EBONE

European Biodiversity Observation Network:

Design of a plan for an integrated biodiversity observing system in space and time

D1.1

The Selection of Biodiversity indicators for EBONE Development Work

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Authors: T. W. Parr, R.H.G. Jongman, M.Külvik.

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Executive Summary

1. The main aim of this report is to assess which biodiversity indicators should be selected as the basis for developing new EBONE methodologies for assessing biodiversity. These methodologies will combine different types and scales of biodiversity relevant observations and form the basis of recommendations on the design and implementation of the European Biodiversity Observation Network.

2. The development of EBONE and the choice of these test indicators are set in the context of the emerging goal to develop a GEO (global) Biodiversity Observation Network (GEO BON) and its implementation within an institutional framework operating at the European level. One of the main requirements from EBONE will be to provide continued access to data for CBD reporting against the 2010 target at national and European levels. Hence, the indicator selection process began with a brief overview of biodiversity indicators used (or proposed) in large scale (national, continental or global) programmes. It covered indicators in the GEO Global Biodiversity Observation Network (GEO BON), the European CBD indicators (SEBI), composite indicators and indicator taxa. It also made use of results and ongoing efforts of European research projects.

3. The lack of data is probably the biggest constraint on the development and use of indicators for large-scale (national, European and global) biodiversity assessments. Two of the key questions EBONE is addressing 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 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) in-situ biodiversity data from Long-term Ecosystem Research Sites (LTER) in Europe; and (iii) remote sensing data, from both satellite and airborne data sources.

4. The EuMon database has shown that there are major gaps in the coverage of biodiversity data at the European level. Some of the most significant gaps for the delivery of biodiversity indicators are in relation to systems for monitoring changes in the extent and quality of habitats and the lack of systems and models for combining in situ observations with remotely sensed data to provide reliable European statistics and “wall to wall” assessments of a broader range of biodiversity indicators.

5. In the FP5 BioHab project a habitat monitoring system has been developed that enables consistent recording and monitoring of habitats across Europe, and potentially, globally. The habitat monitoring methodology that EBONE is using is based on the methodology developed in BioHab and has 154 General Habitat Categories (GHCs) derived from 16 easily identifiable Life-Forms and 18 Non Life Forms. This GHC methodology 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 and Non Life Forms. They may 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 because the system is based on habitat structure. The approach provides 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 from remote sensing.

6. One of the main aims of EBONE is to develop and test methods aimed at realising the potential of BioHab as a core component of a European Biodiversity Observation system. To identify appropriate indicators for this development work we undertook an expert assessment of the SEBI “Streamlining European 2010 Biodiversity Indicators” set of 26 indicators taking account of: the availability of data;

and the potential added value of combining data from different sources (including BioHab) to produce a more cost-effective set of indicators.

7. The conclusion of this assessment was that EBONE would focus its initial development work 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 species (birds, butterflies and plants); and (iii) fragmentation of natural and semi-natural areas.

8. Two additional indicators were also identified that might fill key gaps in the SEBI set. These were related to: (i) indicators of climate change impacts on biodiversity and ecosystems; and (ii) assessments of ecosystem services. These two areas may be considered again later in the project as methodologies for combining data from different sources are developed.

9. Work will now focus on the statistical aspects of inter-calibration and the development of criteria for assessing the added value of combining data from different sources.

1 Introduction: scope and objectives of this report

1.1 Background to the work on indicators

1.1.1 The main aim of the European Biodiversity Observation Network (EBONE) project is to provide the scientific foundation and practical instruments for a harmonised monitoring system. To help achieve this, the EBONE project will develop new techniques enabling better use of observations made using different types of method and across different scales (e.g. from in situ and remote sensing (RS) sources).

1.1.2 The biggest 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, large-scale observation systems usually have to meet the requirements of many different stakeholders are often required to fulfil multiple objectives and this can complicate the design of the system (Parr *et al* 2002).

1.1.3 The specific goals of the integrated biodiversity observation system for Europe will be developed during EBONE and will to some extent be determined by the new techniques that emerge from the project. The general features of this system are likely to be that it should be:

(i) stakeholder and policy led: to ensure that the observation system provides data and information products that are relevant to current research and policy requirements;
(ii) 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: Responses (DPSIR) at multiple scales;
(iii) hierarchical: linking observations from small to large scales;
(iv) cost effective: Developing a field monitoring system that delivers statistically correct data at the lowest costs, making best use of existing data through the development of new techniques that optimise the use of field and remote sensing data sources and taking into account scientific rigour, proof of concept, fitness for purpose and quality issues; and
(v) supported by an effective institutional and programme framework: ensuring that proposals are realistic, cost-effective and can be implemented through existing or easily developed institutional arrangements and programmes and can be harmonised between countries and regions. To achieve this EBONE is developing close cooperation with biodiversity conservation agencies, international organisations and the biodiversity-relevant treaty bodies, non-governmental organisations (both national and international) in the fields of biodiversity protection as well as environmental and scientific research organisations both in and out of academia.

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

1.1.5 The aim of this report is to assess which biodiversity indicators should be selected as the basis for developing new EBONE methodologies for assessing biodiversity. These indicators will be used in the development of new approaches to combining different types and scales of biodiversity relevant observations and the work will contribute to recommendations on the design and implementation of the European Biodiversity Observation Network. Recommendations from this report will inform the research and development activities being delivered in many of the other EBONE work packages (see Section 6).

1.2 The scope of EBONE in relation to indicators

1.2.1 One of the main objectives of EBONE is to improve the delivery of biodiversity information to decision makers. The main users of EBONE are likely to be decision makers at European level, but also at regional and national level in relation to their national and European tasks and the obligations under biodiversity-related conventions.

1.2.2 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 in EBONE is to provide observations and methodologies that meet policy requirements for indicators that are relevant to the assessment of biodiversity and that can be applied on a European scale and linked to global requirements. Amongst other things, EBONE aims to provide access to indicator data for CBD reporting against the 2010 target as currently covered by the "Streamlining European 2010 Biodiversity Indicators" (SEBI) (EEA 2007). The developments made by EBONE should provide a system that: (i) enables cost-effective reporting on the agreed SEBI indicators; (ii) helps develop and provide data for new indicators to fill gaps; (iii) provides background information and understanding necessary to interpret indicators, understand processes of change and help deliver appropriate solutions to current and future biodiversity related challenges; (iv) identifies a core set of measurements for biodiversity, combining species and habitat level measures, to enable consistent approaches to the assessment of change in the status and extent of habitats of European interest and their capability to deliver key ecosystem services; and (v) help define the requirements and technological specifications for the use of in situ and EO sensors and computer technologies to enable real-time monitoring of biodiversity and ecosystem processes.

1.2.3 EBONE is focussing on terrestrial biodiversity and will therefore not develop marine indicators. However, a link with freshwaters will be made.

1.3 Report objectives

1.3.1 The objectives of this report are to provide:

- (i) a brief overview of biodiversity indicators used (or proposed) in large scale (national, continental or global) programmes, including an overview of the main indicator frameworks used in the Convention on Biological Diversity (CBD) process;
- (ii) a discussion of the steps that EBONE could take to address some of the main limitations of current indicators sets, particularly those related to the availability of data; and
- (iii) the rationale and recommendations for the selection of indicators for method development in EBONE.

1.3.2 This report does not make recommendations on the full set of measurements and indicators that will eventually form part of the design for the European Biodiversity Observation Network. These will be considered as part of a broader review of stakeholder requirements being undertaken in work done in other parts of the EBONE project, including work in Work package 8 on the design of a monitoring system.

2 Background to indicators of biodiversity

2.1 What makes a good indicator: concepts and criteria

2.1.1 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.

2.1.2 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 2.1). Just monitoring birds or butterflies, because they are attractive and easy to measure is insufficient. A monitoring system also should include important aspect of the structure, compositional or functional attribute of the system.

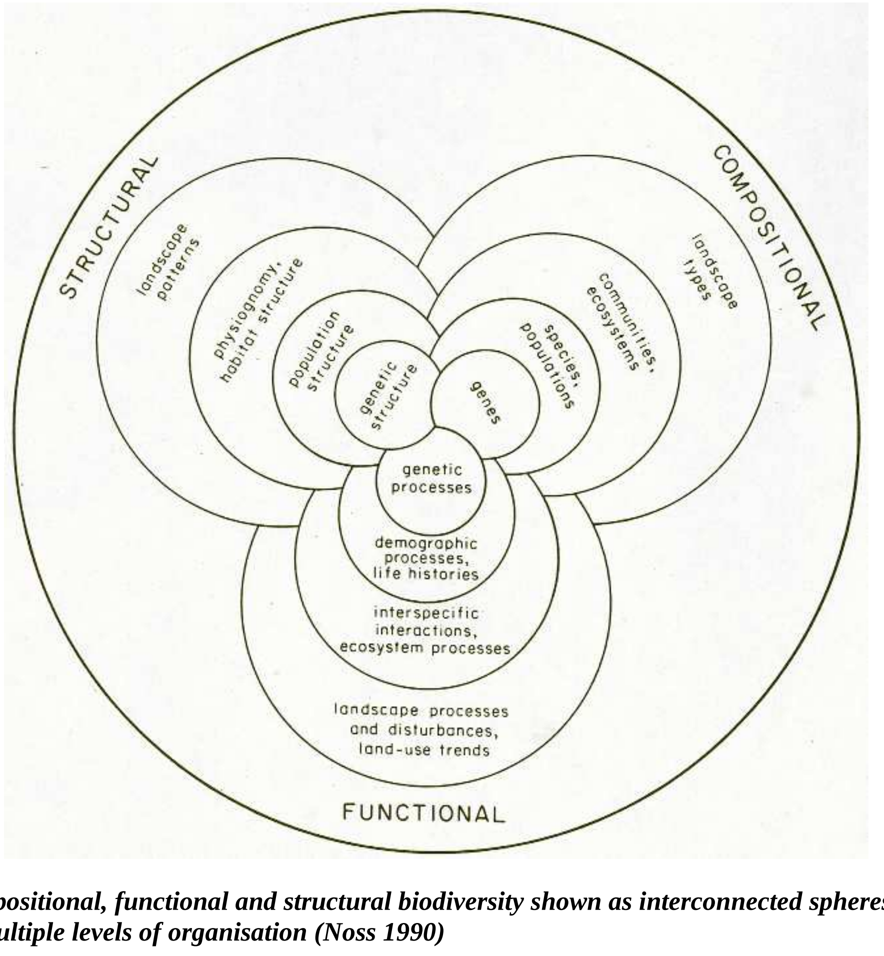

Figure 2.1. Compositional, functional and structural biodiversity shown as interconnected spheres, each encompassing multiple levels of organisation (Noss 1990)

2.1.3 These structural, functional and compositional aspects of biodiversity are needed to address big questions related to forest development, desertification, the impact of climate change and require the consideration of global and continental climate related processes such as habitat change, 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 full picture. Upscaling and downscaling is also essential for understanding processes.

2.1.4 The definition of a good indicator is largely dependent on the use to which it will be put. 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 that they should:

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

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

(iv) Be based on a 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) Be acceptable and intelligible outside of the scientific community: 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) Be based on routinely collected data: indicators must be based on routinely collected, clearly defined, verifiable and scientifically accepted data.

(vii) Demonstrate cause-effect relationships: 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) Have a wide spatial coverage: indicators should ideally be pan-European and include adjacent coastal areas, if and where appropriate.

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

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

(xi) Be sensitive to 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.

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

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

- What is the indicator supposed to measure, what quantity does it represent?
- Why is the indicator thought to be relevant for biodiversity and its sustainability in relation to environmental, social and economic change?
- Does it support EU concerns as expressed in EU policies?
- 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?
- At what spatial level is the indicator available? How can it be used in regional, national or European models and scenarios as indicators policy impacts and ecosystem changes.

3 Observations and indicators relevant to EBONE

In this Section we present four examples of large scale approaches to observation systems and indicators that are relevant to the development of a European Biodiversity Observation Network.

3.1 Indicators in the GEO Global Biodiversity Observation Network (GEO BON)

3.1.1 EBONE is a European pilot project for the Global Biodiversity Observation System serving European and Global requirements for data, information and knowledge on the state, drivers and consequences of changes to biodiversity and ecosystems. GEO BON is the Community of Practice on biodiversity of GEO's Global Earth Observation System of Systems (GEOSS). Its goal is specified in the GEO 2007-2009 Work Plan (Task BI-07-01): *"Develop and implement a biodiversity observation network that is spatially and topically prioritized, based on analysis of existing information, identifying unique or highly diverse ecosystems and those supporting migratory, endemic or globally threatened species, those whose biodiversity is of socio-economic importance, and which can support the 2010 CBD target. Develop a strategy for assessing biodiversity at both the species and ecosystems level. Facilitate the establishment of monitoring systems that enable frequent, repeated, globally coordinated assessment of trends and distributions of species and ecosystems of special conservation merit……..."*

3.1.2 The conceptual framework for GEO BON (GEO BON 2008, Scholes et al 2008) is wider than EBONE, but EBONE has a similar approach. GEO BON supports the need to make and link observations across different levels of biological organisation from "genes to ecosystems" and across a range of scales involving top-down (remote sensing) and "bottom-up" (sites) observations. In EBONE genes are not included.

3.1.3 GEO BON's long-term vision is "to provide timely and relevant information on biodiversity status and functions so as to improve environmental management and human well-being." One of the main goals of GEO BON is to use baseline data to produce one or a few reliable and comprehensive indicators of global biodiversity. In this way GEO BON would support the world's ability to assess biodiversity change world-wide and report at continental and global levels. The methods and indicators to be developed in EBONE should contribute to the implementation of the GEO BON concept.

3.1.4 The scope of GEO BON includes all components of biodiversity, terrestrial, freshwater, coastal, and open ocean marine components. It includes limited analyses, such as change detection, trend analyses, forward projections, range interpolations and model-based estimations of the supply of ecosystem services. It can support further detailed assessments undertaken by biodiversity and ecosystem assessment bodies. In this assessment process indicators are being used. To provide the data for these indicators, GEO BON also has the goal to establish a coordinated global *in situ* sampling scheme for monitoring change in a large set of species and ecosystems to cover the major aspects of biodiversity. Since only a tiny and non-representative percentage of all species is currently being monitored, GEO BON will establish a comprehensive global sampling scheme for baseline data based on key groups of species (Table 3.1) and parameters that relate to these (Table 3.2).

3.1.5 The GEO BON list is currently aspirational. Although GEO BON's concept document does indicate some broad categories of measurements that might be included in a global observing system final agreement on the list of measurements and how they should be implemented has not yet been achieved. A more detailed implementation plan will be available in 2010.

Stratum	Included groups
Provisioning species	Domesticated mammals & birds, food crops, forestry species, medicinal plants, wild-harvested mammals, freshwater fish, coastal reef fishes, marine high tropic fish, pelagic fish, demersal fish
Treaty species: Migratory, RAMSAR, CBD, etc.	Migratory passerines, migratory waterfowl, sedentary waterfowl, large marine mammals, sea turtles
Key functional groups	Pollinators, N-fixing organisms, soil nematodes, keystone food plants
Top predators	Sharks, raptors, mammalian predators, snakes, spiders
Herbivores	Bovids, caprids, camelids, antelopes, rabbits, hares (e.g., for mammals)
Primary producers	Grasses, trees, shrubs, mosses, corals, phytoplankton, seagrass
Detritivores	Crayfish, lobsters, crabs, dung beetles, earthworms, molluscs, termites
Charismatic species	Elephant, rhino, hippo, primates, large cats, wolves, bears, pandas, whales, dolphins
Indicator groups	Salamanders and newts, rainforest frogs, freshwater frogs, butterflies, moths, bats, lichens, fruit-eating birds, ants, seed-eating birds, insect-eating birds
Disease and pest species	Human disease-vector insects, ticks, small rodents, locusts, crop pest insects, crop weeds, aquatic weed plants, toxic algal bloom species
Evolutionary clade representatives	Ferns, cycads, echinoderms, ascidians, crocodiles, tortoises
Major Ecosystem types	Freshwater, coastal, marine, forest & woodland, wetland, dryland

Table 3.1. Reproduced from Table 4 of the GEO BON concept document. It shows general categories that could be used to prioritise the choice of intensively monitored species across all biomes, ecosystems, habitats, taxa, functional types, etc.

Criteria	Parameters
Metrics of change	Spatial shifts: movement of species distribution areas, changing altitudinal ranges, habitat shifts
	Abundance shifts: change of numbers and density
	Community shifts: changes in endemicity and homogenization
	Migration: phenological and spatial changes
	Local and global extinction rates
	Demographic changes: standing age structure, sex ratios/recruitment intensity, trophic structure
Drivers of change and threats	Direct drivers - habitat change, climate change, pollution, invasives, overexploitation
	Indirect drivers - increasing global trade, population growth, increasing consumer demands, etc.

Table 3.2. Reproduced from Table 5 of the GEO BON concept document. It shows a provisional list of parameters that should be measured for a selected group of species.

3.2 The CBD indicators in Europe: SEBI

3.2.1 The development of biodiversity indicators in Europe has been heavily influenced by the requirements of the CBD target (more usually known as the 2010 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”.

3.2.2 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).

3.2.3 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.

3.2.4 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 (EEA, 2009).

3.2.5 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 (see 3.2.2) and were selected according to the criteria described in Section 2.1.4. 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).

3.2.6 A recent EEA report (2009b) on "Progress towards the European 2010 biodiversity target" 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. See:
http://www.eea.europa.eu/highlights/publications/progress-towards-the-european-2010-biodiversity-target/

3.2.7 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 approaches 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 an absence of indicators that reflect climate change impacts on biodiversity and ecosystems as these are not easy to derive directly from biodiversity data because climate effects are often confounded with many other factors. These are currently being developed and should appear in future SEBI reports.

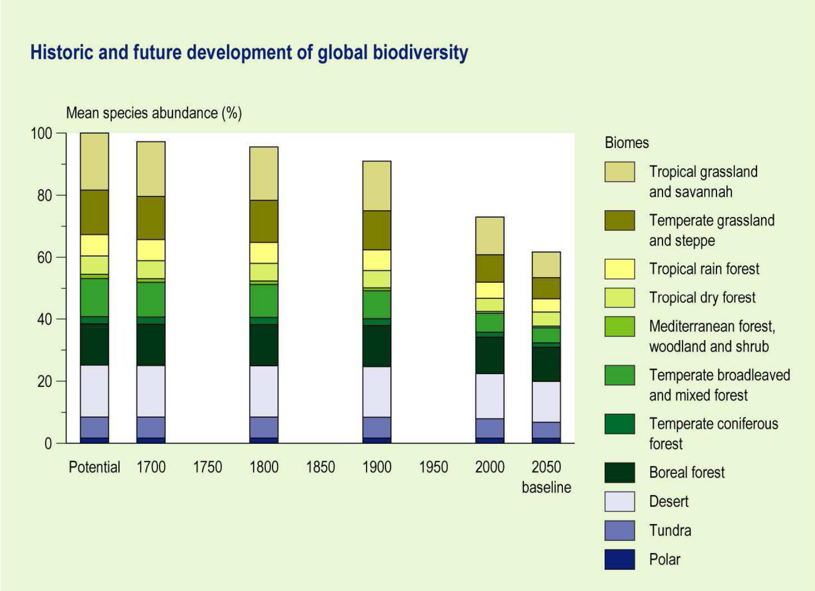

Figure 3.1. Historic and estimated future development of global biodiversity

3.3 Composite Indicators

3.3.1 The indicators of the state of biodiversity proposed in GEO BON and SEBI are based on relatively simple aggregations of data which can be intuitively understood by non-experts. The disadvantage of this is that they usually only cover limited aspects of total biodiversity and do not provide a broad assessment of biodiversity loss or gain (or its drivers).

3.3.2 There have been several attempts to address this through the development of composite indicators which seek to aggregate many different components of biodiversity. These indicators have often been used to provide regional or global scale assessments of biodiversity. Interpretation of these indicators is often aided by reference to a "baseline" date or condition. Composite indicators may also require judgements to be made about the relative importance (i.e. a value or weight) given to the component parts of the indicator.

3.3.3 Indicators of this type have been reviewed by ten Brink (2006). They include ecosystem-level and species level indicators such as the:

- Natural Capital Index (NCI) – a measure of species abundance relative to a low impacted or pre-industrial state calculated from estimates of ecosystem area (i.e. quantity of the ecosystem) and ecosystem quality (mean species in the remaining areas).
- Living Planet Index (LPI): a measure of the mean species abundance of a core set of species relative to 1980.
- Mean Species Abundance (MSA) – a measure of the mean species abundance relative to the natural or low impacted state at the ecosystem level. The MSA at global and regional levels is the sum of the underlying biome values, in which each square kilometre of every biome is equally weighted. This indicator was used in the Cost of Policy Inaction (COPI) study on biodiversity (Braat and Ten Brink, 2008).
- Species Assemblage Trend index (SAT): is the mean species abundance of a species group compared to a reference year (i.e. 1980). The groups could be taxonomic groups, species of cultural interest, endemic species, migratory species, threatened species etc.
- Red-list index (RLI) is a weighted assessment of extinction risk in particular taxonomic groups (e.g. birds).
- Biodiversity Intactness Index (BII) (Scholes and Biggs, 2005).

3.3.4 An example of the use of such indicators is provided by Braat and ten Brink (2008) in their overview of global biodiversity in five different forest types, two grassland types, tundra, deserts and polar ecosystems (Figure 3.1).

3.3.5 These kinds of generalisations provide a general overview of what is happening to biodiversity. Several of them (e.g. the NCI and MSA) are based on estimating biodiversity from ecosystem or land-cover areas and are used in data-poor situations where simple assumptions are made about the relationships between land cover and biodiversity. However, the general lack of field data for calibrating the relationship between land cover and biodiversity means that there is inevitably a lot of uncertainty in the maps and estimates derived from them.

3.4 Indicator Taxa

3.4.1 The development of indicators has been a busy area for research over recent years. Much of this work is related to the need to provide specific indicators of key species or general ecological condition. A common approach is to use data on the species richness of particular taxa within sites or communities as an indicator of overall species diversity. The SEBI indicators on birds and butterflies are examples of this type.

3.4.2 The two examples below explore the extent to which such measures might be representative of other taxa-based indicators of biodiversity and develop ideas for applying the approach to a wider range of taxa and geographical coverage.

A comparison of taxa for biodiversity assessment (the BioAssess project)

3.4.3 The Biodiversity Assessment Tools Project (BioAssess) was an EC FP5 project aimed developing biodiversity assessment tools for inland terrestrial ecosystems, comprising sets of indicators of biodiversity, to assess the impact of policies on changes in biodiversity in Europe. The impact of land-use intensity on biodiversity was measured in the sites (land-use units) along a transect in each country by assessing the diversity of soil collembola, soil macrofauna, ground beetles (Carabidae), plants, lichens, butterflies and birds. Protocols were developed for each group of plants and animals. Each of the potential indicators was evaluated by analysing their ability to predict other elements of biodiversity because such biological relevance had been identified as the most important criterion for a biodiversity indicator (Box 3.1). Although BioAssess showed that a single measure of biodiversity is unlikely to satisfy most stakeholder needs it did show how these indicators were inter-related. Birds, butterflies, plants and lichens provided the best indicators of overall biodiversity.

3.4.4 Several landscape indices derived from remote sensing were shown to be potentially useful indicators of the richness of single taxa and although no single index was correlated with the diversity of all components of biodiversity studied, a few indices correlated with more than one taxon. For example, total core area correlated with the richness of lichens, butterflies and ground beetles. Patch richness correlated with the richness of birds and collembola. Landscape evenness correlated with the richness of birds and butterflies.

Indicator taxa for the global monitoring of biodiversity change

3.4.5 Pereira and Cooper (2006) advocated the establishment of global biodiversity monitoring network based on a global sampling programme of indicator taxa. The recommended monitoring of birds and vascular plants at 2-5 year intervals integrated with 5 –yearly global land-cover maps. These global assessments would be integrated with regional programmes undertaking specific monitoring programmes of regional importance.

3.4.6 In the FP7-BioBio project that runs parallel to EBONE and focuses of agrobiodiversity in low input and organic farming a selection of indicator taxa was made for habitats to provide a basic measure of biodiversity. This selection included vegetation (flora), earthworms, bees and wasps and spiders as these species fulfil the requirements to be meaningful, easy to sample, sensitive to changes, representing other species and recognised by stakeholders (farming community). The choice of earthworms, bees and wasps and spiders was made based on their scientific value for monitoring, the preference of the stakeholders (a.o. farming representatives), the effort required to collect them and the global knowledge on the species groups. Among the farmer representatives bees and wasps were preferred over butterflies as pollinators and earthworms were preferred over collembola as soil organisms.

Box 3.1 BioAssess - summary of results showing the extent to which the key taxa provided good "indicators" of general biodiversity.. Reproduced from http://www.nbu.ac.uk/bioassess/

- **Birds** were found to be useful indicators of biodiversity; they significantly predicted the species richness of butterflies, lichens and plants. However, they were not found to be a good indicator of soil and soil-surface dwelling biodiversity. Birds are also suitable indicators of biodiversity for a number of other reasons including the ease with which they can be identified, the existence of ample ecological information and bird monitoring schemes and the fact that they are more threatened than most other taxa.

- **Butterflies** were found to be useful indicators of biodiversity; they significantly predicted the species richness of birds, lichens and plants. However, they were not found to be a good indicator of soil and soil-surface dwelling biodiversity. Butterflies are also suitable indicators of biodiversity because they are relatively easy to identify, are more threatened than most other taxa and there are butterfly monitoring schemes, using well-tested protocols, in many countries.

- **Plants** were found to be useful indicators of biodiversity; they significantly predicted the species richness of birds, butterflies, and lichens. However, they were not found to be a good indicator of soil and soil-surface dwelling biodiversity. Plants are also suitable indicators of biodiversity because they are relatively easy to survey and identify, as primary producers they play a critical role in supplying ecosystem goods and services, and because they are the single most important group of organisms in shaping the habitats and determining the physical environments for other species.

- **Lichens** were found to be useful indicators of biodiversity; they significantly predicted the species richness of birds, butterflies and plants, although a poorer predictor of the richness of other groups of species than birds, butterflies and plants. They were not found to be a good indicator of soil and soil-surface dwelling biodiversity. Lichens are also suitable indicators of biodiversity because they are easy to survey and many species are relatively easy to identify. In addition, their particular sensitivity to a wide range of anthropogenic factors and the length of time they tend to take to recover from their impacts make them a unique taxon.

- **Macrofauna** were found to be the most promising of the three groups of soil (or soil-surface) dwelling organisms as an indicator of the richness of other taxa, showing weak correlations with butterflies and carabids and stronger correlations with plants. However, only two of the many invertebrate groups that comprise soil macrofauna- soil Coleoptera and earthworms- were evaluated at species level, leaving the potential of this taxon least well understood in this project. A rapid assessment of soil macrofaunal could be done through combining measures of ant and earthworm diversity with macrofaunal family diversity.

- **Carabidae** (ground beetles) were found to be a poor indicator of other elements of biodiversity, only showing a weak correlation with soil macrofauna. Carabids are, however, potentially useful indicators of biodiversity because they are a very easy group of invertebrates to survey and are relatively easy to identify.

- **Soil Collembola** were found to be a poor indicator of other elements of biodiversity, only showing a weak correlation with lichens. Collembola are, however, potentially useful indicators of biodiversity because they are an easy group of soil invertebrates to survey. It is also possible to compare samples at a higher taxonomic level (genus) thus decreasing identification costs.

4 Indicators for EBONE: data constraints.

4.1 The lack of data is probably the biggest constraint on the development and use of indicators for large-scale (national, European and global) 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 (Table 4.1).

4.2 Two of the key questions EBONE is addressing 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 main types of data we are looking to combine in this process are collected at different scales and levels of sampling intensity. They correspond to the 3 levels identified by Diversitas (Ash *et al,* 2009) in its science plan for "assessing, monitoring and predicting biodiversity change" and they cover:

- in-situ biodiversity survey and monitoring data on species or habitats i.e. from field observations or samples;
- in-situ biodiversity data from Long-term Ecosystem Research Sites (LTER) in Europe; and
- remote sensing data, both satellite and airborne data sources.

Status and trends of the components of biological diversity	Trends in abundance of selected species	1a Birds
		1b 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
Ecosystems integrity and ecosystem goods and services	Connectivity/fragmentation of ecosystems	13 Fragmentation natural and semi-natural areas
		14 Fragmentation of river systems
	Water Quality in aquatic ecosystems	16 Freshwater quality

Table 4.1. Directly measurable indicators that can be based on species and habitats (European Environmental Agency, 2009)

4.1 Field survey data

4.1.1 Direct measurements of biodiversity are made for many purposes including research, policy evaluation, general surveillance compliance monitoring by environment agencies, and for general public interest often by amateur experts (Schmeller et al 2008). These data may be used as direct measures of the state and change in biodiversity provided they are of sufficient quality, cover a sufficiently long time periods (e.g. over 10 years) and are representative of the target area (e.g. national or European).

4.1.2 Work done during the development of the SEBI indicators evaluated available data and found few cases, where data were sufficiently comprehensive to be used for deriving indicators. A more complete analysis of the availability of biodiversity data is now possible through the use of the EuMon database of biodiversity monitoring schemes in Europe (http://eumon.ckff.si/). Results of this work will be reported by the EBONE Work Package 2 and will be used to highlight potential data sources for state and change indicators. This report shows that despite a large number of monitoring schemes few of these provide a comprehensive or representative European coverage and those that do have already been exploited as the basis for indicator development during the SEBI process.

4.2 In situ data from LTER sites

4.2.1 Long-term ecosystem research sites (LTER) make site based measurements of the main ecosystem components, include the biotic (biodiversity) and abiotic components (e.g. soils, waters, atmosphere, and climate). These data enable an understanding of the processes of ecosystem change and can be used to make strong inferences about the main drivers and pressures causing change. LTER-sites are often joined into networks that operate at national level (Hobbie et al 2003, Morecroft et al 2009) and work is in progress to develop co-ordinated approaches at European and Global levels.

4.2.2 A web-based, database of LTER sites (INFOBASE) was developed during the Framework 6 Network of Excellence, ALTER-Net (www.alter-net.info). This provides metadata on over 1000 LTER sites across Europe, including information on what measurements are made at each site.

4.2.3 Cocciufa et al (2007) reviewed the availability of data from LTER sites across Europe in relation to the SEBI headline indicators (Figure 4.1) as part of a process of developing recommendations for a core set of measurements at LTER sites. On the basis of this work a set of minimum recommended parameters has been agreed by LTER-Europe (Table 4.2). At present there is no guarantee that these measurements will be undertaken by all sites or national networks.

	Terrestrial	**Aquatic**
Abiotic (pressures)	Land cover and land use intensity *	
	Physical data (meteorological and water observations)*	
	Atmospheric deposition, water chemistry and eutrophication*	
	Soil chemistry and classification*	
Biotic (states)	Primary producers (vascular plants, phytoplankton, bacteria, biomass, NPP)*	
	Invertebrate taxa (selected on the basis of ecosystem type)	
	Invasive alien species in Europe since 1900 (EU check list)	

Table 4.2 Minimum recommended parameters to be collected at LTER-Europe Sites. *=highly recommended

4.2.4 At present there are some restrictions with the use of LTER sites for deriving indicators. First, sites are not selected randomly and do not provide a statistically representative sample of European systems and secondly, there is only a very limited degree of harmonisation of measurements at national or European levels. Work undertaken by ALTER-Net and the LTER-Europe network is aimed at addressing these problems (e.g. through the recommended standard measurements shown in Table 4.1).

4.2.5 Despite these problems, data from existing LTER sites can be used to inform the development and use of indicators in three ways:

(i) as a source of data for existing indicators. For example, data on butterfly trends in the UK contribute to the UK and European headline indicators on butterflies (note this reflects the fact that the data used for some of the existing SEBI indicators are not based on a statistically representative sampling framework at European levels);

(ii) to show the relationship between general pressures on biodiversity and biodiversity change. For instance climate change impacts; and

(iii) as a basis for extrapolation. For example, relationships between remotely sensed data and biodiversity parameters can be derived and then used to model biodiversity indicators across regions although the statistical basis of this will be difficult if it is unknown what the sites represent.

4.2.6 Approaches (ii) and (iii) in paragraph 4.2.5 have not yet been used to develop practical indicators at European level.

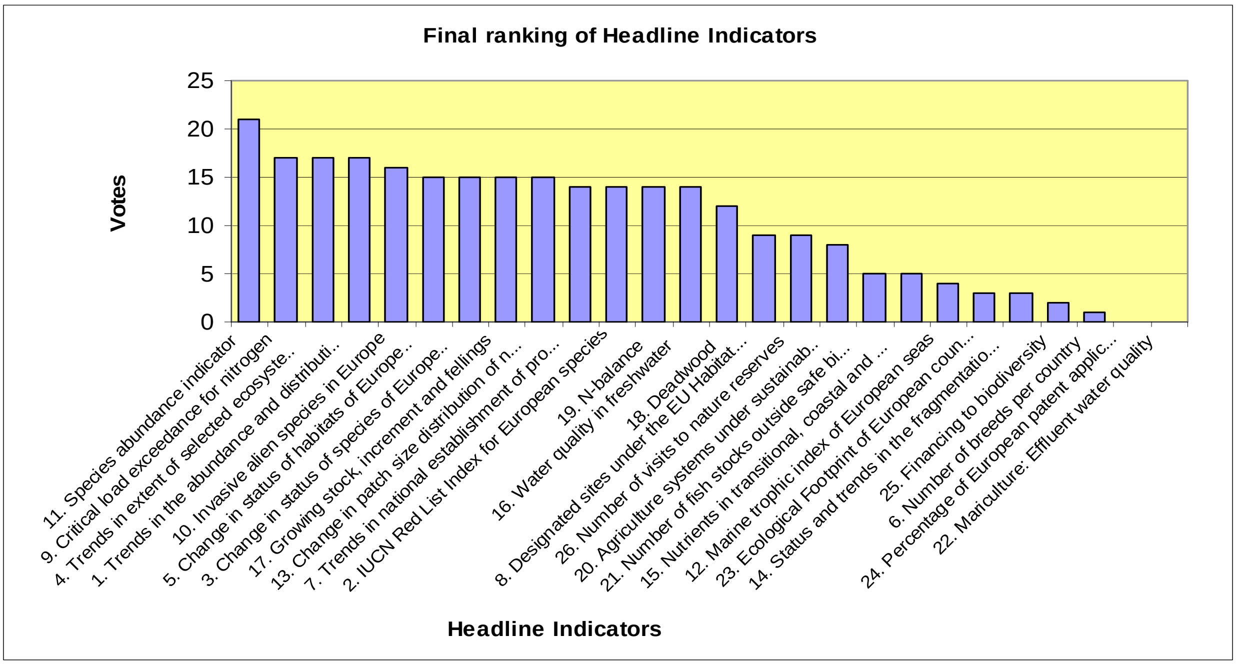

Figure 4.1. Assessment of availability of data from LTER sites in relation to the SEBI headline indicators.

4.3 Remotely sensed data

4.3.1 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. This forms a large part of the rationale of the EBONE project, particularly Work package 5.

4.3.2 The main advantages of using RS data as a source of data for biodiversity indicators is that they provide an easy (and relatively cheap) source of data covering wide areas with the opportunity of regular repeats. But RS data usually only provide measurements of broad habitat, ecosystem or land cover types and measurements of landscape and vegetation structure and rarely give direct measurements of biodiversity. The possibility deriving direct biodiversity measurements related to genes, species, populations, and species from RS observations remains remote.

4.3.3 Despite the limitations of existing RS data, they 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.

4.3.4 RS data have a vast potential for improving on current indicators by providing indirect measurements and for modelling and upscaling from in situ data to provide 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.

4.3.5 RS data also have potential for making 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 if habitats can be separated (e.g. Eucalyptus plantations 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 for airborne or satellite borne high spatial resolution, hyper spectral or specialised LiDAR EO data.

5 A new approach to habitat monitoring for biodiversity indicators

5.1 Developing the potential for using remote sensing data for biodiversity indicators

5.1.1 A priority for EBONE is to develop and test methods that can be used to link field based biodiversity observation measures to remotely sensed data as a basis for a range of new indicators that combine the strengths of in situ and remote sensing approaches.

5.1.2 Developing the ability of RS to discriminate habitat and ecosystem types at a finer scale and to provide wall-to-wall national or continental coverage may be the key to providing a far more extensive assessment of state and change in some of the main components of biodiversity. This is because:

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

(ii) Habitats provide the home for species and populations and, 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 with vegetation types and although vegetation provides one of the main components required for ecosystem functioning and ecosystem services it is rarely covered consistently in space and time in ways that can provide data for use in a broad-scale indicator;

(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.

5.1.3 The use of RS for the assessment of biodiversity is based on the premise that a relationship exists between the reflectance of land cover and in this way with the composition and structure of the landscape and the diversity of ecosystems, species and genotypes that may be present within it. Thus, RS can 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, forest types, vegetation structure, landscape structure and broad habitat fragmentation is possible. For some habitat types, quite detailed types can be distinguished using EO. A multi-temporal approach can contribute to better resolution; radar can be used to monitor seasonal variation in wetlands (Jongman et al 2008). Moreover, tools such as new hyperspectral sensors can potentially be used to monitor other features of biodiversity related to site conditions, physiological processes, pollution, stress conditions or vegetation damage. Earth Observation can become a part of a biodiversity monitoring system providing a vehicle for interpolation and extrapolation. It can deliver additional contextual information on land cover and provide data on trends if linked with in situ observation data. It is expected that its use for landscape structure and linear features complementing the observed species and habitat data may deliver proxies for in situ change.

5.1.4 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 (Figure 5.1). EBONE will investigate some approaches to doing an improving this. 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.

One promising approach is the use of the habitat classification system of General Habitat Categories based on Life Forms as a core part of a biodiversity observation system. This system has a comparable as the FAO LCCS (Di Gregorio and Jansen 2000), but is more habitat oriented.

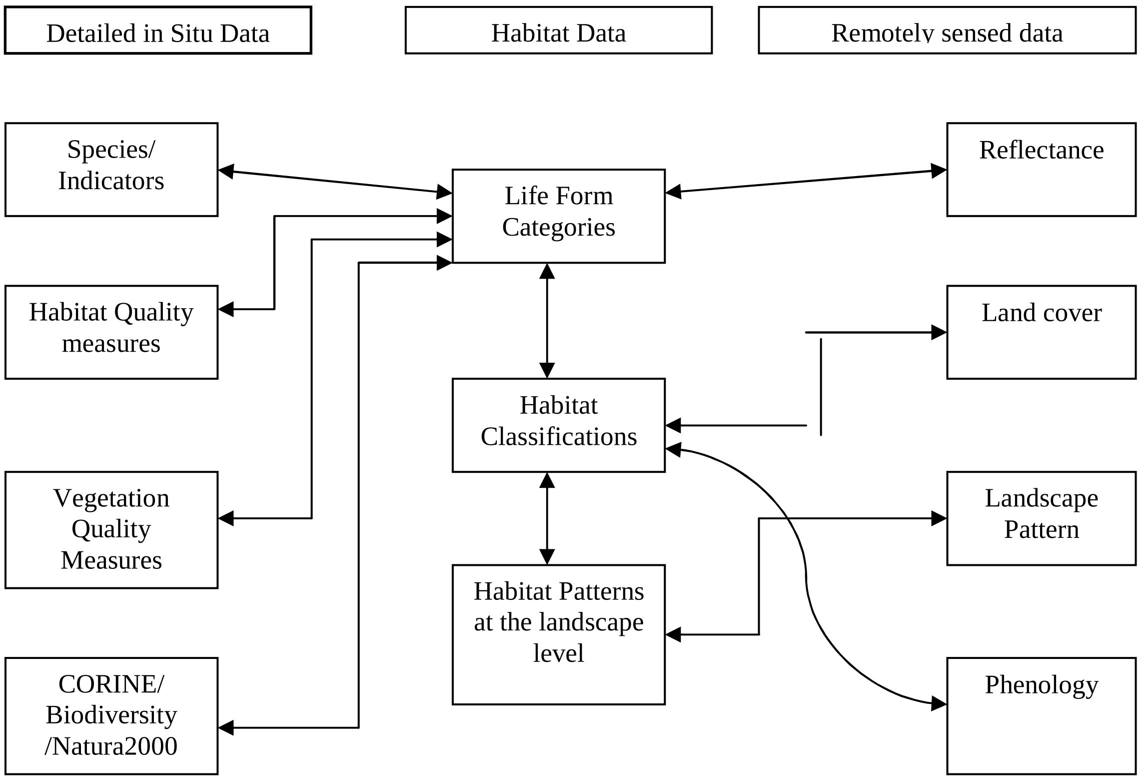

Figure 5.1. Relations between different land and biodiversity observation levels.

5.2 BioHab and its potential role in EBONE

5.2.1 The GHC methodology (Bunce *et al*, 2005, Bunce *et al*, 2008) was a product of the EC FP5 project BioHab on surveillance and monitoring of European habitats. The GHC methodology provides a system for consistent recording and monitoring of habitats across Europe with the potential for extension to other parts of the globe. Because the GHCs are primarily based 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. Potentially, the GHC methodology provides a useful assessment tool for biodiversity, providing a missing link (Figure 5.1) between detailed site-based species, population and community level measures and extensive assessments of habitats and land cover from remote sensing. One of the main aims of EBONE is to develop and test methods to realise this potential.

5.2.2 From the BioHab project it has been concluded that the way forward is to measure habitat diversity as a proxy for biodiversity on the basis plant life forms but also including information on environmental variation in humidity and trophic level using a stratified random sampling system (Figure 5.2). Key biodiversity indicators can be linked to the habitats e.g. the large blue butterfly with calcareous grasslands. The monitoring system could consist of a baseline monitoring system combined with selected sites for intensive sampling in conservation sites (Natura 2000) and sites for intensive ecological monitoring (LTER). These systems deliver detailed ecosystem information for general observation. Larger LTSER regions deliver information on conservation policy measurements and in depth information on ecological and socio-economic development. They will also provide the basic data for linking with data from remote sensing.

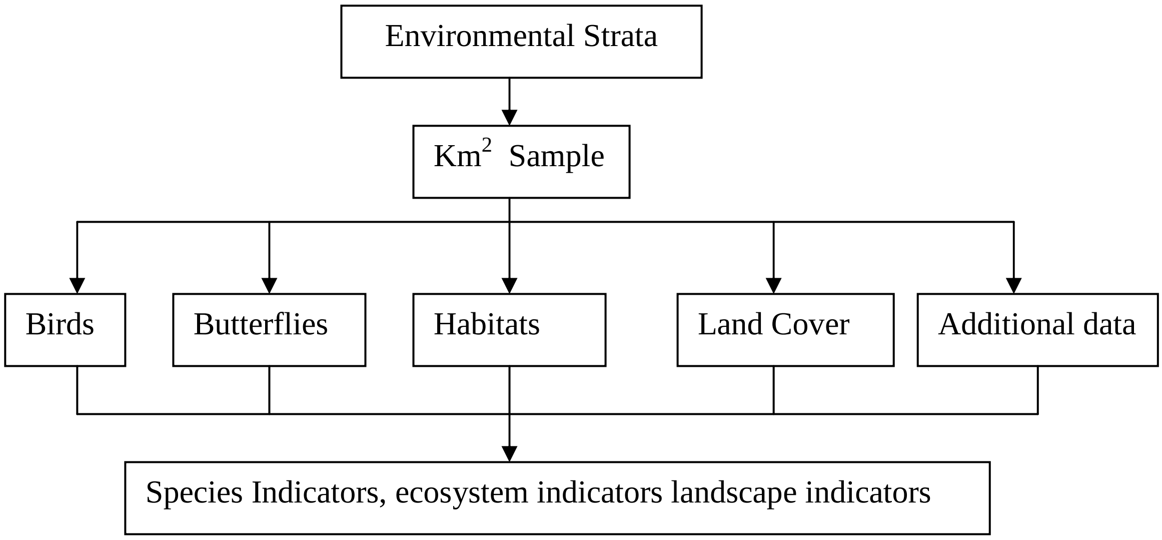

Figure 5.2. Data to be measured in a 1 km^2 sample unit. For every Environmental Stratum the adequate data should be determined to fill databases for species, ecosystem and landscape indicators.

5.3 Proof of concept

5.3.1 The relationship between the different levels of biodiversity monitoring (detailed, habitat, RS) is presented in Figure 5.1. Many of the linkages in this conceptual framework are under development and will be tested before they can be included in a final design for a European Biodiversity Observation system. Development and testing during EBONE includes:

(i) further development of the GHC monitoring methodology for in situ monitoring (WP4, WP6, WP9);

(ii) development and testing of RS methods for identifying and mapping GHCs from remote sensing through the inter-calibration between RS data or products (e.g. Land Cover Maps) and GHC's (WP5);

(iii) testing the use of GHCs a means of assessing biodiversity parameters at the species , population and taxa levels (partly WP9);

(iv) testing the overall efficacy of a biodiversity monitoring system based on a combined use of RS data/GHC field observations/ and sites based observations of key species, taxa or populations (WP5);

(v) bringing together the components within a sampling framework and environmental stratification that would allow the robust estimation of key biodiversity parameters (WP3, WP7).

5.3.2 EBONE will address the issue of applying RS data to taxon specific monitoring. The eventual aim is to develop a scheme that enables biodiversity parameters to be modelled (and mapped) from a combination of RS, GHCs, *in-situ* data and contextual; data (e.g. soils, climate, topography). The aim is to be able to provide statistics on diversity in different taxa for broad scale regional assessments of stock and change in biodiversity at different scales (e.g. for use in regional and global composite indicators).

5.3.3 A first step in this process is to test the hypothesis that GHCs can be used to predict stock and change in species richness of particular taxa at different scales. One approach would be to test the power of GHC's for predicting field based measurements of taxon specific diversity at different scales using Whittaker's (1972) alpha, beta, and gamma diversity concepts. Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (i.e. species richness) in that ecosystem. Beta diversity is a comparison of diversity between ecosystems, usually measured as the amount of species change between the ecosystems. Gamma diversity is a measure of the overall diversity within a large region (sometimes called geographic-scale species diversity). Existing data from LTER sites could be used in this work.

5.3.4 EBONE will explore three areas in which RS data may be better applied in biodiversity monitoring through the use of BioHab GHCs:

(i) direct measures of ecosystems or habitats;

(ii) as a surrogate measures of habitat specific species or taxa;

(iii) for enhanced measurements related to landscape pattern.

6 The selection of indicators for development work in EBONE

6.1 Introduction

6.1.1. The development work summarised in 5.3.1 will initially be focussed on a sub-set of observations and indicators selected from the SEBI set. In this Section we explain how and why these indicators were chosen.

6.1.2 The indicators used in the development work in EBONE 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 become part of 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.

6.1.3 A main driver for the development of EBONE has been the SEBI process and its related policy areas. 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 EBONE methodologies will be based primarily on the current SEBI list. However, it also takes into account the data issues described in Section 4.

6.2 Process for the selection of indicators

6.2.1 At a joint working group meeting of EBONE's WP1 and WP2 (June 2008, Utrecht) a rationale and procedure was agreed for an assessment of which indicators and observations should be prioritised for more detailed assessment in other Work packages. This took into account the:

- policy relevance and fit to the "Streamlining European 2010 Biodiversity Indictors" (SEBI 2010);
- the potential to independently test the efficacy of new approaches either through the use of existing data (assessed in collaboration with WP2) or through the collection of new data;
- potential added value of combining data from different sources (including in site and remotely sensed sources) to produce a more cost-effective indicator.

6.2.2. Project participants (n=10) reviewed each indicator against these criteria and the results were discussed at a project meeting (September 2008). Respondents did not provide opinions in areas in which they felt they lacked sufficient expertise.

6.2.3 Participants were asked to use their knowledge of data from four sources: (i) LTER sites; (ii) in situ data sources; (iii) field habitat surveys, including the use of the GHC methodology; and (iv) remote sensing sources (including satellite and air-borne) to assess contribution of these sources to indicators on the SEBI lists. Participants were also asked to assess whether they expected there to be any added value from combining two or more data sets. A simple qualitative scoring system from 0 (no value) to 3 (high value) was used.

6.2.4 The conclusion of this assessment (Annex A) was that there were several indicators where we expect a gain from combining data sources and that these could provide the focus for the development work listed in Section 5.3. The most added value was expected from work on indicators of ecosystem coverage, habitats of European Interest (Annex 1 habitats), a new indicator based on common plant species, fragmentation and forest stock. Some added value was anticipated from using combine data sources to improve butterfly and bird indicators.

6.3 Conclusions: choice of indicators for EBONE

6.3.1 Taking into account the expert assessments together with the scientific results described in Section 5, we recommend that EBONE should focus its initial development work on three main indicators covering:

(i) the extent and change of habitats of European interest in the context of a general habitat assessment;

(ii) abundance and distribution of selected species (birds, butterflies and plants); and

(iii) fragmentation of natural and semi-natural areas.

6.3.2 Tables 6.1, 6.2, and 6.3 provide an assessment of the indicators selected for further work and a summary of the approaches that may be adopted in EBONE to develop more cost effective techniques for providing the data on which they are based.

Table 6.1. SEBI Indicator: Habitats of European Interest	
Aim:	To show the conservation status of habitats of European Interest (as listed in the Annex 1 of the Habitats Directive.
Headline Result (EEA 2009, 2009b):	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 assessments 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 N2000 network and compliance with the Habitats Directive but have limited value in relation to comparative assessments of changes in biodiversity in space or time. The EEA Topic Centre on biodiversity concluded that approaches and data are at present too fragmented and different for reliable conclusions.
Opportunities:	Developments in remote sensing combined with the use of GHCs provide an opportunity for more detailed and objective assessments of habitat quantity and quality inside and outside of N2000 sites. 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 (e.g. plants, birds, butterflies).
EBONE 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 N2000 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 Corine Land Cover (CLC) map which is the best available source of land cover data with almost pan-European coverage. The CLC methodology is based on remote sensing data which means that detail is lost (e.g. areas of habitat less than 25 ha are lost). The definitions of habitats are not always compatible with other schemes (e.g. forest and croplands). To address this challenge EBONE will develop and test the use of the GHC methodology (alone and in combination with RS data) to map and delimit a range of habitat types across Europe and a more accurate, consistent and repeatable basis.
Criteria for success:	As described in EBONE report D1.2. (Halada et al 2010).

Table 6.2. SEBI Indicator: Abundance and Distribution of Selected Species	
Aim:	To assess whether declines in widespread species in Europe been halted.
Headline Result (EEA 2009, 2009b):	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.
EBONE challenge:	The current indicators for birds and butterflies are based on direct field observations taken from a limited number of sites that are not usually representative of either all N2000 areas or the wider countryside. EBONE will investigate the potential for using GHCs as a surrogate measure of some other measures of species diversity, using birds, butterflies, plants species and other taxonomic groups for which sufficient data are available. In theory, decreases in the area of a habitat would have a negative effect on the species dependent on that habitat. It is particularly useful for specialist species that are dependent on a restricted number of habitats. However, CORINE has not been used in this way to indicate species loss/gain and is probably at too coarse a resolution to be used for this purpose. A more accurate assessment of changes in the extent and condition of the habitat on which selected species occur may provide a way of estimating indicators on a more broad scale either (within sites e.g. N2000 sites) or across wider landscapes. The development of the GHC methodology for monitoring habitat extent and change of habitats will give EBONE the opportunity to improve upon this approach. Data from field sites with biodiversity and habitat assessments done using GHCs will be used to test associations between diversity within taxa at different scales (e.g. alpha, beta and gamma diversity) (see Section 5.3).
Criteria for success:	As described in EBONE report D1.2. (Halada et al 2010).

Table 6.3. SEBI Indicator: Fragmentation of natural and semi-natural areas	
Aim:	To show how fragmented European natural and semi-natural landscapes 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 greater risk.
Headline Result (EEA 2009, 2009b):	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 is relatively stable.
Source data:	The indicator shows changes in the average size of patches and semi natural areas derived from the Corine Land Cover maps produced from interpretation of satellite 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. The indicator does not provide a direct measure of the impact of habitat fragmentation on species populations. A transfer from old-growth forest to production forest through forest management leads to an almost permanent fragmentation of high-quality forest. The most valuable species in old-growth boreal forest very seldom occur in production forest. This distinction is often difficult to make from satellite imagery and impossible from the Corine Land Cover.
Opportunities:	Data from new approaches to habitat mapping using BioHab and new developments in spatial analysis provide an opportunity to improve on the current indicator and could improve the reliability of data in many areas, especially boreal forest.
EBONE challenge:	Work in WP5 and WP9 will investigate the derivation of landscape indicators at various spatial resolutions. 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.
Criteria for success:	As described in EBONE report D1.2. (Halada et al 2010).

7 Next steps: development work on selected indicators

7.1 The link between the work described in this report other work planned in EBONE is summarised in Figure 7.1.

7.2 The indicators described in Section 6 will be used in the development of EBONE monitoring methodologies including:

(i) The further development of the BioHab monitoring methodology (WP3, WP4, WP6, WP9);

(ii) The development and testing of RS methods for identifying and mapping GHCs from remote sensing through the inter-calibration between RS data or products (e.g. Land Cover Maps) and GHC's (WP5);

(iii) The testing of GHCs a means of assessing biodiversity parameters at the species, population and taxa levels (partly WP9);

(iv) The testing of the overall efficacy of a biodiversity monitoring system based on a combined use of RS data/GHC field observations/ and sites based observations of key species, taxa or populations (WP1, WP5, WP7); and

(v) Bringing together the components within a sampling framework and environmental stratification that would allow the robust estimation of key biodiversity parameters (WP3).

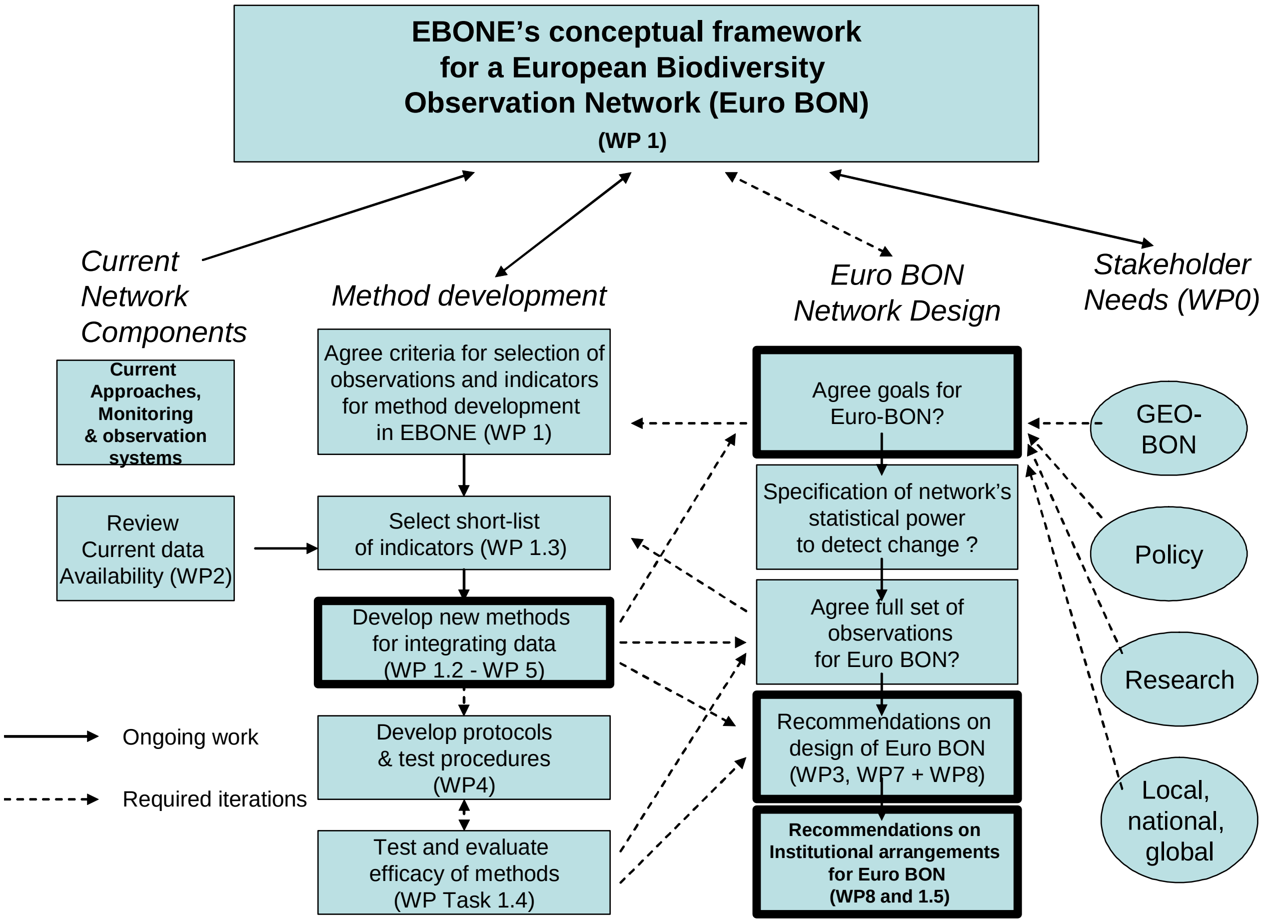

Figure 7.1 Schematic showing how the work on indicators is linked to other parts of the EBONE project and the development of a European Biodiversity Observation Network (Euro BON).

7.3 WP 1 will now begin on the development of criteria for assessing the added value of combining data from different sources. To measure improvement we will:

(i) review the current situation and describe:
- current assessment methods for each of the selected indicators
- baseline data used in the current methods
- current knowledge in each country or trial area to establish variations across Europe.

(ii) assess potential inter-calibration improvements for each of the selected indicators from this report. For example, with the habitat indicator on "Habitats of European Interest" these could include:
- introduction of new sites/habitats
- refinement of distribution maps
- reduced standard errors and more accuracy
- cost effectiveness

(iii) assess inter-calibration improvements against agreed criteria, for example in relation to the habitat indicator these may relate to:
- the number or area of new sites;
- the number of squares improved in distribution maps;
- greater accuracy of estimation;
- cost.

(iv) consider spatial scale issues at 1 km, county and European levels.

7.4 This work on the development of criteria for assessing added value will be reported in the work of Halada et al (2010).

7.5 The current list of SEBI indicators has not yet been fully developed and there are opportunities to fill some key gaps using the EBONE approach, particularly if the limitations associated with the lack of available data can be overcome. Two potentially new areas for indicator development were identified related to:

(i) indicators of climate change impacts on biodiversity and ecosystems; and

(ii) assessments of ecosystem services.

These two areas may be considered again later in the project as methodologies for combining data from different sources are developed.

Relevance to future requirements for indicators

7.6 As we reach the biodiversity target year of 2010 there has been much discussion on the setting of new biodiversity targets and the suitability of the indicators used in the SEBI set as a means of assessing and managing progress towards it. The issue of a new target was resolved in the meeting of the Council of the European Union Environment Council meeting on 15 March 2010. The Council's conclusions on biodiversity post-2010 (Council of European Union, 2010) included agreement on a "headline target of halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss". This extends the 2010 target to 2020 and adds an important component related to ecosystem services.

7.7 Some recent thinking on the development of the SEBI indicators that is likely to be relevant to the 2020 target was developed at a UNEP/WCMC (2009) international workshop on the development of post-2010 indicators. This proposed a new simplified framework based on: (i) threats to biodiversity; (ii) state of biodiversity; (iii) ecosystem services and (iv) policy responses. The workshop also made specific recommendations relevant to the development of post-2010 indicators that will be addressed by the development work in EBONE. In particular EBONE will:

- contribute to filling a specific gaps identified in measures of ecosystem extent and condition;

- contribute to the development of national capacity for indicator development, data collection and information;
- EBONE's multi-scale approach should also help with the recommendation that *"individual indicators should be capable of disaggregation, for example into functional groups, biome and geographic areas, in order to allow the identification of trends and priorities for action at meaningful scales"*.
- EBONE will also contribute to addressing general recommendations concerning the need for transparent documentation on the representativeness and adequacy of the data underlying indicators and improvements in their geographic/taxonomic and temporal coverage. It will help by establishing clear processes or criteria for evaluating the scientific rigor of the indicators.

The report also suggests that priority should be given to expanding the taxonomic, biome and geographic coverage of existing state indicators. The pragmatic choice of birds, butterflies and plants for indicator development in EBONE addresses the last two of these issues but does not immediately open-up the prospect for greater taxonomic coverage. However, investigations of the use of BioHab and remote sensing data to model in situ biodiversity may open-up possibilities for doing this.

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9 References

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Annex A. Assessment of the relevance of different types of observations to SEBI indicators and EBONE development priorities

The 26 Indicators for the first European Set of (SEBI) indicators grouped by CBD focal area and EU/PEBLDS headlines. This assessment shows the relevance of different data types to the proposed indicators based on “expert” assessments by EBONE participants of relevance of each data type to each indicator and the potential added value of combining more than one type of data. The indicators highlighted are the ones selected for use in the EBONE development work.

				Assessment of relevance of different data types to each indicator				EBONE Priorities?
CBD focal areas	**EU Headline**	**Proposed Indicators**	**Detailed indicators**	**LTER sites** ***** = high** **** = med.** *** = low** **blank = none**	**In-situ data sources** ***** = high** **** = med.** *** = low** **blank = none**	**Field habitat survey (incl BioHab)** ***** = high** **** = med.** *** = low** **blank = none**	**Remote sensing** ***** = high** **** = med.** *** = low** **blank = none**	**Added value (AV) from combining two or more data sources (A,B,C,D)** ***** = high AV** **** = med AV** *** = low AV** **blank = no AV**
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	New SEBI working group established January 2008. The objective is "the selection or development of a high quality indicator on impacts of climate change on biodiversity…. " .	*	**	**	*	**
			11.1 Indicator on climate change of climate change on European bird populations	*	**	*	*	**
			11.2 Indicator on climate change impacts on European butterflies	*	**	**	*	**
			11.3 Indicator on 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		*	*			
	Inter-linkages between indicators		New SEBI working group has discussed "interlinkages between indicators, to maximise efficient use of the indicators as integrated subsets to address various aspects of biodiversity and related threats and pressures."	**	*	*	*	*
	Other – new EBONE potential indicator	1. Abundance and distribution of selected species	Others suggested by EBONE (eg raptors, ungulates, rodents, reptiles, plants)	*	**	*	*	**
	Other – new EBONE potential indicator	General habitat condition as indicator of BD						
	new EBONE potential indicator	Large or small mammal indicators						
	Other – new EBONE potential indicator	Agricultural diversity indicator (complementary to 13 & 20) including forest edges, size, diversity of LC						
	Other – new EBONE potential indicator	Bumblebees (pollinators)						