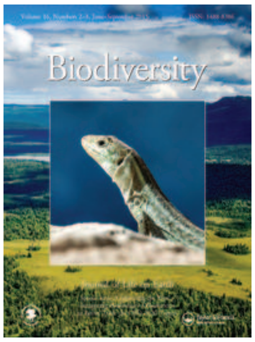

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The roles and contributions of Biodiversity Observation Networks (BONs) in better tracking progress to 2020 biodiversity targets: a European case study

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The Aichi Biodiversity Targets of the United Nations' Strategic Plan for Biodiversity set ambitious goals for protecting biodiversity from further decline. Increased efforts are urgently needed to achieve these targets by 2020. The availability of comprehensive, sound and up-to-date biodiversity data is a key requirement to implement policies, strategies and actions to address biodiversity loss, monitor progress towards biodiversity targets, as well as to assess the current status and future trends of biodiversity. Key gaps, however, remain in our knowledge of biodiversity and associated ecosystem services. These are mostly a result of barriers preventing existing data from being discoverable, accessible and digestible. In this paper, we describe what regional Biodiversity Observation Networks (BONs) can do to address these barriers using the European Biodiversity Observation Network (EU BON) as an example. We conclude that there is an urgent need for a paradigm shift in how biodiversity data are collected, stored, shared and streamlined in order to tackle the many sustainable development challenges ahead. We need a shift towards an integrative biodiversity information framework, starting from collection to the final interpretation and packaging of data. This is a major objective of the EU BON project, towards which progress is being made.

Keywords: Biodiversity; Convention on Biological Diversity; Biodiversity Observation Networks; GEOSS; Aichi Biodiversity Targets; informatics; biodiversity portal

Introduction

Biodiversity supports essential ecosystem functions and, consequently, many ecosystem services that are key to human well-being (Cardinale et al. 2012). The ongoing global biodiversity decline is a threat to human well-being, particularly in developing countries (MEA 2005). And yet, mankind contributes directly to the many factors that drive this decline (CBD 2014; EEA 2010, 2015). There is, however, a high potential for mitigation measures aimed at reducing human pressure and impact on biodiversity (Pereira et al. 2010) and this represents an important field of action for environmental policy.

One central political and international instrument aimed at halting biodiversity loss is the Convention on Biological Diversity (CBD), which sets ambitious goals to protect various levels of life forms and to implement sustainable use of natural resources (CBD 2005). The goals were formalised in the UN Strategic Plan for Biodiversity 2011–2020 along with 20 specific targets, called Aichi Biodiversity Targets (CBD 2010). However, as shown by a recently published mid-term review of progress (CBD 2014; Tittensor et al. 2014), many of these global targets are unlikely to be met unless efforts are increased. Indeed, the situation at European level is not much better (EEA 2015).

In order to more effectively inform and implement environmental policies, including tracking progress towards regional and global biodiversity targets, there is an increasing demand for comprehensive, sound and up-to-date biodiversity data. Key gaps, however, remain in our knowledge of the status and trends of biodiversity and associated ecosystem services, mostly as a result of barriers preventing existing data from being discoverable, accessible and digestible. Existing data are often not *discoverable*, i.e. it is not easy to locate them, because they are not uploaded in a well-known public repository (portal) or they have poorly documented/structured, or even absent, metadata. Existing data are also often not *accessible*, making them unavailable for use, for instance because of usage restrictions (licensing) and confidentiality. Finally, existing data are often not *digestible* (i.e. interoperable), for instance because they do not follow agreed standards, and it makes it difficult to integrate/combine them with other similar data. Besides these three main issues, certain expertise is often required to use data, which must be packaged into 'data

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and knowledge products' (e.g. indicators, maps, databases) that can be understood and used by the non-experts, for instance for policy-level purposes (e.g. reporting, assessment).

In this paper, we describe a number of the roles and contributions of Biodiversity Observation Networks (BONs) towards mobilising biodiversity information for use by policy development and decision-makers, and taking the European Biodiversity Observation Network (EU BON) as an example. EU BON (Hoffmann et al. 2014) seeks to enhance biodiversity data availability and integration, and is the European contribution to GEO (Group on Earth Observations) and the wider Global Earth Observation System of Systems (GEOSS). In the next sections of this paper, we outline steps needed to achieve this ambition. These include capacity building of the biodiversity community (within and outside EU BON), providing the community with access to data and information through a portal, and developing data standards, data-sharing specifications and strategies for accommodating 'Big Data'. Based on these activities, EU BON aims to improve the biodiversity data landscape so that biodiversity data and knowledge can flow better to support policy implementation.

Biodiversity Observation Networks act at the science/policy interface

There are many and diverse requirements by policies for biodiversity data, information, and knowledge. The biodiversity policy landscape in Europe is complex and national governments can be parties to a number of regional instruments (e.g. European Union Directives, Regional Seas Conventions) but also global ones (e.g. CBD, Convention on the Conservation of Migratory Species), with specific and often overlapping reporting needs (Figure 1). Additionally, many countries have also committed to take part in global processes such as the Intergovernmental Platform on Biodiversity & Ecosystem Services (IPBES, http://www.ipbes.net/) and national processes such as National Biodiversity Strategies and Action Plans (NBSAPs). All of these require assessments and/or reporting and, therefore, data, information and knowledge to feed into these (Geijzendorffer et al. 2015; Tittensor et al. 2014; Walpole et al. 2009).

It is well-established that there are large gaps in our knowledge of biodiversity, including seasonal (e.g. Kot et al. 2010) and taxonomic gaps (e.g. IUCN 2014; Mora, Tittensor, and Myers 2011; Narayanaswamy et al. 2013), gaps in geographical coverage (e.g. Collen et al. 2009; Mora et al. 2008; Tittensor et al. 2014; Figure 2) and gaps in our knowledge of species and habitats (Fraschetti, Terlizzi, and Boero 2008; Loh et al. 2005). Superimposed onto these gaps are additional gaps in temporal data to track pressure-driven changes from the baseline and/or progress against biodiversity targets; few data sets indeed exist with sufficient spatiotemporal coverage (Magurran et al. 2010). A recent high-level analysis of policy reporting needs showed that even for the most comprehensive policy instrument analysed (the United Nation's Strategic Plan for Biodiversity 2011–2020), decision- and policy-makers were constrained by the lack of data and indicators on changes in genetic composition and, to a lesser extent, species populations (Geijzendorffer et al. 2015). However, there is also a large suite of *existing* (i.e. already collected) biodiversity data, information and knowledge that is currently inaccessible to policy and decision makers, and these gaps could be bridged, to an extent, by further mobilisation, modelling and processing of such existing data (Geijzendorffer et al. 2015).

One of the key objectives of BONs is the mobilisation of data to close existing gaps. BONs can contribute efficiently to data mobilisation, modelling and processing of existing data by breaking down barriers and making data *discoverable*, *accessible* and *digestible*. BONs are therefore a key building block of the science/policy interface in the environmental domain, and their role extends to translating policy demands into research and monitoring, thereby catalysing bi-directional exchanges between science and policy (Figure 3).

The need for biodiversity data interoperability and the role of Biodiversity Observation Networks

One of the central tasks within BONs like EU BON is the interoperability of data sets from different origins (e.g. observation or specimen data, remote sensing data) or thematic areas that represent the entire range of Essential Biodiversity Variables (EBVs, cf. Pereira et al. 2013). Of the 20 Aichi Biodiversity Targets (https://www.cbd.int/sp/targets/), we highlight 11 that are strongly linked to EU BON's core objectives and strength (Table 1). Interoperability can take place at different levels of complexity, from thematic and spatial overlaps, through to the planned European biodiversity portal intending to offer visualisation and monitoring tools. Table 1 shows key biodiversity information required for Aichi Biodiversity Targets' reporting (and also whether genetic, species or ecosystem data are needed) and the needs for additional data from other domains (e.g. policy and socio-economic data, Earth observation products). Field data from monitoring networks provide crucial baseline data (e.g. for Aichi Biodiversity Targets 9 and 12). However, remote sensing products can deliver additional and useful data (O'Connor et al. 2015; Secades et al. 2014), particularly to track changes in loss and degradation of natural habitats, be it for protected areas and/or ecosystem service assessments (Aichi Biodiversity Targets 5, 11 and 15; see Table 1). Furthermore, policy and socio-economic data

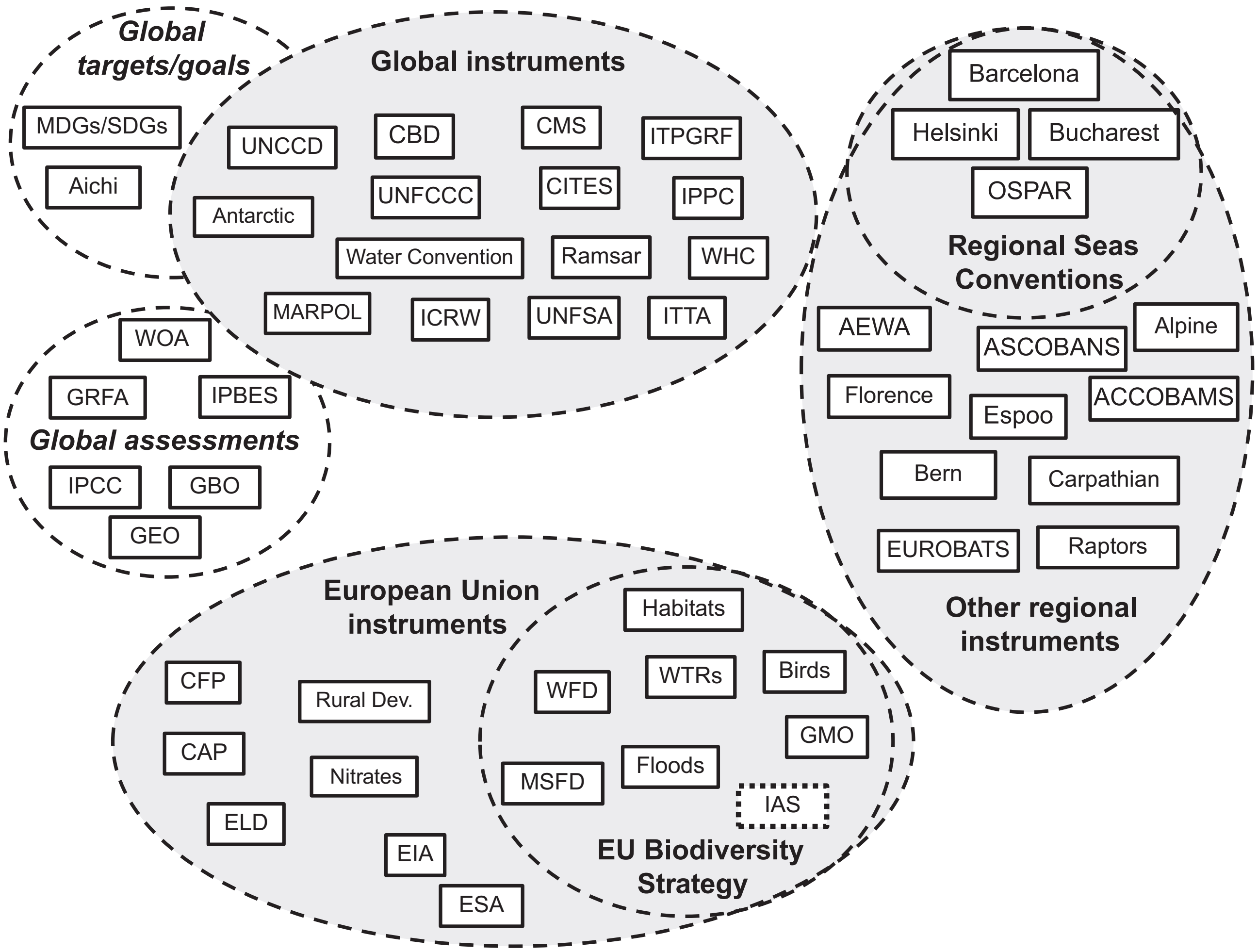

Figure 1. There are many and diverse requirements by policies for biodiversity data, information and knowledge. This figure illustrates the complex biodiversity policy landscape in Europe where national governments can be parties to a number of regional instruments (e.g. European Union Directives, Regional Seas Conventions) but also global ones (e.g. CBD, CMS). Countries are also committed to taking part in global processes such as the Intergovernmental Platform on Biodiversity & Ecosystem Services (IPBES). See Appendix 1 for full names behind the acronyms.

are required for most of the targets (7 out of 11 targets). As the table suggests, for most Aichi Biodiversity Targets, species based data are essential, along with ecosystem-based data (e.g. for targets 5 and 11). However, genetic data are crucial for some targets, e.g. Aichi Biodiversity Target 13 and can deliver additional useful data for many others (e.g. targets 5 and 6).

Overall, biodiversity data of different levels (genetic, species and ecosystem level) and from various domains (biodiversity, socio-economic data or remote sensing) need to be made accessible for reporting and assessment work on a national, regional and, finally, on a global scale. Hence, one of the core aims of a global BON (Scholes et al. 2008) and its regional components (EU BON, Arctic or Asia-Pacific BON) is to provide help and guidelines to accommodate different data types, thereby making them digestible, as well as a technological infrastructure to make data accessible.

Capacity building for biodiversity communities involved in collecting and disseminating biodiversity information

To support biodiversity data mobilisation and integration/interoperability, EU BON undertakes capacity building of biodiversity communities (e.g. researchers, citizen scientists, non-governmental organisations (NGOs)) that are involved in collecting and disseminating biodiversity information, including monitoring initiatives. There are three levels of capacity building that are of great importance to Earth observations (GEO 2006): the user, infrastructure and institutional levels. The needs of all

Figure 2. This figure illustrates geographical gaps in biodiversity data in Europe, using Arthropoda as an example. The figure uses 12.62 million occurrence records (globally) from 1970 to March 2015, accessed from the Global Biodiversity Information Facility (GBIF). Lighter colours indicate more available data (interactive version at http://www.gbif.org/occurrence).

three levels need to be addressed. For instance, many data creators are willing to upload their data in online repositories but lack the technical knowledge or data are often stored in closed repositories and data standards are not commonly followed.

To overcome existing limitations and improve data digestibility, EU BON has developed a training framework that includes supporting data mobilisation and interoperability at the user and institutional level. A comprehensive training programme was implemented with a focus on data and metadata integration strategies, use of standards and data sharing tools for institutional data and IT managers, researchers, citizen scientists and monitoring programmes. Several technical (informatics) workshops have been held on data standards and prototypes, e.g. of data sharing tools and the biodiversity portal. In addition, interdisciplinary 'task forces' such as those on EBVs and remote sensing have been set up to foster capacity building.

On the infrastructure and institutional level the project will contribute to capacity building by a task focussing on data mobilisation (e.g. web page for products and services: http://eubon.cybertaxonomy.africamuseum.be/) including, for example, the Data Mobilisation Toolkit, which will be linked to the EU BON web portal which will be known as the European biodiversity portal (EBP). The Data Mobilisation Toolkit will offer virtual help by assembling good practices (e.g. monitoring protocols, publishing guides) and training materials in biodiversity data management (e.g. GBIF resources, GEO BON online tutorials, DataOne guidelines). Overall, the Toolkit is aimed to guide the data providers through different steps of data mobilisation (upload, edit, analyse and publish data with open access), and provide them with suitable tools (Robertson et al. 2014; Smith et al. 2013). Furthermore, EU BON fosters collaboration among major players of the biodiversity data community and works together with a number of international initiatives and infrastructures (e.g. the Long Term Ecological Research Network, the Consortium of European Taxonomic Facilities or the European Citizen Science Association) to exchange knowledge (e.g. on standards, best practices and user needs) and to further develop existing approaches (e.g. on biodiversity data integration, interoperability and open access).

Enhancing biodiversity data sharing and accessibility of data

Data sharing is generally seen as important prerequisite for an increasing accessibility of biodiversity data, but implementation remains difficult (Costello 2009; Savage and Vickers 2009; Turner et al. 2015). The reasons for this are manifold: there is a lack of suitable standards, incentives and resources and, on a political level, a lack of national and European open data sharing policies.

One of the first accomplishments of the GEO was the acceptance of a set of high level data sharing principles as a foundation for GEOSS (GEO 2014), but its implementation remains a challenge.

The GEOSS data sharing principles are:

- There will be full and open exchange of data, metadata and products shared within GEOSS, recognising relevant international instruments and national policies and legislation.
- All shared data, metadata and products will be made available with minimum time delay and at minimum cost.
- All shared data, metadata and products being free of charge or no more than cost of reproduction will be encouraged for research and education.

Based on these principles, the EU BON project has produced a data sharing agreement that will be used to share data through a planned EBP and data hosting services (EU BON 2014) with the primary aim of enhancing data accessibility. It implements the GEOSS principles by being specific on details relevant to the biodiversity community, such as potentially sensitive data on endangered species and the need for an embargo on data release to support priority in scientific publishing. This agreement has yet to be tested in practical terms. Other related initiatives include the revision of the GBIF data sharing agreement to ensure that all data sets are associated with a standard, machine-readable Creative

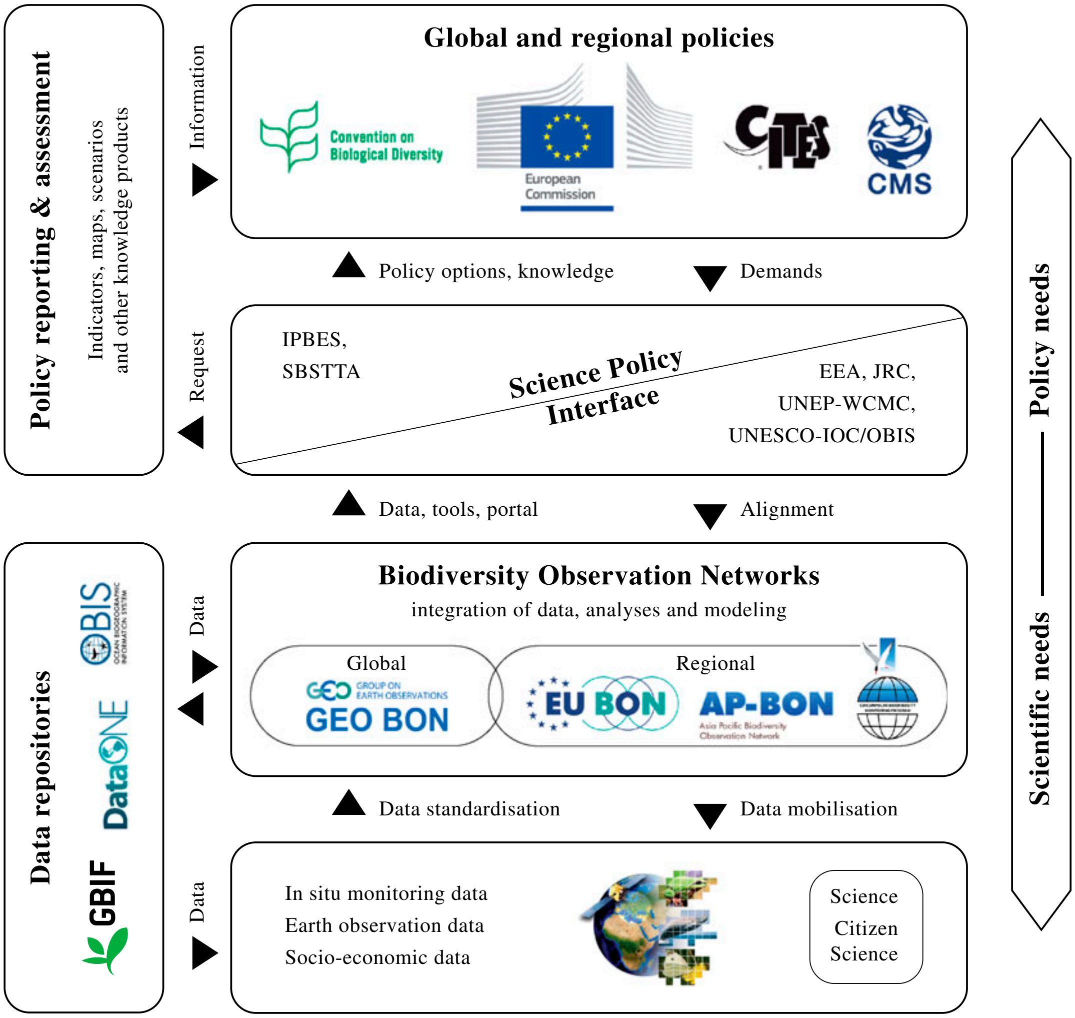

Figure 3. This figure illustrates how biodiversity data can be mobilised by Biodiversity Observation Networks (BONs), such as the European Biodiversity Observation Network (EU BON), for use in policy implementation. Data leveraged from various sources are standardised and integrated by BONs (e.g. application of standards, creation of data and knowledge products, modelling), whilst ensuring alignment with policy needs. For full names of the acronyms see Appendix 2.

Commons equivalent licence (i.e. CC-0, CC-BY, CC-BY-NC) that can be automatically processed to support data integration across large number of data sets, and the Bouchout declaration (http://www.bouchoutdeclaration.org/declaration/) that promotes licences or waivers in support of open biodiversity knowledge management. The data sharing agreement is in line with the main principles of the Bouchout declaration on open biodiversity knowledge management, and recommendations that are beyond the scope of the agreement are also promoted (e.g. the need for persistent identifiers for data, linking data using agreed vocabularies and sustaining identifiers in the long term).

Biodiversity data coverage is spatially biased and this is in part due to uneven data sharing practices (Figure 2). Currently, there is not any mechanism to fill the gaps. Firstly, a thorough gap assessment has to be conducted to show the most obvious temporal, spatial and taxonomic biodiversity data gaps, as exercised in EU BON. Secondly campaigns are needed that systematically mobilise biodiversity data across borders. In EU BON, data is mobilised, e.g. by fostering citizen science and by providing guidelines to assemble and upload data. There is also a focus on monitoring scheme data and a tool for data sharing has been further developed to cover sample-based monitoring data (GBIF Integrated Publishing Toolkit, version 2.3). The other problem is that older data is often not available in digital format because only 10–20% of specimens in collections are digitised. However, the focus of the EU BON project is not on

Table 1. Overview of selected Aichi targets and associated biodiversity targets of the European Union that are core objectives of EU BON (based on http://biodiversity.europa.eu/policy/target-1-and-related-aichi-targets). The table shows an EU BON perspective on types of data that will be needed for the Aichi target progress report and where BONs can mainly contribute, categorised into biodiversity data (GD: Genetic Data; SD: Species Data; ED: Ecosystem and Ecosystem Services Data), policy and socio-economic data (PSD) and Earth observation data (EOD). Black cells in the 'data requirements' columns express the need to include data from these fields, e.g. via biodiversity portals, grey cells indicate additional supporting information that could be added. EOD assessment is based on Secades et al. (2014), assessments for other types based on Aichi targets and its indicators, e.g. Tittensor et al. (2014).

Aichi Targets	Aichi targets Biodiversity information	Data requirements biodiv data GD	 SD	 ED	 other data PSD	 EOD	EU biodiversity targets Biodiversity information	EU Targets
5	loss of all natural habitats, incl. forests; degradation and fragmentation	▒	■	■		■	agriculture, forestry, biodiversity & measures, genetic diversity	3
6	fish, invertebrate stocks, aquatic plants, threatened species, vulnerable ecosystems	▒	■	▒	■	▒	fisheries, fish populations, marine protected areas	4
7	agriculture, aquaculture and forestry, conservation of biodiversity		■	▒	■	▒	agriculture, forestry, biodiversity & measures, genetic diversity, fisheries, fish populations, marine protected areas	3, 4
9	invasive alien species and pathways		■		■	▒	invasive alien species and pathways	5
10	coral reefs and other vulnerable ecosystems		▒	■	■	▒	ecosystem and services	2, 4
11	protected areas, other areas with effective conservation measures	▒	■	■	■	■	Birds and Habitats Directive	1
12	threatened species and conservation status	▒	■		▒	▒	Birds and Habitats Directive	1
13	genetic diversity of cultivated plants, farmed/domesticated/wild	■			▒		agriculture, forestry, biodiversity & measures, genetic diversity	3
14	ecosystems that provide essential services		▒	■	■	■	ecosystem and services	2
15	ecosystem resilience & restoration, contribution of biodiversity to carbon stocks		▒	■	■	▒	ecosystem and services	2
19	knowledge, the science base and technologies relating to biodiversity						building on the biodiversity knowledge base	H

H: Horizontal issue

digitisation, as it is a long and expensive process but coordinated actions and new funding mechanisms for digitisation of natural heritage are clearly needed (cf. section 22 in Hardisty, Roberts, and The Biodiversity Informatics Community 2013).

Improved strategies for accommodating Big Data in biodiversity research and the development of coherent monitoring schemes

We are dealing with Big Data when the volume of the data becomes an issue in itself and cannot be analysed by conventional methods (cf. Brust 2012; Ward and Barker 2013). The Information Science & Technology Commission of CETAF (Consortium of European Taxonomic Facilities) has concluded that biodiversity data qualifies as Big Data because of its complexity, heterogeneity and widely distributed nature, even though the petabyte numbers so far may be less than in some other fields.

There is a need for new strategies to accommodate Big Data as the amount of biodiversity data is steadily increasing: GBIF has made some 14,000 data sets available (www.gbif.org/) with over 500 million records, out of which ca. 100 million are digitised specimens in collections with the remainder being observation records. DataONE (http://www.dataone.org/) provides 104,000 data sets of which 5–10% are biodiversity data. A widely cited estimate (Duckworth, Genoways, and Rose 1993; OECD 1999 in Chapman 2005) is that about 2.5–3 billion collection units (specimens) are housed in institutions worldwide. A more recent investigation deploying a range of modelling approaches puts the number of specimens in the range 1.26–2.06 billion (Ariño 2010).

What have been shared so far are mostly simple observations, i.e. occurrence records that do not follow any particular collection protocol. Such data records can be reused outside their original context, and Hui et al.

(2009) have shown that estimating abundance from occurrence records is achievable, although it requires complex computations. However, for the purposes of a BON, quantitative and temporal (i.e. monitoring) data would be more useful. In 2003–2008, the EuMon project (Schmeller et al. 2009) identified 643 such monitoring schemes in Europe, and gathered basic metadata of their protocols and extents (http://eumon.ckff.si/monitoring/). However, the real number of these schemes is probably about threefold. What is needed is completing and maintaining this inventory and using a metadata standard such as the Ecological Metadata Language (EML) to make the data discoverable. Once that inventory is in place, it can be used as basis for targeted data mobilisation efforts and data hosting services.

A considerable number of monitoring schemes have quantitative data that can be processed to derive estimates of biodiversity change through time. To make these data usable, i.e. digestible, collection protocols need to be described in the associated metadata or ideally, be standardised across the various schemes in existence. Describing the protocols in standardised ways would allow automated processing of the data, and integration of data from different schemes. This is a necessity for bringing together large quantities of data from multiple sources to support analyses and calculations. Basically this is a fundamental part of the data integration process that requires considerable further investigation and agreement on methods. Although the metadata language, EML, guarantees data discoverability, the raw data must also be accessible for automated data integration. Data mining techniques and further knowledge discovery could help to detect inherent relations among variables that were previously difficult to recognise in order to make additional data available.

Another important step to standardise large data sets and to make them available for analyses is to store results of data processing in an intermediate format, such as estimated densities of species in grid cells through time. This actually corresponds to the working definition of the Essential Biodiversity Variable for species populations, which GEO BON and EU BON agreed on in their meeting in Leipzig on 1 October 2014: *'the relative abundance of a taxon in a place at a time, measured repeatedly over time with consistent methodology'*. Such layers would need to be made openly accessible through biodiversity data portals. They can be reused in various ways, e.g. for evaluating trends in species populations, without the need for understanding and redoing all the heavy and error-prone computation from raw data.

Data standards and integration

In order to promote data integration/interoperability, accepted standards are essential and they are a prerequisite for data digestibility. A standardisation body particularly relevant to EU BON is Biodiversity Information Standards (a.k.a. TDWG, www.tdwg.org). Focussing initially on organisms (specimens and observations), standards were also developed to accommodate environmental, climate, geospatial and molecular information. For specimen and observation records, the TDWG standards Access to Biological Collection Data (ABCD version 2.06) (Güntsch, Berendsohn, and Mergen 2007) and Darwin Core (Wieczorek 2007) are already widely used by existing networks, including within the framework of EU BON. In March 2015, five new terms for quantitative sample-based data for Darwin Core were ratified, which had been proposed to TDWG by GBIF and EU BON (Wieczorek et al. 2015). The new terms (parentEventID, sampleSizeValue, sampleSizeUnit, organismQuantity, organismQuantityType) are now supported by the newest release of the GBIF IPT (v2.3), e.g. in order to better capture species trends. The new terms allow for a standardised exchange of ecological data at a much wider scale than has hitherto been possible.

Apart from the technical challenges other aspects like legal or intellectual property right issues can be barriers to data integration and access. With increasingly more automated data sharing processes from multiple sources, cascading citations or application of specific licensing conditions becomes very challenging. A more flexible system needs to be implemented that acknowledges the rights of data providers and owners, gives credits by providing citations and enables open access. Best practice examples towards solving these issues are the Bouchout Declaration (2014) and the CReATIVE-B roadmap (Alonso et al. 2014), promoting Open Science, while ensuring proper citation and re-use of data.

There are also other challenges ahead for assembling additional data for policy reporting. Lang et al. (2015) addressed the challenges of data integration combining satellite and *in situ* sources. They also identified the need for a multiscale approach from biomes down to the individual species and their population studies to efficiently cope with the expectations of policy-making, like the CBD and the related EU directives. Nieland, Kleinschmit, and Förster (2015) insist on the use of ontologies and controlled vocabularies to enhance the transferability of data and the interoperability of remote sensing outputs. In turn, the remote sensing data should be combined with field-based data for developing use cases across very heterogeneous habitats and regions in the framework of Natura 2000. Recent papers (Chavan et al. 2013; Costello and Wieczorek 2014; Flemons et al. 2007; Hobern, Appeltans, and Costello 2014; Zhang 2012) come to similar conclusions of the added value of having biodiversity data originating from multiple sources permanently published, archived and available online with sufficient metadata to enable easier future use by the different target audiences.

A European biodiversity portal for different stakeholders

There still is no central entry point for the dispersed and heterogeneous biodiversity data. In order to enhance data discoverability and accessibility, the EBP, which currently is a prototype, uses metadata to discover and access data sets stored in a range of biodiversity registries and catalogues. Shared metadata (with linking access point to the actual data) across the network is essential to enable data discovery and access. This also means that extensible software architecture is needed for the successful integration of heterogeneous metadata sources in a biodiversity portal. Particularly the compatibility with the majority of standardised metadata formats is therefore a prerequisite to discover valuable biodiversity data, e.g. ISO 19115, EML and OGC CSW standards. After the biodiversity portal is finalised and tested in 2017, the developed software components and tools will be freely available in order to provide other BONs with a basic technological framework for their data mobilising approaches.

EU BON has focussed on the design of a service-oriented architecture where loosely coupled components are coordinated via a core, known as the Enterprise Service Bus, and a broker catalogue system, the GEOSS GI-cat (Figure 4). Using both architectural components, integration of distributed metadata catalogues and data discoverability will be facilitated. The broker catalogue system will be able to cope with a plethora of standardised input and output formats, after translating previously each message to the core ISO-19115 data model, whilst the Enterprise Service Bus will manage to extend each standardised message with more valuable information obtained through external service consuming.

The system architecture of the EBP needs to cope with the latencies and time slots required by each data provider to search and dispatch aggregated metadata to the message broker. In order to accomplish that goal, the portal's architecture will not only provide a direct service connection, but also harvesting and caching capabilities (cf. Copp and De Giovanni 2010).

Offering a rich and user-specific interface is crucial for the success of a data-oriented portal, which implies small latencies while querying databases, obtaining results and returning integrated information to the different users and stakeholder groups. The EBP is envisaged as a dynamic and appealing web portal, with an adaptive design, that will vary its functionalities depending on each user role. Main users of the portal are researchers and policy makers but also citizen scientists and NGOs. Whilst the researchers need to access raw data and detailed information for each data set to perform analyses using published tools and workflows, such as those of the BioVeL project (Vicario, Hardisty, and Haitas 2011; Wolstencroft et al. 2013), the more general users (i.e. non-technical) only need to perform filtered searches and access to integrated results. The citizen science

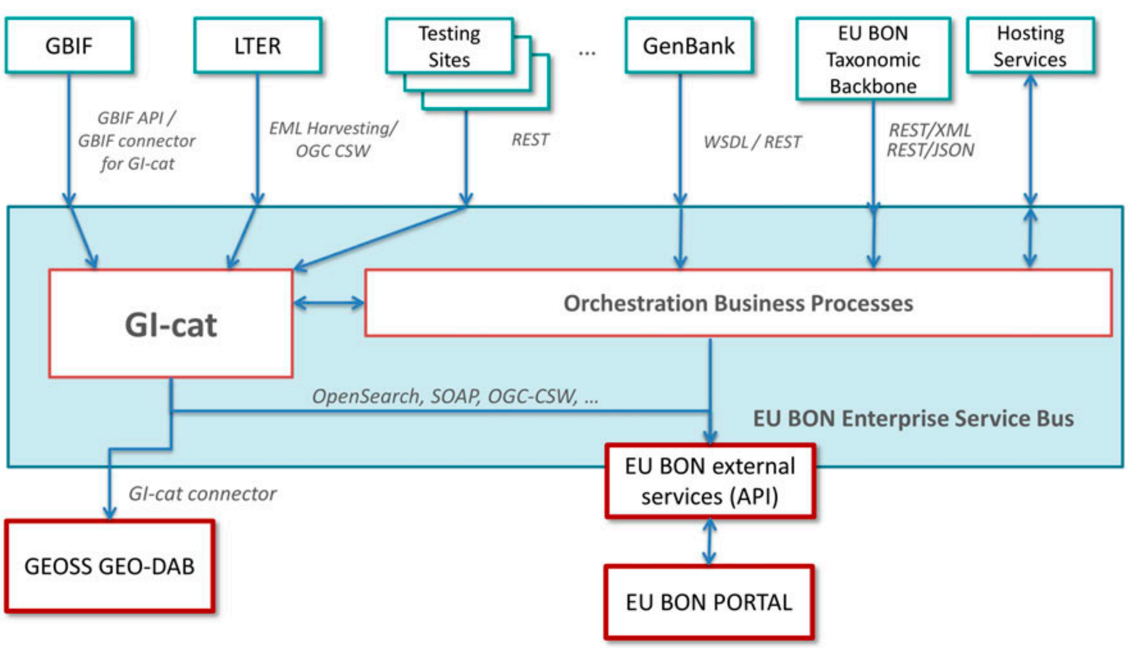

Figure 4. Schematic diagram of the service-oriented architecture of the EU BON platform to integrate various biodiversity data. Data providers are linked to the portal through a message broker (GI-cat) or through the Enterprise Service Bus. Message exchange and mediation is performed using standardised formats, for full names of acronyms see Appendix 2.

community is one of the key stakeholders as much biodiversity related data has its origin in citizen science, most prominently in biodiversity monitoring (Schmeller et al. 2009) and increasingly in the area of conservation management (e.g. Hobbs and White 2012). During the second EU BON stakeholder round table (http://eubon.eu/show.php?storyid=11924), high synergetic potential was expressed, especially in the field of data mobilisation and visualisation. Thus, the EBP of EU BON will specifically provide data mobilisation tools for both scientists and citizen scientists and offer access to biodiversity data with appropriate and easy-to-use visualisation features. Also, policy and decision makers will need specific access to a simplified search user interface, to obtain graphical visualisations of trends, charts and other relevant information on policy related questions. The portal will not only provide access to integrated data, but also provide analysis workflows, models and tools.

Conclusions

Biodiversity Observation Networks (BONs) play an important role in ensuring that data, information and knowledge are discoverable, accessible and digestible for regional and global policy reporting and related assessments (see Figure 3). They have the means to technically support science-policy interfaces with models, data and tools, and to streamline data into usable products (e.g. Essential Biodiversity Variables).

Biodiversity data, information and knowledge are diverse, dispersed and disparate (such as genetics, species distributions and Earth observations data). Hence, a central task of BONs is the standardisation of data formats to achieve interoperability of data sets from various sources and different spatial scales. Where such harmonisation cannot be achieved, brokerage and gateway transformations will also be necessary tasks to make data from different sources interoperable (Nativi, Craglia, and Pearlman 2012), as demonstrated in the EuroGEOSS project. Current efforts in EU BON are targeted to promote existing standards of good practice and to integrate data within a single portal in order to make data discoverable, accessible and digestible. Such portals will play an essential role as central access points for stakeholders from different disciplines.

Existing available data (e.g. in GBIF) needs to be updated, if possible, to identify those additional data sources that can be used to detect trends, e.g. in species populations, and to use EBVs as an overarching framework. Generally, existing (raw) biodiversity data sets need to be further processed and strategies have to be developed to accommodate the increasing amount of (big) biodiversity data (e.g. in GBIF or from remote sensing). BONs could actively help to make this data usable and accessible by standardising protocols, publishing data sets and provide feedback from science-policy interfaces.

BONs can further support and strengthen current policy reporting by making biodiversity data more discoverable, accessible, and digestible. The biodiversity community has already had considerable success in this through GBIF. This is unprecedented in most other GEOSS Social Benefit Areas. The usefulness of these types of large data pools can further be enhanced when quantitative data becomes more widely accessible, and novel methods for processing heterogeneous big data on biodiversity developed and deployed.

Finally, BONs are important human networks enabling the biodiversity community to access training, establish data sharing agreements, agree common data standards and interoperability, share their data and build capacity for mapping and facilitating the upload of data to open access repositories.

Overall, there is an urgent need for a paradigm shift with regards to how biodiversity data are collected, stored, shared and streamlined in order to tackle many sustainable development challenges ahead. The experience gained in EU BON and preceding projects such as EuMon and BioVeL emphasise the importance of developing coherent processes right from the beginning of data collection. Therefore, we need a shift towards an integrative biodiversity information framework, starting from collection to the final interpretation and packaging of data. This is a major objective of the EU BON project, toward which progress is being made.

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Appendix 1.

Acronyms of European and Global Policies that require biodiversity data, information and knowledge used in Figure 1.

ACCOBAMS – Agreement on the Conservation of Cetaceans in the Black sea, Mediterranean sea and contiguous Atlantic area
AEWA – Agreement on the Conservation of African-Eurasian Migratory Waterbirds
Aichi – Aichi Biodiversity Targets (CBD)
Alpine – Convention on the Protection of the Alps
Antarctic – Antarctic Treaty
ASCOBANS – Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
Barcelona – Convention for the protection of the Mediterranean Sea against pollution
Bern – Convention on the conservation of European wildlife and natural habitats
Birds – Directive on the conservation of wild birds (79/409/EC)
Bucharest – Convention on the protection of the Black Sea against pollution
CAP – Common Agricultural Policy
Carpathian – Convention on the protection and sustainable development of the Carpathians
CBD – Convention on Biological Diversity
CFP – Common Fisheries Policy
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS – Convention on Migratory Species
EIA – Directive on Environmental Impact Assessment (85/337/EC)
ELD – Environmental Liability Directive (2004/35/EC)
ESA – Kyiv Protocol on Strategic Environmental Assessment
Espoo – Convention on Environmental Impact Assessment in a Transboundary Context (UN)
EUROBATS – Agreement on the Conservation of Populations of European bats
FAO – Food and Agriculture Organization of the United Nations
Floods – Directive on the Assessment and Management of Flood Risks (2007/60/EC)
Florence – European Landscape Convention
GBO – Global Biodiversity Outlook (CBD)
GRFA – Genetic Resources for Food and Agriculture (FAO)
GEO – Global Environment Outlook (UNEP)
GMO – Directive on the deliberate Release into the Environment of Genetically Modified Organisms (2001/18/EC)
Habitats – Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EC)
Helsinki – Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM)
IAS – Directive on Invasive Alien Species (still under development)
ICRW – International Convention for the Regulation of Whaling
IMO – International Maritime Organisation
IPBES – Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC – Intergovernmental Panel on Climate Change (UNEP & WMO)
IPPC – International Plant Protection Convention
ITPGRF – International Treaty on Plant Genetic Resources for Food
ITTA – International Tropical Timber Agreement
MARPOL – International Convention for the Prevention of Pollution from Ships (IMO)
MDGs – Millennium Development Goals (UNDP)
MSFD – Marine Strategy Framework Directive (2008/56/EC)
Nitrates – Nitrates Directive (91/676/EEC)
OSPAR – Convention for the Protection of the Marine Environment of the North-East Atlantic
Ramsar – Convention on Wetlands of International Importance
Raptors – Memorandum of Understanding on the conservation of African-Eurasian Birds of Prey
Rural Dev. – EU Rural Development priorities (No.4 Restoring, preserving and enhancing ecosystems dependent on agriculture and forestry)
SDGs – Sustainable Development Goals (UN)
UN – United Nations
UNCCD – United Nations Convention to Combat Desertification
UNCLOS – United Nations Convention on the Law of the Sea
UNDP – United Nations Development Programme
UNEP – United Nations Environmental Programme
UNFCCC – United Nations Framework Convention on Climate Change
UNFSA – UN Fish Stocks Agreement (UNCLOS)
Water Convention – Convention on the Protection and Use of Transboundary Watercourses and International Lakes
WFD – Water Framework Directive (2000/60/EC)
WHC – World Heritage Convention
WTR – Wildlife Trade Regulations – Basic Regulation (EC 338/97), Implementation Regulation (EC 865/2006), Permit Regulation (792/2012), Suspension Regulation (757/20112), EU Enforcement Plan (338/97)
WMO – World Meteorological Organization
WOA – World Ocean Assessment (UN)

Appendix 2.

Acronyms of institutions and policies stated in Figure 3 and Figure 4

AP-BON – Asia Pacific Biodiversity Observation Network, www.esabii.biodic.go.jp/ap-bon/index.html
Artic BON – see under CMBP
CBD – Convention on Biological Diversity, www.cbd.int/
CBMP – Circumpolar Biodiversity Monitoring Programme (www.cbmp.is) of the Conservation of Arctic Flora and Fauna (CAFF, www.caff.is) working group
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora, www.cites.org/
CMS – Convention on the Convention of Migratory Species of Wild Animals, www.cms.int/
DataONE – Data Observation Network for Earth, www.dataone.org
EEA – European Environment Agency, www.eea.europa.eu/
EU BON – European Biodiversity Observation Network, www.eubon.eu

GBIF – Global Biodiversity Information Facility, www.gbif.org/
GEO – Group on Earth Observations, www.earthobservations.org/geoss.php
GEO BON – Group on Earth Observations Biodiversity Observation Network, http://geobon.org/
GEOSS – Global Earth Observation System of Systems, www.earthobservations.org/geoss.php
IPBES – Intergovernmental Platform on Biodiversity and Ecosystem Services, www.ipbes.net/
JRC – Joint Research Centre of the European Commission, https://ec.europa.eu/jrc/
LTER – The Long Term Ecological Research Network, www.lternet.edu/
OBIS – Ocean Biogeographic Information System, www.iobis.org/
SBSTTA – Subsidiary Body for Scientific and Technological Advice (CBD, UNFCC), www.cbd.int/sbstta/
UNEP-WCMC – UNEP World Conservation Monitoring Centre, www.unep-wcmc.org/