BIO_SOS

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Abstract	To identify appropriate indicators for BIO_SOS we have used previous expert assessments of the SEBI "Streamlining European 2010 Biodiversity Indicators", as well as the ongoing work for the CBD2020 assessments. BIO_SOS will focus on three main headline indicators covering: (i) habitats of European interest; (ii) abundance and distribution of selected plant species; and (iii) fragmentation and functional connectivity of Natural and semi-Natural areas. BIO_SOS will add indicators for pressure that can be detected through land cover changes at very fine resolution.
Keywords	Status Indicator, Trend Indicator, Pressure Indicator, SEBI indicator, CBD 2020

COOPERATION

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1. Executive summary

The main aim of this report is to assess which biodiversity indicators are to be selected as the basis for common use within BIO_SOS assessing biodiversity. Indicators combine different types and scales of biodiversity relevant observations and recommendations from preceding work such as in Streamlining European 2010 Biodiversity Indicators (SEBI).

The choice of the indicators is set in the context of the emerging goal to develop Biodiversity Observation an institutional framework operating at the European level. One of the main requirements from BIO_SOS will be to provide continued comparability in biodiversity development in Natura 2000 sites. Hence, the indicator selection process began with a brief overview of biodiversity indicators used (or proposed) in large scale (national, continental or global) programmes, the European CBD indicators (SEBI), composite indicators and indicator taxa. It also made use of results and on-going efforts of European research projects.

The lack of data and the differences between areas in scale and character are probably the biggest constraints on the development and use of indicators for comparative biodiversity assessments. Two of the key questions are: (i) can we make better use of the existing biodiversity observation data (e.g. to produce indicators) by combining them in novel ways and making better use of remote sensing technologies? and (ii) are there some simple observations that could be used across Europe within existing programmes and that would give added value to existing data? The types of data we are looking to combine in this process are collected at different scales and with different methodologies and levels of sampling intensity. They include: (i) *in-situ* biodiversity survey and monitoring data on species or habitats i.e. from field observations or samples; (ii) remote sensing data, both satellite and airborne data sources.

An *in situ* habitat monitoring system has been developed in EBONE that enables consistent recording and monitoring of habitats across Europe, and potentially, globally. The habitat monitoring system that is developed within EBONE and based on BioHab has 154 General Habitat Categories (GHCs) derived from 16 easily identifiable Life-Forms and 18 Non Life Forms. This provides an easily repeatable system for use in the field that can be cross-related to other habitat classification schemes such as Habitat Directive Annex I and EUNIS. The GHCs can be easily identified on the ground, because they are based on life forms. They provide the lowest common denominator linking to other sources of data required for assessing biodiversity e.g. phytosociology, birds and butterflies. They are also more easily discriminated using remote sensing methods due to the system which is based on lifeforms and therefore on habitat structure. The GHC-approach provides therefore a powerful assessment tool for BIO_SOS, providing the link between detailed site-based level measures and habitat assessments from remote sensing. In the BIO_SOS project an effort will be made to improve the possibility of discriminating GHC from space, which is at present a great potential for this habitat monitoring system.

To identify appropriate indicators for BIO_SOS we have used previous expert assessments of the SEBI “Streamlining European 2010 Biodiversity Indicators” set of 26 indicators taking into account: data availability and the potential added value of combining data from different sources to produce a more cost-effective set of indicators.

The conclusion of this assessment was that BIO_SOS would focus on three main headline indicators covering: (i) habitats of European interest in the context of a broad habitat assessment; (ii) abundance and distribution of selected plant species; and (iii) fragmentation of natural and semi-natural areas. BIO_SOS will also look at indicators for pressure that can be detected through land cover changes, such as change from natural or semi-natural Annex 1 habitat type into a non-Annex 1 habitat type (cultivated land, urban areas, etc).

2. Introduction

The main aim of the BIO_SOS project is the development of an operational ecological modelling system suitable for effective and timely multi-annual monitoring of Natura 2000 sites and their surrounding in areas particularly exposed to different and combined type of pressures. The project will:

1) adopt and develop novel operational automatic high spatial resolution (HR), very high spatial resolution (VHR) and hyper-spectral resolution EO data pre-processing and understanding techniques for **land cover** (LC) map and **LC change** (LCC) map generation eligible for use in biodiversity monitoring. This is tantamount to saying that BIO_SOS is expected to provide improved operational core service products with respect to state-of-the-art satellite-based LC and LCC mapping systems.

2) Develop a modeling framework (scenario analysis) to combine EO and on-site in-situ data in support to the automatic provision of **biodiversity indicators** and provide a deeper understanding, assessment and prediction of the impacts that human induced pressures may have on biodiversity. This means BIO_SOS aims at developing and integrating new and existing models able to evaluate and predict trends in biodiversity issues. This will led to the development of *new downstream services* production.

In order to achieve this, the BIO_SOS project will test the integration of existing and new automatic EO data processing techniques to enable better use of observations over different scales and link that with in situ information. Focus is on the use of Very High Resolution (VHR) EO data to detect changes to be embedded in innovative ecological modelling.

The greatest challenge for all monitoring systems is to provide convincing scientific underpinning for management and policy decisions on real-world problems (Niemi and McDonald 2004). Therefore, a fundamental requirement for the design of an effective monitoring and observation system is a clear specification of its goals and objectives or the questions it should address (Lindenmayer & Likens, 2009). Furthermore, observation systems usually have to meet the requirements of many different stakeholders and are often necessary to fulfil multiple objectives. This can complicate the design of the system (Parr et al 2002). The general features of a European Biodiversity Observation Network are likely the ones listed here:

1. stakeholder and user led: to ensure that the observation system provides data and information products that are relevant to current management and policy requirements;
2. based on a strong scientific rationale: providing a system that meets research requirements for data relevant to understanding the complex relations between biodiversity Drivers, Pressures, State, Impacts and Responses (DPSIR) at multiple scales;
3. hierarchical: linking observations from small to large scales;
4. cost effective: developing a system for monitoring that delivers correct data at the lowest costs, making best use of in situ data in combination with techniques that optimise the use of multi-source and multi-temporal remote sensing data and prior knowledge.
5. reduced timeliness: reducing time span between data acquisition and product delivery to the End Users
6. increased robustness: to changes in the input data set and in user defined parameters, if any.

It is already apparent that one of the main policy requirements for a biodiversity monitoring system is to provide data to support the development and reporting of biodiversity indicators

that can be generalised over Europe. Biodiversity indicators span broad levels of biological, spatial and temporal organisation within ecosystems, and the options for choosing variables to measure and sampling designs are almost infinite. The aim of this report is to select biodiversity indicators as the basis for developing the BIO_SOS approach for assessing biodiversity. These indicators will form the basis for the use and combination of different types and scales of biodiversity relevant observations. The present project will be based on the activities carried out in Europe through SEBI, and on the work done in the frame of the EBONE project for the definition of Indicators (Parr et al. 2010).

BIO_SOS aims at developing an automatic system for the delivery of biodiversity information to users and managers. The main users of BIO_SOS are likely to be the local /regional managers of the Natura2000 sites and the supervising national and/or regional authorities with responsibility for reporting to European Commission on the conservation status of species and habitats (Article 17 of the Habitats and Species Directive and Article 12 of the Birds Directive). Indicators have a wide range of uses according to geographical scale (e.g. from local to global) and user domain (e.g. scientific, site condition assessments, resource management, and policy purposes). The emphasis of the work on indicators in the BIO_SOS project is to provide observations and establish methodologies that meet requirements for indicators relevant to the assessment of biodiversity at the site level, which could also be generalised at a European level. The developments made in the framework of BIO_SOS should build on what has been achieved in EBONE and will provide a system that: (i) enables insight in status, trends of Biodiversity, as well as information on pressures and threats, (ii) reports cost-effectively on the agreed SEBI indicators (EEA 2007); (iii) identifies a core set of measurements for biodiversity, combining species and habitat level measures, to enable consistent approaches for the assessment of changes in the status and extent of habitats of European interest and their capability to deliver key ecosystem services; and (iv) helps defining the requirements and technological specifications for the in situ use and EO sensors and computer technologies to enable real-time monitoring of biodiversity and ecosystem processes.

The objective of this report is to provide the rationale and recommendations for the selection of indicators for method development in BIO_SOS.

3. Background to biodiversity indicators

What makes a good indicator: concepts and criteria

A widely cited definition of biological diversity is "the variety and variability among living organisms and the ecological conditions in which they occur (US Congress Office of Technology Assessment 1987)". If biodiversity monitoring has to deliver data for biodiversity indicators, then sensitive and essential elements of biodiversity should be measured and translated into indicators. When it is too costly or too difficult to measure these variables, then proxies should be used that are measurable.

A conceptual and theoretical basis for indicators of biodiversity is summarised by Noss (1990). In his hierarchical characterisation of biodiversity, he emphasises that biodiversity is not just a number of genes, species and ecosystems, but should also cover the most important structural, functional and compositional aspects of biodiversity (Figure 1). Just monitoring birds or butterflies, because they are attractive and easy to measure is insufficient. They also should represent some important aspect of the structure, compositional or functional attribute of the system.

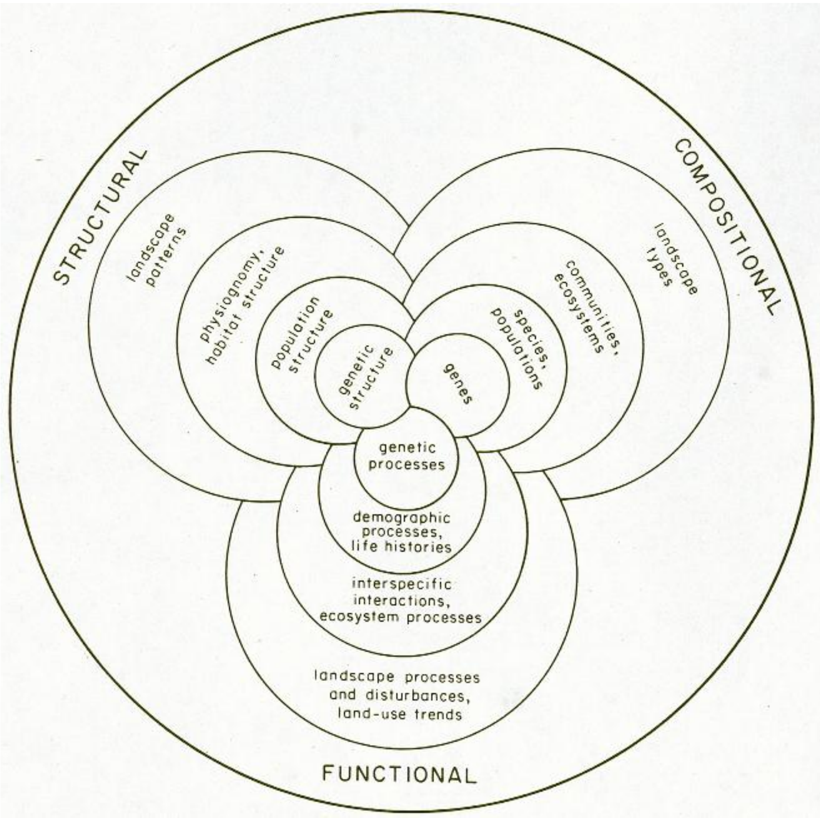

Figure 1. Compositional, functional and structural biodiversity shown as interconnected spheres, each encompassing multiple levels of organisation (Noss 1990)

These structural, functional and compositional aspects of biodiversity are needed to address important questions related to forest development, land management and the impact of climate change, and require the consideration of global and continental climate related processes, such as habitat change and land use change, variation and change in vegetation patterns, genetic adaptation of species and populations, physiological adaptations, soil processes, soil species change and the interaction with invading species, especially parasites. This therefore requires a multidisciplinary approach to analyse and understand the overall problem. Upscaling and downscaling is also essential for understanding processes.

The definition of a good indicator is largely dependent on its foreseen use. According to the SEBI report (European Environment Agency, 2007), the European biodiversity indicators should monitor progress in and support the achievement of the European targets for biodiversity (Section 3.2). The criteria for selecting these indicators were:

(i) Policy relevant and meaningful: indicators should send a clear message and provide information at a level appropriate for policy and management decision-making by assessing changes in the status of biodiversity (or pressures, responses, use or capacity), related to baselines and agreed policy targets if possible.

(ii) Biodiversity relevant: indicators should address key properties of biodiversity or related issues as pressures, state, impacts and responses.

(iii) Progress towards the 2010 target: indicators should be able to measure progress towards the 2010 target and its revision.

(iv) Well founded methodology: the methodology should be clear, well defined and relatively simple. Indicators should be measurable in an accurate and affordable way and constitute part of a sustainable monitoring system. Data that are used for the indicator should be collected using standard methods with known accuracy and precision, using determinable baselines.

(v) Acceptance and intelligibility: the power of an indicator depends on its broad acceptance. Involvement of policy-makers as well as major stakeholders and experts in the development of an indicator is crucial.

(vi) Routinely collected data: indicators must be based on routinely collected, clearly defined, verifiable and scientifically accepted data.

(vii) Cause-effect relationship: information on cause-effect relationships should be achievable and quantifiable in order to link pressures, state and response indicators. These relationship models allow scenario analysis and represent the basis of the ecosystem approach.

(viii) Spatial coverage: indicators should ideally be pan-European and include adjacent coastal areas, if and where appropriate.

(ix) Temporal trend: indicators should be capable to show temporal trends.

(x) Country comparison: as far as possible, it should be possible to make valid comparisons between countries using the indicators selected.

(xi) Sensitivity towards change: indicators should show trends and, where possible, permit distinction between human-induced and natural changes. Indicators should thus be able to detect changes in systems in timeframes and on scales that are relevant to the decisions, but also be robust enough to measure errors that do not affect interpretation.

In addition, the following criteria were used to evaluate the set as a whole:

(i) Representative: the set of indicators provides a representative picture of the DPSIR chain (EEA Technical Report 25) in which:

- D = *Drivers* of change
- P = the resulting environmental *Pressures* on
- S = the *State* of the environment which
- I=*Impacts* on ecosystem services as a result of changes in environmental quality which then
- R = induces societal (or individual) *Responses* to the changes … which in turn modify *Drivers* of change.

(ii) Small in number: the smaller the total number of indicators, the easier it is to communicate cost-effectively to policy-makers and the public.

(iii) Aggregation and flexibility: aggregation should be facilitated on a range of scales.

Similar criteria for indicators were used in the SENSOR project (Kristensen et al. 2006) based on criteria outlined by the European Commission (2005).

More broadly, it is also useful to assess indicators in relation to five overarching questions:

a) What is the indicator supposed to measure, what quantity does it represent?
b) Why is the indicator thought to be relevant for biodiversity and its sustainability in relation to environmental, social and economic change?
c) Does it support EU concerns as expressed in EU policies?
d) What data are needed and available to populate the indicator and how important is it to collect these data to show the current values of the indicator and the past and future trends?
e) At what spatial level is the indicator available? How can it be used in regional, national or European models and scenarios as indicators of policy impacts and ecosystem changes?

The CBD indicators in Europe: SEBI

The development of biodiversity indicators in Europe has heavily been influenced by the requirements of the CBD target which aims "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth (more usually known as the 2010 target). Now new targets have been set for 2011-2020 (Appendix 1). These can influence the targets of the European Union and the new Strategy document is on its way. However, at present we will focus on the existing targets and indicators.

In 2004, the parties to CBD adopted a global framework for evaluating progress, including a first set of indicators, grouped in focal areas such as "status and trends" or "threats". The CBD focal areas are:

- Status and trends of the components of biological diversity (where we are now and where we may be heading);
- Threats to biodiversity (the main pressures that need to be countered through policy measures and action);
- Ecosystem integrity and ecosystem goods and services (functioning of ecosystems in terms of their ability to provide goods and services);
- Sustainable use (specifically in relation to forestry, agriculture and fisheries);
- Status of traditional knowledge, innovations and practices (this focal area was not included at the European level);
- Status of access and benefit-sharing (the sharing of benefits derived from biodiversity, particularly from genetic resources);
- Status of resource transfers (the extent to which society is willing to invest in biodiversity conservation by providing financial resources).

The first focal area (status and trends) is directly measurable in the field or through earth observation. All other focal areas require additional information and modelling of societal and ecological relationships.

The European Community's 2006 Biodiversity Communication and Action Plan provided a detailed strategic response to accelerate progress towards the 2010 targets at Community and Member State level. The EU's target was more ambitious than the CBD target and aimed at "halting biodiversity loss by 2010" but the requirement for indicators to measure progress was effectively the same. Building on the conceptual framework provided by the CBD, the European Union and the members of the Council of the Pan-European Biological and Landscape Diversity Strategy agreed a set of headline indicators within the CBD focal areas (European Environmental Agency, 2009).

In Europe this led to the Streamlining European 2010 Biodiversity Indicators (SEBI 2010) project and the development of a set of indicators to meet the CBD requirements. The 26 SEBI “headline” indicators are clustered within the 7 CBD focal areas. The set is not designed to be comprehensive, but to provide the best coverage on the basis of available information and resources. The technical report containing specifications of the 26 indicators selected was published in 2007 (available at http://reports.eea.europa.eu/technical_report_2007_11/en).

The EEA report on "Progress towards the European 2010 biodiversity target" (EEA, 2008) is the first assessment of progress towards the target to halt the loss of biodiversity in Europe, based on the SEBI 2010 set of biodiversity indicators. The SEBI process will continue to further improve the indicators, to fill major gaps in the set and to enhance its biological, temporal and geographic coverage. Indicators or approach confirmation of causal links to drivers, pressure (e.g. climate change, land use change) and state are also needed (Mace and Baillie, 2007). For example, there is a lack of indicators that reflect climate change impacts on biodiversity and ecosystems, as these are not easy to derive directly from biodiversity data due to climate effects often confounded with many other factors. These are currently being developed and should be part of the future SEBI reports.

4. Post -2010 Indicator Development Trend

As recognized in the July 2009 workshop summary of the Secretariat of the CBD and the UNEP WCMC (Workshop 2009), in a number of Natura 2000 sites (including many Mediterranean Areas), 5 indicator sets, have not been developed, others are still under-development and only 9 can be considered fully developed with well-established methodologies and global time-series data. As national and regional differences in policies and funding occur, there is still a lack of: a) long-term baseline data; b) standardized and cost-effective monitoring techniques; c) methods for assessing the significance of measured changes and evaluating trends; d) modelling techniques for evaluating the combined impact that different drivers effecting soils and/or vegetation may have on biodiversity in time; e) adequate communication to disparate, often contrasting, audiences corresponding to different groups of stakeholders. Among these final recommendations, the following ones are particularly relevant to the proposal:

- Previous indicators should be reduced to a smaller set (10-15), by dropping the ones where there is little prospect of collecting data with continuity and re-aligned in four simplified focal areas i.e. 1) Threats to Biodiversity; 2) State of biodiversity; 3) Ecosystem Services; 4) Policy Responses, in order to maintain continuity and enhance their use, according to the following scheme.

Proposed new (modified) framework	Current framework focal area/s
Threats to Biodiversity - Direct - Indirect	• The same
State of Biodiversity	• Status and trends of components of biodiversity
Ecosystem Services	• Ecosystem Integrity, goods and services • Sustainable use
Responses	• Access and Benefit-Sharing (ABS) • Resource transfers • Traditional knowledge, innovations and practices

- Some additional measures should be developed in previous focal areas by the scientific community to monitor progress towards the post-2010 target;
- Such targets should be formulated in terms of reliable detection of level of change rather than rate of biodiversity loss. e.g. maintaining and restoring levels rather than reducing the rate of loss;
- A high priority should be given to expanding, especially in biodiversity rich regions, the geographic coverage of existing indicators, especially biodiversity status and threats to it, including in the latter case direct and indirect threats as they relate to biodiversity, ecosystem services and human wellbeing.

Table 1 of the referenced workshop (Workshop 2009) shows the content of existing focal areas versus new proposed focal areas with current and new proposed indicators as

elaborated by the workshop working group. Although no list of indicators to populate this proposed new/revised framework was discussed during the workshop, some of the working groups did discuss indicator gaps in the *Pressures* focal area and possible candidates for filling them as shown in the original Table 2 of the report (Workshop 2009)

Building on the outcome and action point raised by the UNEP-WCMC-SCBD workshop (Workshop 2009) a new meeting of an Ad Hoc Technical Expert Group (AHTEG) on Indicators for the Strategic Plan for Biodiversity 2011-2020, will take place in June 2011 (Workshop 2011). The objectives of this meeting are to:

- Provide advice on the further development of indicators agreed through decisions VII/30 and VIII/15 and the information contained in Annex III of the document note by the Executive Secretary on examination of the outcome-oriented goals and targets (and associated indicators) and consideration of their possible adjustment for the period beyond 2010 (UNEP/CBD/SBSTTA/14/10), as well as in the table provided in the note by the Executive Secretary on the Strategic Plan for Biodiversity.
- Suggest additional indicators that have been, or could be, developed, where necessary, to constitute a coherent framework designed to assess progress towards targets of the Strategic Plan for Biodiversity 2011-2020, for which the current suite of indicators is not adequate.
- Develop further guidance and propose options for the establishment of mechanisms to support Parties in their efforts to develop national indicators and associated biodiversity monitoring and reporting systems, in support of setting targets, according to national priorities and capacities, and in the monitoring of progress towards them.
- Provide advice on the strengthening of linkages between global and national indicator development and reporting.

The BIO_SOS project will follow the progress of this discussion to identify the possible contribution of the Remote Sensing to indicators extraction and monitoring. (As an example, refer to Table 4 of this Deliverable, Section 6)

5. Remote sensing and habitat information

Provision of suitable data is probably the biggest challenge in what concerns the development and use of indicators for biodiversity assessments. The SEBI process explored the availability of data in the indicator development process and the final choice of indicators was highly data constrained (Parr et al 2010).

The key question for BIO_SOS is to provide biodiversity observation data combining them in novel ways and making better use of remote sensing technologies. The main types of data we are looking to combine in this process will be collected at different scales and levels of sampling intensity, corresponding in two levels:

- in-situ biodiversity survey and monitoring data on habitats i.e. data based on field observations and sampling;
- remote sensing (RS) data, both satellite and airborne data sources.

Strand et al (2007) in their “Sourcebook on Remote Sensing and Biodiversity Indicators“ review the use of RS for assessing biodiversity. They provide many examples of how RS is being used and list the main satellites and sensors than can be used for biodiversity assessments, including airborne approaches involving radar and LiDAR. Most of the examples given represent relatively small scale applications relevant to site or regional management issues but there is clearly much potential for the use of RS techniques for biodiversity observations and in monitoring systems.

RS data already provide the data behind two of the SEBI indicators: “ecosystem coverage“ and

“fragmentation of natural and semi-natural areas“. Both of these are based on the CORINE Land Cover Map, which does not give always reliable results.

The main advantages of using RS techniques as a data source for biodiversity indicators definition, is that they: a) provide an easy source of data covering wide areas, b) give the opportunity of regular repetitions.rivisits. However, RS data usually can only provide measurements on broad habitat, ecosystem or land cover types, as well as on landscape and vegetation structure; they rarely give direct measurements of biodiversity. The possibility obtaining direct biodiversity measurements related to genera, species, populations from RS observations remains a complicated task.

RS data have the potential to provide indirect measurements from modelling and upscaling of in situ data for large scale assessments. Some of the approaches and sources of RS data of relevance to a Global Biodiversity Observation System were recently reviewed by Buchanan et al. (2008). Duro et al. (2007) suggested a framework for the development of a large area biodiversity monitoring system driven by RS based on indirect measures of: (i) the physical environment e.g. climate and topography; (ii) vegetation production; (iii) habitat suitability (spatial arrangement and structure); and (iv) disturbance.

RS data also have the potential for more accurate assessments of ecosystem and habitat cover at finer scales that may offer better opportunities for deriving associations with other measures of biodiversity. The spatial and spectral resolution is crucial in determining which habitat data can be observed from space or air as discrimination of habitat depends on the question of whether habitats can be separated (e.g. *Eucalyptus* forest and *Quercus Ilex* forest), as well as the grain size of the habitats compared with satellite pixel size (Hedgerows, ponds). Therefore, habitat discrimination will be different depending of the RS EO data that are used (air- or spaceborne high spatial resolution, hyper spectral or specialised LiDAR).

Developing a system based on RS for the discrimination of habitat and ecosystem types at finer resolution and the supply of a wall-to-wall national or continental coverage, may be the key for a far more extensive assessment of state and change in some of the main components of biodiversity. This is due to the fact that:

(i) Habitat data are of direct significance to biodiversity (e.g. the Habitats Directive) and information on stock and trends is a useful direct indicator of broad scale changes in biodiversity;

(ii) Habitats provide the home for species and populations and provide – if used carefully – an indirect indicator of their presence; for instance habitats and vegetation (plant species composition and structure) are very closely connected;

(iii) Habitats are usually closely associated to vegetation types and although vegetation provides one of the main components required for ecosystem functioning and ecosystem services, it is rarely covered in most monitoring schemes;

(iv) A number of habitats occur at scales that can be identified using remote sensing techniques and therefore it is more practical to deliver large scale assessments.

The use of RS for biodiversity assessment is based on the premise that a relationship exists between the reflectance of land cover with the composition and structure of the landscape and the existing diversity of ecosystems, vegetation and habitat types, habitat categories, as well as of species and genera that may be present within it. RS can thus especially contribute to the indirect assessment of biodiversity by providing information on the structures and composition of landscape and land cover. Principally, the coarse mapping of habitat and forest types, vegetation structure, landscape structure and broad habitat fragmentation is possible. For certain habitats, quite detailed types can be distinguished using EO techniques. New sensors and multi-temporal approach could contribute to higher resolution; radar can moreover be used to monitor seasonal variation in wetlands (Jongman et al 2008). Furthermore, some other features of biodiversity related to site conditions, physiological processes, pollution, stress conditions or vegetation damage can be used for monitoring of biodiversity and its changes. Earth Observation can become part of a biodiversity monitoring

system providing a vehicle for generalisation (i.e. extrapolation) and context to the field samples. It can deliver additional contextual data on land cover and provide information on trends if linked with field observation data. It is expected that its use for landscape structure and linear features will complement the observed species and habitat data and, in some cases (e.g. linear features), may deliver proxies for field observation.

A possible key to success in the use of remote sensing is its ability in some cases to discriminate habitat types more precisely and to levels that relate directly to other components of biodiversity. In the framework of the EBONE project, investigations have been done to some of these approaches. Habitat structure is something that can now be increasingly discriminated remotely, particularly with finer scale airborne sensors. The structure of vegetation is a key feature enabling classification of habitats but also relates directly to the habitat requirements of many species and general relationships with measures of species' diversity.

The approach developed in BIOHAB (FP5) and refined in EBONE (FP7) allows the use of a habitat classification system based on General Habitat Categories (GHCs) as a core part of a biodiversity observation system.

The GHC approach (Bunce *et al.*, 2005, Bunce *et al.*, 2008) provides a system for consistent recording and monitoring of habitats across Europe, with the potential for extension to other parts of the globe. Due to the fact that the GHCs are based primarily on life forms, they can provide the lowest common denominator linking to other sources of data required for assessing biodiversity e.g. phytosociology, birds and butterflies. They may also be more easily discriminated from the air or space using remote sensing methods and show great comparability with the LCCS system that has been used for Land Cover in Africa by FAO (DiGregorio and Jansen 2002). Potentially, GHCs provide an extremely powerful assessment tool for biodiversity, providing a missing link between detailed site-based species, population and community level measures and extensive assessments of habitats and land cover from remote sensing. In the BIO_SOS project an effort will be made to improve the possibility of discriminating GHC from space, which is at present a great potential for this habitat monitoring system.

However, the already discussed contribution to biodiversity assessment and monitoring are not only at the level of indices, but also at levels which are either broader or finer than the details defining indices. The BIO_SOS proposed system might detect elements which can be extremely useful for better description of habitat status: lines of trees, bushes and grass can help to better define connectivity for given animal species. The presence of early pressure effects will be considered in Task 6.3 of WP6: e.g. small decrease in size of a prairies or forests, increase of paths (specific path may be tracked in favourable conditions e.g. seasonal, phenological, size and alignment). Tourism might also leave linear signatures in the images. Soil erosion, that often follows the presence of a new path, might also be detected as soon as it causes small landslides, large sedimentation patches or digs new gullies. The effects of excessive tillage in sloping ground may also be visible. A small but important part of the until-now-hidden (to medium spatial resolution satellite images) soil surface modifications, might be revealed and observed in the images by integrating ancillary information and expert knowledge. Most probably, only some of the given examples will end up in the final list of the project achieved results. Nevertheless, BIO_SOS can provide a series of keys to observations which are basic for understanding what is happening, hence how the habitat quality is probably changing. Even though, BIO_SOS will not produce a final software for all the expected results (e.g. due to lack of detection on our images), it will nevertheless provide a guidance for future observations through examples of what has been achieved.

On the basis of this last paragraphs it is obvious that the list of adopted indicators represents only a first step.

6. The selection of indicators for BIO_SOS

The indicators used in the development work in BIO_SOS should:

(i) build on existing ideas and priorities from policy and research fields – ideally our indicators should be of broad relevance to policy and research requirements
(ii) form part of any standard set of observations that might ultimately be integrated in a Global or European Biodiversity Observation Network;
(iii) have data available from sufficient sites and sources to enable testing of development options;
(iv) provide a fair test of whether added value can be obtained by linking data from different levels through increased power to detect change over time, increased capacity for assessments in space, or reductions in cost and efficiency e.g. timeliness of data.

The SEBI list is now broadly accepted by the EEA and EU partner countries and opportunities for a radically new approach are currently limited. Hence the selection of indicators and observations for the initial development of BIO_SOS methodologies will primarily be based on the current SEBI list. However, it also takes into account the data issues described in Section 4.

In EBONE already an expert assessment has been carried out to determine potential indicators that can be used among others by applying RS. The conclusion was that three main indicators should be used, covering:

(i) Extent and change of habitats of European interest in the context of a general habitat assessment;
(ii) Abundance and distribution of selected plant species;
(iii) Fragmentation of Natural and semi-Natural areas.

For BIO_SOS, Pressures can be added as far as they are spatially explicit.

Tables 1, 2 and 3 provide an assessment of the indicators selected for further work and a summary of the approaches that may be adopted in EBONE and accepted in BIO_SOS as well. For completeness, Table 4 on threats and indicators includes the first four columns of the original Table 2 presented in Annex 2 of the cited UNEP workshop (Workshop 2009), excluding what concerns marine habitats not included in the BIO_SOS test sites, along with a fifth column indicating BIO_SOS EO based proposed contribution to indicator extraction. This contribution will be further investigated in WP4, WP5 and WP6, which are starting in month 3, month 5 and month 3, respectively.

Table 1. SEBI Indicator: Habitats of European Interest	
Aim:	To show the conservation status of habitat types of Community Interest (as listed in Annex 1 of the Habitats Directive).
Headline Result:	Between 40% and 80% of habitats of Community Interest (within the EU) have an unfavourable conservations status.
Source data:	Data provided by 25 EU states (Bulgaria and Romania to be included in 2013). Based on member state assessment of each habitat in each biogeographical zone.
Issues:	The extent and condition of habitats is one of the most important and useful measures of the state of biodiversity in Europe. There is a legal obligation to protect priority habitats and the condition of habitats is often related to the distribution and abundance of many other species and populations of value. Habitats are also providing the basis for many assessments of ecosystem services. The current measures are restricted to EU member states, do not cover the broad habitat types representative of the wider countryside in which many people live and interact with biodiversity, and are based on relatively subjective (expert) assessments of habitat condition related to site specific objectives. These qualitative assessments are used to assess the effectiveness of Natura 2000 network and compliance with the Habitats Directive but have limited value in relation to comparative assessments of changes in biodiversity in space or time.
Opportunities:	Developments in remote sensing combined with the use of GHCs provide an opportunity for more detail assessments of habitat quantity and quality. This indicator has a high relevance for biodiversity assessments in Europe because it indicates the area of available habitats and ecosystems across Europe and might also be used to make inferences about species‘ status and taxon-specific indicators of biodiversity.
BIO_SOS challenge:	The challenge is to develop methods for ”wall to wall“ mapping and assessments of habitats across Europe that will be relevant to habitats in Natura 2000 sites and the wider countryside. This is currently delivered by a combination of two SEBI indicators “Habitats of European Interest” and ”Ecosystem Coverage“. The “Ecosystem Coverage” indicator is based on the habitat coverage; this can be currently done by using CORINE Land Cover (CLC) map, which is the best available source of land cover data with pan-European coverage. However, for the test areas also other and more refined observation tools will be used. As in the CLC methodology, detail is lost below an area of 25 ha. This is not acceptable for Natura 2000 sites. To address this challenge BIO_SOS will develop and test the use of GHCs in combination with several types of VHR RS data derived products to map and delimit a range of habitat types across Europe and a more accurate, consistent and repeatable basis.
Criteria for success:	Detection of fine scale habitats of European Interest such as dolinas, springs, as well as within habitat patches structure.

Table 2. SEBI Indicator: Abundance and Distribution of Selected Species	
Aim:	To assess whether decline in widespread species in Europe has been halted.
Headline Result:	Europe's common birds have declined by 10% since 1980 with particularly severe declines in farmland birds (50%) and forest birds (9%). Europe's grassland butterflies have declined by 60% since 1990.
Source data:	Data for these indicators are based on standard techniques and sound methodologies for aggregating indicators from different countries. Habitat related presentation of indicators. Birds: based on common bird monitoring schemes in 21 EU countries + Norway and Switzerland. Butterflies: limited geographical coverage: based on variables number of sites and time series in 9 countries.
Issues:	The indicators are based on a limited number of selected sites and only two taxa for which extensive data are available. The data for the indicator are sample based but not always random and may not reflect what is happening outside the selected areas.
Opportunities:	This indicator needs to be developed for additional taxa and have a coverage that is more representative of Europe.
BIO_SOS challenge:	The current indicators for birds and butterflies are based on direct field observations taken from a limited number of sites that are not always representative of either all Natura 2000 areas or the wider countryside. In the modelling modules, BIO_SOS will investigate the potential for using GHCs and its detection by RS tools as a surrogate measure of species diversity, using birds, butterflies, and other insect species, plant species and other taxonomic groups for which sufficient data are available from literature or previous projects. In theory, decreases in the area covered by a habitat would have a negative effect on the species dependent on this habitat; it is particularly useful for specialist species that are dependent on a restricted number of habitats. An assessment of changes in the extent and conservation status of the habitat, on which selected species occur, may provide a way of estimating indicators on a broader scale within N200 sites. The test of a combined GHC methodology with RS-monitoring of habitat extent and change of habitats, as well as with both Ecological Niche Models (ENM) and indices of landscape functional connectivity, will make possible the evaluation of this approach. Data from field sites (collected in Task 4.4 of WP4) with biodiversity and habitat assessments using GHCs, will be used to test associations between different diversity between diversity (e.g. alpha, beta and gamma diversity). This is also done in tasks 6.2 of WP6 as well as in WP7, in which the reporting takes place.
Criteria for success:	Habitats are successfully detected and assessed and linked with species abundance/probability of distribution.

Table 3. SEBI Indicator: Fragmentation of natural and semi-natural areas	
Aim:	To show how fragmented European natural and semi-natural landscapes are and what can be done to preserve biodiversity despite fragmentation (e.g. by understanding the main causes of fragmentation). The fragmentation of natural and semi-natural areas is regarded as a major pressure on biodiversity as species and populations dependent on large patch sizes or dispersal between patches are put at a greater risk.
Headline Result:	Core forest areas have been fragmented between 1990 and 2000, most severely in North-eastern and South-western Europe – this change may be temporary (associated with forest management). In south-eastern Europe fragmentation is more permanent, associated with urbanization and agriculture. With a few regional exceptions, connectivity for forest species with short (1 km) dispersal distances are relatively stable.
Source data:	The indicator shows changes in the average size of patches and semi natural areas. Currently, it is derived from the CORINE Land Cover maps produced from the interpretation of medium resolution satellite imagery. But the monitoring of Natura 2000 sites and their neighbouring areas at regional and local scale requires the use of Land Cover maps originating from very high resolution imagery.
Issues:	The emphasis is on the fragmentation of forest patches and species depending on them. Fragmentation below the threshold of 25 ha is not detectable using the CLC. The RS tools in BIO_SOS will allow achieving better results. The measure does not provide a direct measure of the impact of habitat fragmentation on species populations.
Opportunities:	Data from new habitat mapping approaches, using the GHC approach, in combination with specific RS tools such as LiDAR, will give an opportunity to improve the current indicator.
BIO_SOS challenge:	Work in BIO_SOS will explore the extraction of landscape indicators at various spatial resolutions, but mainly focusing on very high spatial resolution. This will focus on traditional spatial pattern indicators, such as fragmentation and connectivity but also explore the potential for using more detailed information on habitats from GHCs in combination with LiDAR, where available. This will be done in task 6.2 and will be reported in WP7.
Criteria for success:	Capability to detect better differences between heterogeneity and fragmentation.

Table 4.

Broad threat category	**Existing indicators**	**Gaps**	**Potential indicators**	**BIO_SOS contribution to indicator extraction**
Habitat loss: agriculture Forestry Built area	Trends	Degradation Infrastructure & Transportation Intensification		Specific **class transition** quantification from land cover change maps obtained by automatic EO data processing. **Example of class transitions:** From natural habitat types and/or habitat categories (GHCs) into: -agricultural land -urban and artificial infrastructure
Invasive species	Trends in invasive species – 4 indicators currently being developed			New research work combining changes in habitat coverage at the site scale with both ENM and indices of landscape functional connectivity to provide inferences on shifts in alien and invasive species potential distribution.
Pollution		Acidification Phosphorus Pesticides & Ag wastes Sediment		
Over-exploitation	Indicators of sustainable use	Logging impacts on habitat quality	Logging intensity	Change in % of coverage by VHR EO data (pansharpened data)
Climate change		Climate change impacts	1) Climate impact indicator (envelope-based birds only) 2) Change in timing &	

			magnitude of peak flows 3) Climate-induced fire regime change 4) Range changes and vegetation shifts 5) Change in sex ratios of turtles (& other herps) due to change 6) Catastrophic events?	3) detection of fires from (LC) and Land cover change map (LCC) 4) from LC and LCC 6) flooded area-task 6.3 extension from LC and LCC
Fire		Altered fire regimes	% fire dependent habitat under fire suppression programmes	Frequency of burnt area from EO time series combined with ancillary data in the neighbouring of Natura 2000 sites
Water extraction/use	River fragmentation	- Water extraction/flow diversion - Water body/course modification	1) % basins with anthropogenically altered flow 2) % river length canalised 3) % river length that has lost floodplain connectivity	From LC and LCC: Artificial infrastructures detection Habitat shifts due to changes in water table height

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Appendix 1: CBD Strategic goals and the 2020 headline targets

The Strategic Plan of the CBD for 2011-2020 includes 20 headline targets for 2020, organized under five strategic goals. The goals and targets comprise both: (i) aspirations for achievement at the global level; and (ii) a flexible framework for the establishment of national or regional targets. Parties are invited to set their own targets within this flexible framework, taking into account national needs and priorities, while also bearing in mind national contributions to the achievement of the global targets. Not all countries necessarily need to develop a national target for each and every global target. For some countries, the global threshold set through certain targets may already have been achieved. Other targets may not be relevant in the country context.

Strategic goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Target 1**:** By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

Target 2**:** By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes are being incorporated into national accounting, as appropriate, and reporting systems.

Target 3**:** By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio-economic conditions.

Target 4**:** By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

Strategic goal B. Reduce the direct pressures on biodiversity and promote sustainable use

Target 5**:** By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 6**:** By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems, and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

Target 7**:** By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 8**:** By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

Target 9**:** By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Target 10**:** By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

Strategic goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Target 11**:** By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes.

Target 12**:** By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Target 13**:** By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services.

Target 14**:**By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15**:** By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Target 16**:** By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.

Strategic goal E.Enhance implementation through participatory planning, knowledge management and capacity building

Target 17**:** By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

Target 18**:** By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels

Target 19**:** By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely

shared and transferred, and applied.

Target 20**:** By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan 2011-2020 from all sources and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

Appendix 2: SEBI Indicators

CBD focal areas	**EU Headline**	**Proposed Indicators**	**Detailed indicators**
Status& trends of components of biological diversity	Trends in abundance and distribution of selected species	1. Abundance and distribution of selected species	1.1 Common birds
			1.2 Butterflies
	Change in status of threatened and/or protected species	2. Red List Index for European Species	
		3. Species of European Interest	
	Trends in extent of selected biomes, ecosystems and habitats	4. Ecosystem coverage	
		5. Habitats of European Interest	
		6. Livestock genetic diversity	
	Coverage of protected areas	7. Nationally designated protected areas	
		8. Sites designated under the EU Habitats and Birds Directive	
Threats to biodiversity	Nitrogen deposition	9. Critical load exceedance for nitrogen	
	Trends in invasive alien species	10. Invasive alien species in Europe	
	Impact of climate change on biodiversity	11. Occurrence of temperature-sensitive species	
			11.1 Indicator of climate change on European bird populations
			11.2 Indicator of climate change impacts on European butterflies
			11.3 Indicator of climate change impacts on alpine plant species
			11.4 Indicator based on common plant species in LTER sites.
Ecosystem integrity and ecosystem good and services	Marine trophic index (or its terrestrial equivalent)	12. Marine trophic Index of European Seas	

	Connectivity/fragmentation of ecosystems	13. Fragmentation of natural and semi-natural areas	
		14. Fragmentation of river systems	
	Water quality in aquatic ecosystems	15. Nutrients in transitional, coastal and marine waters	
		16. Freshwater quality	
Sustainable use	Area of forest, agricultural, fisher and aquaculture ecosystems under sustainable management	17. Forest: growing stock, increment and fellings	
		18. Forest: deadwood	
		19. Agriculture: nitrogen balance	
		20. Agriculture: area under management practices potentially supporting Biodiv.	
		21. Fisheries: European commercial fish stocks	
		22. Aquaculture: effluent water quality from fish farms	
	Ecological footprint of European Countries	23. Ecological Footprint of European Countries	
Status of access and benefit sharing	Percentage of European patent applications for inventions based on genetic resources	24. Patent applications based on genetic resources	
Status of resource transfers and use	Funding to biodiversity	25. Financing biodiversity management	
Public opinion	Public awareness and participation	26. Public awareness	

Appendix 3: Acronym list

CBD	Convention of Biological Diversity
CLC	CORINE Land Cover
DPSIR	Driver Pressures State Impacts Responses
EBONE	European Biodiversity Observation Network
EEA	European Environmental Agency
ENCA	European Nature Conservation Agencies
ENM	Ecological Niche Models
EO	Earth Observation
EODHaM	Earth Observation Data for Habitat Monitoring
EUNIS	European Nature Information System
FAO	Food and Agriculture Organization
GEO BON	Group on Earth Observations Biodiversity Observation Network
GEOSS	Global Earth Observation System of Systems
GHCs	General Habitat Categories
GMES	Global Monitoring for the Environment and Security
LC	Land Cover
LCC	Land Cover Change
LIDAR	Light Detection and Ranging
RS imagery	Remote Sensed imagery
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
SEBI	Streamlining European 2010 Biodiversity Indicators
SR	Spatial Resolution
SRC	Spectral Rule-based Classifier
UNEP	United Nations Environment Programme
VHR	Very High Resolution
WCMC	World Conservation Monitoring Centre
WUR	Wageningen University and Research center