and development by partner groups. [DIP 3]

### **Freshwater ecosystems**

It is widely agreed that freshwater ecosystems and their associated biodiversity are among the most altered on the planet. An early GEO BON deliverable will be directories of global datasets on freshwater biodiversity and on the drivers, threats and pressures operating on freshwater ecosystems. [DIP 4]

A global observation system for freshwater ecosystems does not yet exist. A prerequisite for such a system is a widely accepted and consistently applied set of spatial units. The HydroSHEDS geospatial database and tools are proposed by GEO BON as the basis for

delineating such units. Another critical step is the global classification of freshwater ecosystems based on data obtained globally at the spatial resolution of these units. This issue is highly akin to the classification and mapping task described under terrestrial ecosystems, above, and for marine ecosystems, below, although the procedures differ in the three cases.

The major proposed early product is a global atlas of freshwater biodiversity. [DIP 4] Mapping the current extent of wetlands is also a priority. It requires the development and worldwide testing of a protocol for the application of remote sensing to this issue. [DIP 4]

Remotely observed changes in the drivers of freshwater ecosystem function, and landscape feature surrogates for freshwater compositional biodiversity, will be used to produce estimates of change in freshwater ecosystem condition. Estimates of collective properties of biodiversity, such as compositional turnover among spatial units within the framework, will be derived by integrating species level data at the ecosystem scale, using models. [DIP 4]

## **Marine ecosystems**

Defining marine realms and their associated ecosystems is a major challenge, given the fluid and three-dimensional nature of the system and its relative inaccessibility. The geographic marine realms used by CoML will be the pragmatic starting point adopted by GEO BON. Each of these realms contains many ecosystems. For coastal and shelf systems the Marine Ecoregions of the World (MEOW) will be adopted, and the development of a complementary Global Open Oceans and Deep Sea-habitats (GOODS) for the open ocean will be supported by GEO BON. The visualisation of these marine ecosystems, for which static, two-dimensional maps are inappropriate, is a research development topic. [DIP 5]

Phytoplankton ocean colour and inferred primary production are key marine ecosystem observation products, requiring the integration of *in situ* and remotely sensed data. Acoustic techniques are increasingly used for mapping water layers and the sea floor, and for benthic habitat mapping and monitoring. Time-series observations of seawater chemistry and temperature throughout the profile are key ancillary data for biodiversity observations, along with currents and surface winds. Since there is no dedicated marine SBA, this requires co-development with the Climate SBA, which provides such data for purposes of climate modelling. [DIP 5]

Other GEO BON marine ecosystem priority activities are to stimulate the monitoring of key human-induced changes to the ocean environment that have biodiversity consequences such as pH, nutrients and oxygen levels and currents; and the development of process and forecast models for more marine ecosystems. [DIP 5]

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