# Collaborative Information Systems and Biodiversity

the path for a strategic biodiversity information system

**GUERRA, Carlos; CASTRO, Pedro; HONRADO, João; BUNCE, Bob; JONGMAN, Rob; ALONSO, Joaquim**

Biodiversity now is considered a highly valuable asset, providing services of high importance for the well-being of humankind. However, biodiversity globally is rapidly diminishing and, despite efforts to halt this decline, positive effects are hardly visible. Since 2003, with the creation of the intergovernmental Group on Earth Observations (GEO), and in 2004, with the commitment for the implementation of the Global Earth Observation System of Systems (GEOSS) in the Third Earth Observation Summit, governments have set the pace for earth observation and the urgent need for a combined effort to identify, characterize and evaluate global change. At the European level, initiatives like the Global Monitoring for Environment and Security (GMES), the INSPIRE Directive or the European Biodiversity Observation Network (EBONE) are defining the way to communicate environmental information along geographic, administrative and institutional environments and determining their role in Spatial Data Infrastructures (SDI) development.

Following these initiatives, it became imperative that at the regional and national scales monitoring schemes are developed to ensure the necessary flow of data to support a global assessment. In this context, the Biodiversity Information and Monitoring System for Northern Portugal (SIMBioN) pursuits: i) to harmonize processes; ii) to standardize data collection, systematization and flows; iii) the creation of a collaborative structure that bring together the administration and scientific experts, and that promotes capacity building and a normative support; and iv) the promotion of organizational dynamics that allow an adequate information spread and ensure the fulfillment of the institutional, political and reporting commitments.

In SIMBioN, system requirements are related to: i) dealing with multiple users and multiple purposes; ii) data collection methodological harmonization; iii) data management and access schemes; iv) horizontal and vertical interoperability; v) complying with political commitments and international reporting. These requirements point out the need and opportunity to establish knowledge networks that allow the implementation of a collaboration framework in which scientists and the administration can combine efforts to provide a strategic biodiversity monitoring system. We propose an open source collaborative WebGIS platform as a communication promoter between the (in-situ) monitoring and the (ex-situ) data analysis and modeling to support adaptive territorial management and nature conservation.

The WebGIS platform development has to be preceded by the definition of a database model compatible with the dynamic generation of different data collection protocols and data management specifications. A hierarchic organizational structure will be implemented in order to support the administration body as data viewers and managers, with reporting obligations, and the scientific specialists as data collectors and analysts, with validation and data modeling responsibility. This will represent a system with different operational modules that relate with each taxonomic or working group, and that allows combining information for different aggregation levels and geographical contexts. Future challenges will be focused on integration with others thematic and territorial information systems in order to contribute to SDI development and to establish an organizational and financial support model that plays a crucial role in a long term sustainable and integrated strategic biodiversity monitoring system.

## KEYWORDS

Spatial data infrastructures, Capacity building, EBONE, SIMBioN, Collaborative WebGIS

## 1. INTRODUCTION

Many aspects of our planet are changing rapidly due to human activity [14]. Some impacts of global change on ecosystems have already been observed (e.g. decreases in agricultural productivity, fresh water availability, and biodiversity) [15]. All these changes, including a growing population, biodiversity loss and land use change, are strongly interrelated and cannot be seen in isolation [14]. Ecosystem functions and their related services play an important role in the establishment of ecological balances indispensable to human wellbeing, economic growth and environmental equilibrium. In this context, biodiversity is now considered a highly valuable asset, providing services of high importance for the well-being of humankind. However, biodiversity globally is rapidly diminishing and, despite efforts to halt this decline, positive effects are hardly visible.

Since 2003, with the creation of the intergovernmental Group on Earth Observations (GEO) [12], and in 2004 with the commitment for the implementation of the Global Earth Observation System of Systems (GEOSS) [11] in the Third Earth Observation Summit, governments have set the pace for earth observation and the urgent need for a combined effort to identify, characterize and evaluate global change. One of the main goals of GEOSS is to link existing systems and networks to achieve comprehensive, coordinated and sustained observations of the Earth system [1]. In order to do this it is necessary to implement, standardize and evaluate existing data flows and infrastructures to promote a better communication network between observation systems. In this sense biodiversity represents one of many subsets of an earth observation infrastructure and has to be addressed having into account the specific traits of its implementation.

At the European level, initiatives like the Global Monitoring for Environment and Security (GMES) [17] or the European Biodiversity Observation Network (EBONE) [10] are defining the way to communicate environmental and biodiversity information along geographic, administrative and institutional environments and determining their role in Spatial Data Infrastructures (SDI) development. In this context, a major development has been the adoption of a legal framework in 2007 to establish a distributed Infrastructure for Spatial Information in Europe, the INSPIRE Directive, built on the SDIs of the Member States of the European Union [1].

These global and regional initiatives attend to the fact that valuable temporal and spatial continuous information is needed to address multi-scale problems and to understand territorial trends. The implementation of spatially explicit monitoring programs will be determinant for the gathering and consolidation of knowledge related to the patterns of distribution, function and interaction of natural resources with other spatially explicit factors (e.g. land cover, human development, environmental disasters). In this context the implementation of the best practice network for SDI in nature conservation (NatureSDIplus) [13] intends to involve stakeholders, share data and best practices, to improve and stimulate research, and to improve the re-use of existing information on nature conservation.

In the specific case of Portugal, steps have been taken to develop field monitoring programs to improve the national database for natural resources. The development of SIPNAT (Sistema de Informação do Património Natural) [16] by the national agency for nature protection (ICNB) was an important landmark to the national nature conservation policy and practice, and it aims to: i) constitute a national reference database for information on biodiversity and natural resources; ii) disseminate information to a wide set of stakeholders; iii) contribute to the development of nature conservation plans and activities; and iv) promote information exchange at the national and international level. Other initiatives based on academic monitoring programs also contribute to the improvement of the knowledge related to natural resources, their management and level of risk.

Although these initiatives are implemented and have an important impact in nature conservation efforts, often they lack vertical coherence/integration, between systems and stakeholders represented at different intervention scales, and/or horizontal coherence/integration, between systems and stakeholders represented at the same intervention scale and are disconnected from other complementary initiatives with national (e.g. Sistema Nacional de Informação Geográfica (SNIG), Sistema Nacional de Informação de Recursos Hídricos (SNIRH)) or international coverage (e.g. EBONE, Lifewatch, Global Biodiversity Information Facility, Long Term Ecological Research Europe).

## 2. A FRAMEWORK FOR A STRATEGIC BIODIVERSITY INFORMATION SYSTEM

In this globalized perspective, the design of a Strategic Biodiversity Information System shall take into account not only the specific traits of habitat and biodiversity monitoring, but also their relations to a wider set of national and international initiatives, in order to integrate a comprehensive view of natural resources. In this framework, monitoring represents the act of regularly collecting standardized data during a period of time and has to be spatially and temporally integrated with other data sources [18] in order to produce relevant and unambiguous information. This also promotes a growing chain of value, where the collected data goes through a complex set of validation procedures in order to be converted into valid information to feed the required analysis loops to ensure national and international reporting.

In this sense, it is possible to identify key stakeholders that operate at different levels of the data value chain (Figure 1), namely: i) **companies**: related to environmental monitoring or environmental impact assessment; ii) **universities**: responsible for several monitoring and biodiversity evaluation programs and for the development of concepts, technologies, methods and procedures; iii) **national and regional administrations**: legally responsible for the management and reporting on natural values and resources; and iv) **environmental non-governmental organizations**: responsible for several monitoring and biodiversity evaluation programs.

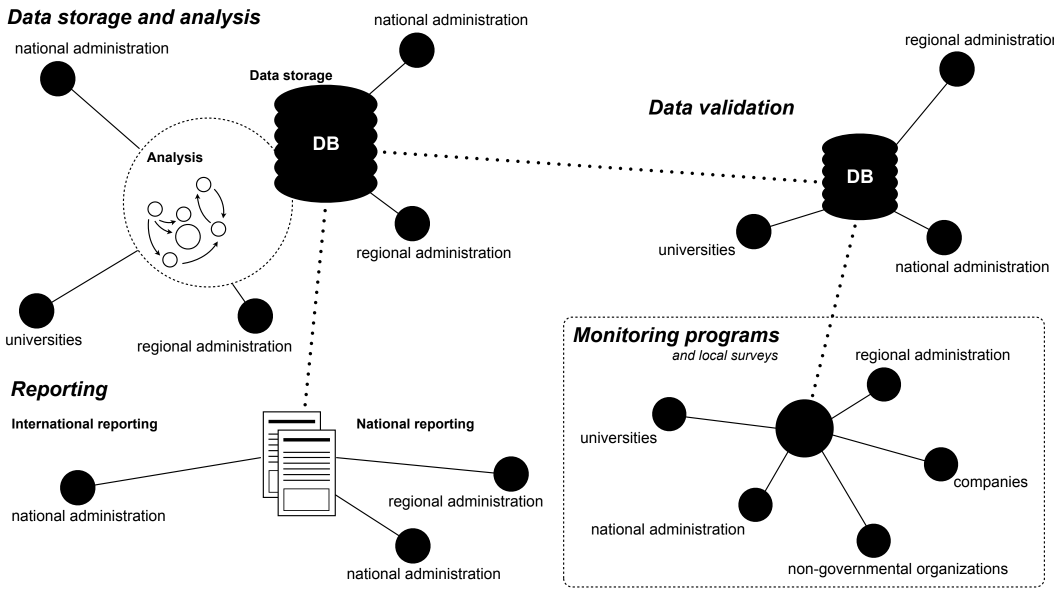


Figure 1: First order interactions between stakeholders in a strategic biodiversity information framework.

In this multi-scale, multi-level and data management and property diverse framework, the only way to create a clear relation between each scale, level and stakeholder is to create a system that follows data collection and validation standards and procedures using a clear configuration of the first order interactions between stakeholders. This configuration will allow the definition of responsibilities within the system and to create a data management policy, where data property and integrity are maintained in each level. This system based in spatially explicit information will also help creating new ontologies enabling stakeholders to communicate clearly without technological or language barriers.

In order to do that it is necessary to identify:

- potential ontological problems among stakeholders and with system developers;

- data collection methodological standards;

- system requirements and potential services;

- technological niches and requirements;

- data management policies and regulations; and

- reporting requirements;

The identification of these topics will allow to strengthen the semantics interoperability within the system and between the system and its users. With time, this system has to progressively evolve to integrate different and diverse types of spatially explicit data regarding habitats and biodiversity but also to communicate and be a part of a broader spatial data infrastructure, that fosters the understanding of the relations between environmental and anthropic factors and impacts and the identified trends of biodiversity and natural resources.

## 2.1. THE DEVELOPMENT OF A COLLABORATIVE INFORMATION SYSTEM

A spatial data infrastructure represents, in this sense, a well connected and functional assemblage of the required technology, policies, and people that enables the sharing and use of geo-referenced information [8]. It should include all levels of organizations and individuals such as government agencies, companies, non-governmental organizations, universities and research centers, scientific and professional organizations, and individuals [8]. In this context, a functional SDI is an important asset in the societal decision and policy making [4], effective governance [5], citizen participation processes [6], and the development of private sector opportunities [1] [3] [7]. It can also provide a perfect standard for data sharing between different scales and levels of interoperability.

The aim is that the strategic biodiversity information system will evolve to a thematic spatial data infrastructure by connecting all the decision levels and individuals through a privileged channel that enables data sharing and the creation of work and knowledge networks. Having into account the specifications of such a system, the option for a collaborative management and data acquisition model appears to be the best approach to determine interaction dynamics that can cope with the amount and quality of necessary data to draw assertive biological and ecological conclusions, and with the efforts to make it sustainable.

Habitat and biodiversity monitoring has a set of specific needs and traits that, if not considered, can hamper the sustainability of this strategic biodiversity information system approach. The fact that the administration, the scientific community, non-governmental organizations, and some companies have their specific monitoring programs with overlapping goals, scales and scopes (but often using dissimilar data collection approaches) is one of the major issues to address, but it will also be necessary to understand how to integrate this multi-purpose and multi-method information into one central data base. From an outside point of view, it is also important to integrate and to open communication channels with other complementary systems and organisms that can provide valuable information or can profit from habitat and biodiversity monitoring information.

In this sense, the common top-down approach to determine communication or methodological standards does not apply in this case because it would be difficult to impose data flows and dynamics in an environment where each stakeholder has a different strategy and/or scope. To cope with this, in this collaborative system ontological views and semantic standards are defined from a bottom-up perspective [9], where dynamics and communication standards are defined taking into account the different ontologies of each interacting group. With this bottom-up strategy and the focus on the development of a collaborative model based on the reinforcement of existing knowledge networks, it will be possible to design a sustainable and inclusive strategic biodiversity information system.

Some of the main benefits of collaborative models are [2]: a) reduced data costs; b) improved data quality; c) minimized data conflicts; d) improved participant operations; e) leveraged technology investments; f) more widely understood benefits of data sharing; g) reduced project costs through collective bidding; h) strengthened rationale for commitment to standards; i) improved support for cross-jurisdictional decision making; and j) strengthened working relationships fostering broader cooperation. To gain from all these benefits, we propose the implementation of a WebGIS platform that functions as the system focal point, providing an important interface between all stakeholders and the general public (Figure 2).

The advantages of such a system are [20] [21]:

- a centralized access for all stakeholders, diminishing miscommunication and improving user interaction;

- the implementation of a data value chain, where both data flow and data standards are validated;

- improved data interoperability, by creating a methodological standard and by giving the same spatial referential to all the uploaded data;

- improved communication between stakeholders and ontological harmonization;

- cost reduction for monitoring programs and better budget allocation.

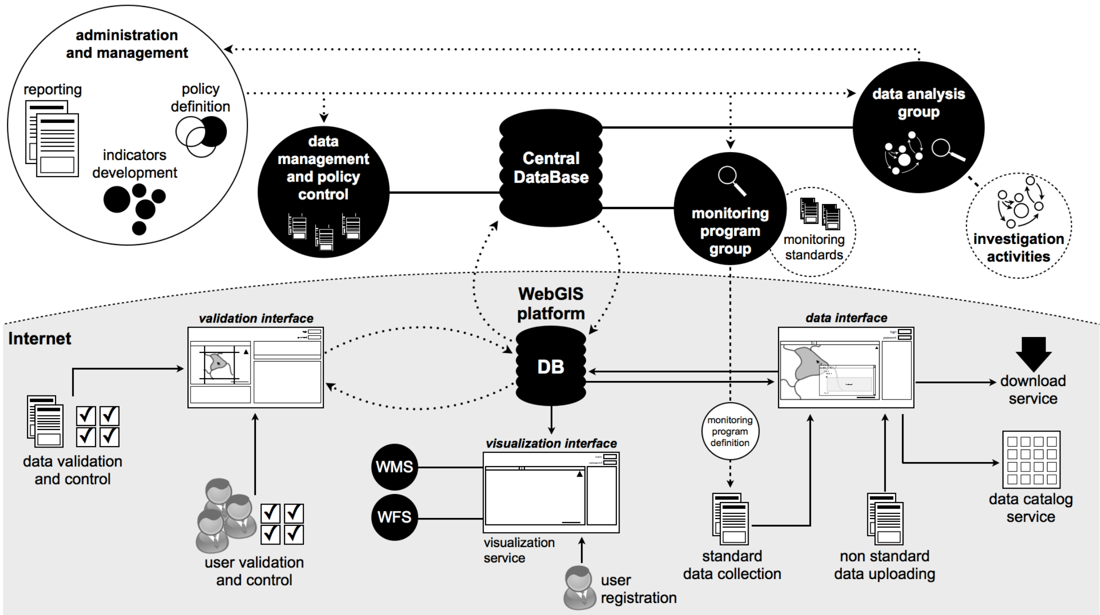


Figure 2: The framework for the development of a strategic biodiversity information system with its focal point in a collaborative WebGIS platform.

Regarding this global and strategic view, system requirements include: a) database management and control; b) optimization of data storage and manipulation technological solutions; c) data management and policy control; d) data catalog and download services; e) improved data analysis routines; f) communication strategies definition; g) the definition of data validation protocols; h) the definition of interoperability (within the system, between systems and for the public) protocols; and i) the definition of system management policy and regulations;

The focus on the integration of different decision and responsibility levels is one of the main strategies to develop a sustainable data flow for the strategic biodiversity information system. This will allow: a) to determine a structured access to habitat and biodiversity datasets; b) to establish collaboration protocols between stakeholders; c) to guaranty the reporting obligations of the administration; and d) to improve monitoring efforts.

## 2.3. THE FRAMEWORK FOR THE DEVELOPMENT AND ORGANIZATION OF THE NOVEL STRATEGIC BIODIVERSITY INFORMATION SYSTEM FOR THE NORTH OF PORTUGAL (SIMBION:INFO)

Following this general framework, developing biodiversity monitoring schemes has recently become imperative in the North of Portugal to ensure the necessary flow of regional data to support national assessments. In this context, the pilot-project “Biodiversity Information and Monitoring System for Northern Portugal” (SIMBioN) pursuits: i) to harmonize processes; ii) to standardize data collection, systematization and flows; iii) to promote a collaborative structure bringing together the administration and scientific experts, and that promotes capacity building and a normative support; and iv) to promote organizational dynamics that allow an adequate information spread and ensure the fulfillment of the institutional, political and reporting commitments.

Having its focal point in a collaborative information system (“SIMBioN:info”), it needs a combination of tools that allows reasoning about change, provides semantic information about biodiversity, and supports cognitive navigation [19] over the focal territory. Within SIMBioN:info, system requirements are related to: i) dealing with multiple users and multiple purposes; ii) methodological harmonization of data collection; iii) data management and access schemes; iv) horizontal and vertical interoperability; v) complying with political commitments and international reporting. These requirements stress the need and opportunity to establish knowledge networks that allow the implementation of a collaboration framework in which scientists and the administration can combine efforts to provide a strategic biodiversity monitoring system.

In this framework, a monitoring modular based system was implemented (Figure 3) to ensure the sustainability and the different development velocities of each monitoring program. Monitoring standards were defined for each monitoring module as well as differentiated user integration protocols. Clearly assuming a bottom-up perspective, non-administration work groups were instituted to develop methodological standards for data collection, spatial referencing, and data validation and harmonization. An open source collaborative WebGIS platform [22] was also implemented as a communication promoter between the (in-situ) monitoring and the (ex-situ) data analysis and modeling to support adaptive territorial management and nature conservation. The WebGIS platform development has to be preceded by the definition of a database model compatible with the dynamic generation of different data collection protocols and data management specifications.

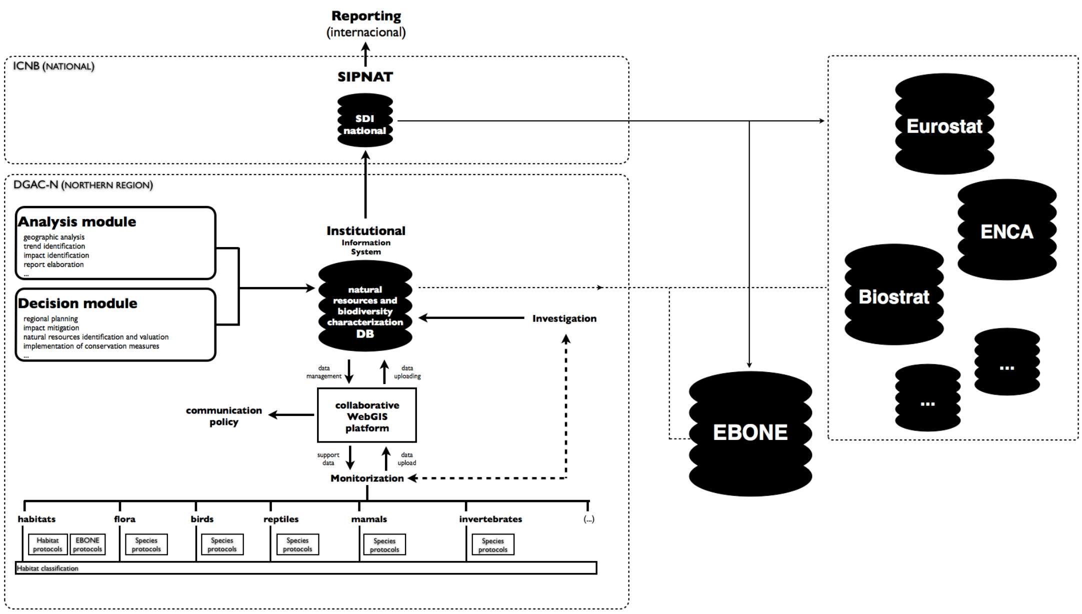


Figure 3: Modular structure of SIMBioN:info and communication strategies with other national and international biodiversity databases.

A hierarchic organizational structure was implemented in order to support the administration body as data viewers and managers, with reporting obligations, and the scientific specialists as data collectors and analysts, with validation and data modeling responsibility. This will represent a system with different operational modules that relate with each taxonomic or working group, and that allows combining information for different aggregation levels and geographical contexts.

This global implementation strategy will not only fulfill the national requirements of information interoperability but will also allow communicating with other relevant international databases. The establishment of these communication protocols is an important landmark for the development and evolution of this strategic information system to a integrated, inter-operant, and cooperative regional biodiversity spatial data infrastructure.

## 2.4. FUTURE CHALLENGES AND FINAL REMARKS

Future work will focus on the following challenges:

- the implementation of other key web services (e.g. WMS, WFS) and analysis capabilities;

- the development and implementation of a spatial data catalog with special emphasis in the creation of spatial explicit metadata;

- the integration with other thematic and territorial information systems in order to contribute to a spatial data infrastructure;

- the development and establishment of an organizational and financial support model that plays a crucial role in a long term sustainable and integrated strategic biodiversity monitoring system;

The development of thematic strategic information systems must consider:

- the development of methodological standards that can cope with the diversity of habitat and biodiversity monitoring protocols;

- the development and implementation of new organizational dynamics and organics;

- the creation of spatially explicit ontologies and tangible communication semantics;

- the implementation of communication interfaces that allow not only data viewing but also data uploading and sharing in a collaborative and cooperative environment;

This represents an important framework for the development, implementation and sustainability of future monitoring programs and strategic biodiversity information systems, as it defines a broad context for individual interaction within a clear, representative and validated data flow where responsibilities, data access and property follow a hierarchical and organic structure. It can also represent an important step into the definition of a financial support model that can cope with the necessary habitat and biodiversity monitoring efforts [23].

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## 2.6. AUTHORS

**Carlos GUERRA**
carlosguerra@esa.ipvc.pt
Instituto Politécnico de Viana do Castelo

**Pedro CASTRO**
pmc@estg.ipvc.pt
Instituto Politécnico de Viana do Castelo

**João HONRADO**
jhonrado@fc.up.pt
Faculdade de Ciências do Porto
Departamento de Biologia

**Bob BUNCE**
Bob.Bunce@wur.nl
Alterra Institute, Wageningen UR

**Rob JONGMAN**
rob.jongman@wur.nl
Alterra Institute, Wageningen UR

**Joaquim ALONSO**
malonso@esa.ipvc.pt
Instituto Politécnico de Viana do Castelo