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Framework for integration of different habitat monitoring schemes

Deliverable 19 of EuMon's Work Package 3

By Szabolcs LENGYEL (UNDEBR) and Andrej KOBLER (SFI)

with contributions by Pierre-Yves HENRY (MNHN), Bernd GRUBER (UFZ), Klaus HENLE (UFZ), Lado KUTNAR (SFI), Matjaž ČATER (SFI), Eva PAPASTERGIADOU (UNPAT), Chrysoula CHRISTIA (UNPAT), Marek SAMMUL (ESTAGUN), Piotr NOWICKI (UJAG), Valerija BABIJ (ZRC SAZU), Andrej SELIŠKAR (ZRC SAZU), Tatjana ČELIK (ZRC SAZU)

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0 Executive summary

The aim of this document is to reveal the conditions, explore the possibilities, and develop criteria for the integration of habitat monitoring schemes in order to improve the ability to detect trends in biodiversity loss in Europe. Habitat monitoring activities encompass a wide range of activities and can be classified into several distinct categories. Therefore, it is essential that a unified framework for the integration of habitat monitoring schemes is established. Such a framework will obviously be an important step in the process, hopefully leading towards a more integrated monitoring of the habitats of Europe.

Habitat monitoring schemes evaluate the conservation status of habitats or habitat types by estimating the following sets of habitat attributes: extent, biotic composition, biological structure, and physical structure. Habitat monitoring schemes can be classified into those with and without a spatial aspect. Both can monitor one, few, most or all specific habitat types within a country, region, or landscape. The schemes that monitor all habitat types within an area hereafter will be termed as belonging to a holistic approach. Schemes that monitor one or a few habitat types of interest will be referred to as representatives of a targeted approach. An important difference among habitat monitoring schemes further lies in whether they use remote-sensing or field-mapping as their primary source of data. Question H4 in DaEuMon (‘Spatial variations in habitats are documented by:’) provides the basis for classification, where only two answers are possible: ‘remote sensing’ and ‘field mapping’.

The potential combinations of the main aspects of habitat monitoring schemes results in several types of habitat monitoring schemes. Whereas some combinations are highly unlikely (e.g., holistic, remote sensing-based, non-spatial), some are frequent (e.g., field mapping-based, targeted, spatial). Scheme integration is easier to carry out for schemes of similar type. Integration will be more difficult for schemes belonging to opposite approaches, e.g., integrating remote sensing-based schemes with field-based schemes. However, the integration of different schemes can give highly valuable insight that within-class integrations cannot provide.

Remote sensing-based monitoring schemes belonging to the holistic approach, i.e. schemes that monitor all habitats within an area, are highly appropriate for integration. These schemes have a common “language” in the form of a geo-referenced spatial information basis. Due to their inherent common interface, holistic remote sensing-based schemes have the best chances to become part of a pan-European integrated monitoring scheme. However, an ideal solution for a pan-European habitat monitoring system would incorporate the best of both the remote sensing approaches (large spatial scales, relatively easy integration etc.) and the field mapping-based approaches (small scales, high sensitivity, detailed etc.).

An ideal pan-European habitat monitoring system should include at least the following aspects. An integrated monitoring should have a remote sensing-basis, assuring the manageability of large spatial scales (cf. entire EU27) and providing an opportunity to detect changes in spatial properties of habitat types. Although a holistic approach would be ideal, an integrated scheme does not have to be holistic, perhaps only encompassing those SCI areas that have been specifically designated for HD Annex I habitat types. Ideally, the integrated monitoring scheme should also include SPAs for establishing a connection point to the most frequently used species monitoring schemes. An integrated scheme should be suitable for extension to possible future pSCI (or SPA) areas. Finally, an integrated monitoring needs to be complemented with field-mapping in habitat types of Community importance because remote sensing alone is not suitable to detect small-scale but relevant changes. Considering the overwhelming scope of the task, it appears inevitable that indicators will need to be used instead of direct measurements to assess achievement of the 2010 target.

1 Background and introduction

1.1 Objective and background

The aim of this document is to reveal the conditions, explore the possibilities, and develop criteria for the integration of habitat monitoring schemes into a unified framework for habitat monitoring in order to be able to assess the achievement of the 2010 target of halting the loss of biodiversity in Europe.. Habitat monitoring activities encompass a wide range of activities and can be classified into several distinct categories. Therefore, it is essential that a unified framework for the integration of habitat monitoring schemes is established. Such a framework will obviously be an important step in the process, which will hopefully lead towards a more integrated, albeit not unified monitoring of the habitats of Europe.

The DaEuMon database can provide data to quantify many of the criteria given below, whereas some criteria cannot be evaluated because the database will not have information on the topic. However, it is important to also list the latter criteria in addition to the ones that can be tested directly from the database in order to provide a complete set of criteria both for WP5 and for future external reference. When data from DaEuMon can be used for the evaluation, specific references for this possibility are given or will become obvious from the text (e.g., when referring to database question numbers).

The EuMon DoW suggests that interest in Phase II of the project should be focused to the following aspects of habitat monitoring schemes: quality, adequacy, cost-efficiency, limits to monitor biodiversity change, achievement of the 2010 target, and motivations for particular methodologies by amateur and professional networks. Quality, cost-efficiency and part of adequacy (coherence) is dealt with in D20. The other part of adequacy, which can be termed as potential for integration, is the primary subject of this Deliverable. Implicit in the potential for integration are the limits of monitoring schemes to monitor biodiversity change and possibilities to measure achievement of the 2010 target. Finally, the implications for selecting particular methodologies by amateur and professional monitoring networks will also be considered from the perspectives of integration by highlighting the advantages of particular methodologies.

Deliverable D19 is complementary to deliverable D16 (Framework for integration of different species monitoring schemes). The deliverables develop the different avenues for integration that could be followed, as well as the methods that can be used to achieve integration. Avenues for integration were determined from questions in the DaEuMon questionnaire. These questions were designed in order to allow a description of monitoring targets, monitoring methods and approaches, designs and efforts by biological scope. This Deliverable provides guidelines as to what aspects of monitoring schemes are important and why they are important from the perspectives of integration, and will lead to a unified framework for the integration of different habitat monitoring schemes.

1.2 Importance of habitat monitoring

Monitoring is an indispensable support for the management and protection of the Natura 2000 international site-network. The Habitats Directive (92/43/EEC) requires EU Member States to monitor the condition of habitat types and species in order to demonstrate whether these have attained "favourable conservation status". The Habitats Directive is one of the EU's most significant contributions to the aim of halting the loss of biodiversity by 2010 as set out by the EU Heads of State at the Gothenburg Summit in 2001. Information gathered under the reporting requirements of the Habitats Directive will be an important data source for that work. Therefore, monitoring, assessment and reporting of conservation status under the Habitats Directive are not only important in relation to the implementation of the Directive itself but are crucial building blocks for an overall assessment of trends in biodiversity in Europe and will consequently influence strategic considerations.

Beyond assessing the role of the Natura 2000 system in maintaining biodiversity in Europe, it is also important to develop methods to determine the responsibility of EU Member States for the species and habitats of Community interests living under their protection. The development of a common framework how to monitor biodiversity time- and cost-effectively, to elaborate national responsibilities, and to cost-effectively reduce gaps in conservation networks addresses the need to integrate Community policy and research.

Monitoring in each country starts from different points in terms of availability of data, defining conservation goals, and overcoming the unique challenges presented in developing state monitoring and conservation strategies. While recognizing that these disparities exist among countries, the monitoring framework assumes that each country is working as best they can to coordinate stakeholders, define conservation goals, and identify, compile, and create data (www.biodiversitypartners.org).

1.3 Definitions and concepts

This section will describe the definitions of "habitat" most frequently used in the literature and then the definitions of "habitat" and "habitat type" applied in EuMon and in this document. Next, the major habitat classification schemes are described as the classification scheme used in habitat monitoring is crucial in assessing whether schemes can be integrated or not. Finally, the favourable conservation status for habitats will be defined.

1.3.1 Definition of habitats and habitat types

According to Blondel (1979, 1995) a habitat can be defined as "a topographical expanse homogeneous in its physical and biotic components at the scale of the phenomenon studied". This is the definition that the CORINE Habitat typology and the PHYSIS database adhere to.

Other definitions of habitat and habitat type include both spatial and non-spatial definitions. An explicitly spatial definition of habitat is given by Hunter (1996) as the physical and biological environment used by an individual, a population, a species or perhaps a group of species (Hunter 1996). An implicitly spatial definition of habitat is that a habitat is the suite of resources (food, shelter) and environmental conditions (abiotic variables, such as temperature, and biotic variables like competitors and predators) that determine the presence, survival, and reproduction of a population (Caughley & Sinclair 1994). A possibly non-spatial definition of habitat emphasises that habitat is a kind of biotic community, or set of biotic communities, in which an animal or population lives (Bailey 1984).

Definitions of “habitat type” are much rarer. One definition suggests that a habitat type is a land or aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance (www.biology-online.org/dictionary/ Habitat_type).

1.3.2 Habitat classification systems: CORINE, PHYSIS, EUNIS

All habitat classifications use, alone or in combination, similarities in physiognomy, abiotic conditions, plant community composition, plant dominance, plant community succession, and, sometimes, animal community composition to combine elementary units into collective entities of successively higher rank (Dierschke 1994).

The Habitat Directive (92/43/EC) is a Community legislative instrument in the field of nature conservation that establishes a common framework for the conservation of wild animal and plant species and natural habitats of Community importance; it provides for the creation of a network of special areas of conservation, called Natura 2000, to “maintain and restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest”. Annex I of the Habitat Directive lists 218 European natural habitat types, including 71 priority ones (i.e., habitat types in danger of disappearance and whose natural range mainly falls within the territory of the European Union). According to the Interpretation Manual of European Union Habitats, EUR 25 (European Commission 2003), habitat types listed in Annex I are based on the hierarchical classification of European habitats developed by the CORINE Biotopes project, which was the only existing classification at the European level at that time.

The first comprehensive, pan-European system of habitat classification developed was the CORINE (CoORdination INformation Environment) programme of the European Union (CORINE 1989, 1991). The guidelines for the CORINE typology suggest that two habitats should be distinguished if the plant or animal communities they support are sufficiently distinct to confer to them different significances in the preservation of sensitive species. First conceived in 1985, the European catalogue was presented as a draft list by the Council of Europe in 1986, then as a part of the CORINE Biotopes manual by the Commission of the European Communities in 1991. With the collaboration of the Council of Europe, it was later extended to the entire Palaearctic region the new, expanded, version being published by the Council of Europe in 1996. This Palaearctic catalogue is still being completed and updated.

The PHYSIS system of habitat classification was originally developed as part of the CORINE (CoORdination INformation Environment) programme of the European Union for the selection and description of sites of nature conservation importance. The system of habitat classification proposed by PHYSIS is based on the matrix-use of two sets of upper category describers, the biotic realms of the IUCN bio-genetic reserve network system (Udvardy, 1975), on the one hand, and a list of upper units of habitats of global application, on the other hand. A unit in the PHYSIS typology is a habitat type. Two habitat types are distinguished if the communities they support are sufficiently distinct to confer to them a different significance in the preservation of sensitive species. Thus, the collection of such spatial entities make up habitats that are sufficiently alike in abiotic conditions, physiognomy, and composition of plant and animal communities.

The EUNIS habitat classification is sponsored by the European Environment Agency (EEA 2004a) and is a common reporting language on habitat types at the European level. Since the inception of the EEA, there has been a continuous work program to develop a comprehensive framework for classification of European habitats and to provide descriptions of European habitat types within the framework. It originated from a combination of several habitat classifications: marine, terrestrial, and freshwater. The terrestrial and freshwater classification builds upon previous initiatives, notably the CORINE biotopes classification (Devillers & Devillers-Terschuren, 1991), the Palearctic habitats classification (Devillers & Devillers-Terschuren, 1996), Annex I of the EU Habitats Directive 92/43/EEC, the CORINE Land Cover nomenclature (Bossard et al. 2000), and the Nordic habitat classification (Nordic Council of Ministers, 1994). The marine part of the classification was originally based on the BioMar classification (Connor et al. 1997).

For the purposes of EUNIS a habitat is defined as a place where plants and animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.) and secondarily by the species of plants and animals that live there. Habitats are necessarily defined at a given scale. Some EUNIS habitats, such as moss and lichen tundra or deep sea mud, may be of vast extent. Others, such as cave entrances or springs, spring brooks, and geysers, are much smaller. Most but not all EUNIS habitats are in effect "biotopes" that is to say, areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms. A few EUNIS habitats, such as glaciers and highly artificial non saline standing waters, may be devoid of living organisms other than microbes. The EUNIS habitat classification is comprehensive. It covers the whole European land and sea area and the archipelagos of the European Union Member States (EEA 2004a).

In general the scale selected for the EUNIS habitat classification is that occupied by small vertebrates, large invertebrates, and vascular plants. It is the same as that generally adopted by other European-scale typologies, for example by the Palearctic habitat classification (Devillers & Devillers-Terschuren, 1996) and is comparable to the scale applied to the classification of vegetation in traditional phytosociology. All but the smallest EUNIS habitats, characterised as microhabitats, occupy at least 100 m^2. At the larger scale, habitats can be grouped as habitat complexes, which are frequently occurring combinations or mosaics of usually inter-dependent habitat types, mostly occupying at least 10 ha. Estuaries, combining tidal water, mud flats, salt marshes and other littoral habitats, are good examples.

SynBioSys (Syntaxonomic Biological System) Europe is an initiative of the European Vegetation Survey. SynBioSys is an information system for the evaluation and management of biodiversity among plant species, vegetation types, and landscapes. It provides a scientific framework for the identification of the relations between the vegetation types and habitats of EUNIS classification system. It incorporates a GIS platform for the visualization of layers of information on plant species, vegetation, and landscape. The information systems will offer the possibility to identify vegetation types and analyze the patterns and processes, which relate plant species, plant communities, and landscape types (Hennëkens et al. 2001; Ozinga & Schaminée 2005).

1.3.3 Favourable conservation status

The Habitat Directive defines the favourable conservation status of habitats as a condition, where:

- its natural range and the area it covers within that range are stable or increasing,
- the specific structure and functions, which are necessary for its long-term maintenance, exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable.

1.4 Main types of habitat monitoring schemes

Habitat monitoring schemes evaluate the conservation status of habitats or habitat types by estimating the following sets of habitat attributes: extent, biotic composition, biological structure, and physical structure. One important experience from the DaEuMon database being developed in the EuMon project is that habitat monitoring schemes in Europe differ greatly. Several aspects need special attention because they are so divisive that they necessitate different avenues for integration.

1.4.1 Habitat monitoring schemes and spatial aspect

One of the most basic difference between species monitoring and habitat monitoring is that the latter usually incorporates a strong spatial element. Spatial patterns occur at scales ranging from centimetres, e.g., the precise location of individuals, to thousands of kilometres, e.g., biogeographical patterns of different biomes. An inappropriate choice of working scale will have a direct influence on the accuracy of a sampling design. For example, data recorded from a Fagus forest at a single location will not provide sufficient information to consider any change in the status of the forest in the entire landscape or country.

Although the majority of habitat monitoring schemes contains a strong spatial aspect, some schemes are not directly spatial. The main difference lies in whether data from monitoring are obtained, analysed, or stored as part of a georeferenced database (Geographical Information System or GIS) or not. Based on this distinction, the following two types of habitat monitoring can be discerned.

- Habitat monitoring schemes with spatial aspect
- Habitat monitoring schemes with no spatial aspect

A GIS is used to provide different views of the electronic habitat maps, e.g., by thematically or spatially aggregating different habitat features. Furthermore, a GIS can combine habitat maps with maps of the relevant environmental factors. Such combinations may be used to analyze some aspects of habitat conservation status and to contribute to a better understanding of factors and processes structuring the distribution of habitats. Often, remotely sensed data are combined with ancillary information in a GIS, improving the reliability of habitat mapping as well as enabling enhanced spatial analyses. Furthermore, by looking into the relationships between the main environmental factors structuring the habitats and the distribution of habitats, models can be developed to predict the likely habitat distribution. Once developed and validated, these models are efficient tools to cover the areas where no habitat information is available.

The existence of the spatial aspect is not explicitly asked for in DaEuMon, therefore, surrogate information need to be used. Questions that may be important are H4, H7, H19, H20, and H28. Certain answers to these questions very likely indicate that a scheme has a strong spatial aspect. These answers are as follows: H4: remote sensing, H7: exhaustive sampling, H19: advanced statistics, H20: all habitats monitored, H28: fragmentation. If coordinators gave at least one or several of these answers, it is very likely that their scheme involves a spatial aspect.

1.4.2 Object of habitat monitoring

Habitat monitoring schemes either monitor one or a few specific habitat types (e.g., Fagus forests) or monitor all or most habitat types within a country, region or landscape. The schemes that monitor all habitat types within an area hereafter will be termed as belonging to the "holistic" approach. Schemes that monitor one or a few habitat types of interest will be referred to as representatives of the "specific" or "targeted" approach.

In general, schemes applying the holistic approach have a strong spatial aspect (as defined in section 1.4.1.). It has to be noted here that land cover monitoring, e.g., the CORINE Land Cover monitoring is also considered a holistic habitat monitoring scheme. In contrast, schemes applying the targeted approach sometimes operate without such a spatial aspect. The question in DaEuMon, which gives information on whether a scheme pursues the holistic or targeted approach is H20 ('Do you monitor all habitats in your area?'). If the answer is Yes, the scheme is holistic, if it is No, the scheme is likely to be targeted (i.e., concerned with some of the habitat types in an area).

1.4.3 Types of data acquisition in habitat monitoring

The general aim of most habitat monitoring schemes is to precisely and accurately measure some kind(s) of attribute(s) of the habitat type(s). It may be possible to measure an attribute for the entire habitat type (or sub-type), e.g., when the entire extent of a landscape is measured using airborne remote sensing. For most attributes, however, this will be impossible and only a proportion of the feature can be measured. In such cases, the results must be extrapolated to represent the entire feature. This procedure is called "sampling" and the procedures for obtaining the samples are collectively known as "sampling strategy". The most important issue in relation to a sampling strategy is to ensure that the samples recorded are representative of the entire habitat or habitat type, and in particular, that the results account for the inherent variability within a habitat or habitat type. Such variability is strongly influenced by both natural change and spatial pattern, and must be considered when planning a sampling strategy. A sampling strategy, however, must also account for the type of attribute being measured, the method and its deployment, the required accuracy and precision of measurement, and the time/budget available for sampling. A detailed review of the issues associated with the design of a sampling strategy, however, are beyond the scope of this deliverable; therefore, the reader is referred to the many handbooks on sampling design theory (Davies et al. 2001).

An important difference among habitat monitoring schemes lies in whether they use remote-sensing or field-mapping as their primary source of data. Question H4 in DaEuMon ('Spatial variations in habitats are documented by:') provides the basis for classification, where only two answers are possible: 'remote sensing' and 'field mapping'.

All mapping relies on generalisation of spatial and thematic complexity of habitats. In monitoring, the habitats need to be described and mapped continuously and consistently. This is ensured by a process of classification using a set of rules. While the direct observation in the field is capable of differentiating the species composition of habitat, the more general vegetation features can be detected using remote sensing, e.g., aireal photography or satellite imagery. The large scale remote sensing-based habitat mapping is faster and cheaper per unit area mapped than field survey and requires less ecological expertise.

Field-based monitoring approaches are based on field surveys and recordings (e.g., botanical/phyto-coenological/vegetation surveys). Field surveys can be highly efficient in detecting changes in species composition, in relative abundances of species or small-scale changes occurring in the monitored habitat. Sampling is conducted in certain locations and generalisations over unsurveyed areas are assured by a priori randomisation or obtained a posteriori by some kind of spatial modelling or extrapolation. The field data are obtained using several approaches. A walk-through approach involves recording presence or abundance of indicator or characteristic species. In a phyto-sociological approach, a detailed description of plant community is compiled in replicated relevés. Relevés can be arranged in, usually, 'permanent' plots or transects. In addition, detailed description of vertical structure of the habitat can be done, especially in forests. Often, description of tree-layer with mentioning of dominant ground-layer species is deemed sufficient to describe the plant community. In some cases, monitoring of change is simplified to a questionnaire where expert field workers answer questions about environmental conditions, external influences to habitat and habitat quality. In all approaches habitat type and vegetation type (e.g., according to Braun-Blanquet, Natura 2000, national or some other classification) have to be determined in addition to quantitative data. Often the visual assessment of habitat condition is also done in the field. Environmental conditions and outside influences on habitats can be either measured or estimated (e.g., soil parameters, human pressure, description of neighboring areas, list of outside threats along with their predicted impact). Also, a wide range of scientific experiment designs can be used for monitoring purposes, which however are outside the scope of this deliverable.

A broad range of remote sensing data sources are used for habitat monitoring. According to platform used these sources can be grouped into aerial- and satellite-based remote sensing (RS). Aerial RS is usually employed at a local or regional scale, often within a sampling design, although it can also support national mapping and monitoring projects (MAFF 2004). The satellite RS usually covers areas ranging from regional to supra-national, although with the advent of the high-resolution scanners, like Quickbird, it has been also applied locally. According to sensor technology remote sensing can be passive (e.g., panchromatic or colour photography, multispectral imaging), or active (e.g., laser scanning, radar imaging). A multitude of RS-based habitat mapping and monitoring approaches have been developed, classified into manual approaches involving photointerpretation of imagery, and automated approaches involving a number of quantitative algorithms. Often a hybrid approach is used, integrating the data crunching capabilities of computers with superior contextual image understanding of human interpreters. Using the RS-based monitoring both the spatial dimension of habitats can be gleaned (extent and spatial pattern), as well as the temporal dimension (change in extent and pattern). A successful application of RS depends on integration of multiple data sources and data analysis procedures, involving at minimum, a clear definition of the monitoring problem, an evaluation of potential of RS to address the problem, the identification of the appropriate RS data source, determination of appropriate data interpretation procedure, and identification of the criteria by which the quality of the collected information can be judged (Lillesand and Kiefer, 1994).

1.4.4 Main types of monitoring: why are they important?

There are several practical points for the above (1.4.1 through 1.4.3.) distinctions. First, the potential combinations of the three main aspects theoretically results in eight different types of habitat monitoring schemes (Table 1). Even though some combinations are highly unlikely or non-existent (e.g., holistic, remote sensing-based, non-spatial), some are frequent (e.g., field mapping-based, targeted, spatial). Therefore, for simplicity, only six combinations, i.e., those whose cells are shaded in Table 1, will be considered further in this document.

Table 1: Illustration of potential combinations of the three main aspects by which habitat monitoring schemes can be classified. Shading is intended to show how widespread each combination may be, whereas (-) indicates that that specific combination is unlikely to exist in habitat monitoring.

	Holistic		**Targeted**	
	Spatial	Non-spatial	Spatial	Non-spatial
Remote-sensing		–		–
Field mapping				

Second, clarifying to which type the monitoring schemes belong that are to be integrated will help greatly in the actual integration. Integration will be easier for schemes of similar type and more difficult for schemes belonging to opposite approaches, e.g., integrating remote sensing-based schemes with field-based schemes. Such integration requires combining across scales and thematic levels.

However, opposite approaches can also be complementary. For example, any application of RS involves also the use of independent reference data, often field-collected, for ground-truthing and for validation. This is also a possible avenue for integration of RS-based habitat monitoring schemes (HMSs) with field-based HMSs. Furthermore, HMS integration may encompass monitoring of high level habitat types (e.g., forests) by remote sensing and field-based monitoring of lower level habitat types (e.g., certain forest association). Threfore, a possible avenue of integration is the use of cost-efficient RS-based HMSs (e.g., CORINE Land Cover) to supplement detailed field-based HMSs with generalized large-scale habitat mapping and monitoring. Even when both approaches are covering the same habitats and areas, they can be complementary in the selection of the estimated habitat attributes. The field surveys are an obvious method for acquisition of ground truth data, necessary in any remote sensing approach. Where direct observation is not feasible, either remotely or in the field, or is not cost-efficient (e.g., some marine habitats), indirect mapping and monitoring is possible, using spatially explicit predictive modeling of habitat occurrence.

2 Avenues of integration

The aim of this section is to develop criteria that need to be evaluated to judge whether two or more schemes can be integrated or that need to be considered during actual integration. Spatial schemes will be discussed first as most habitat monitoring schemes have a strong spatial aspect. In this section, the basic combinations for the integration of monitoring schemes of different classes are reviewed (chapter 2.1). Chapter 2.2 to 2.5 will continue on elaborating the criteria specific to each combination for integration.

2.1 Principles of integration

First, only schemes with a spatial aspect are considered, which involve four classes (remote-sensing based holistic and targeted, and field mapping-based holistic and targeted). These are more frequent and more suitable to integration than are non-spatial schemes. Integration can be envisioned both within the classes and between two (or more) classes. It is easy to see that a total of four within-class combinations and six between-class combinations are possible (Table 2).

Table 2: Illustration of possible integration combinations for the four classes of schemes with spatial aspect. Arrows indicate between-class integration (six potential combinations), whereas within-class integration, i.e., integration of schemes of similar class, are not shown (four potential combinations).

	Holistic	**Targeted**
Remote-sensing		
Field mapping		

Depending on the habitat attribute in question, different monitoring methods might be adequate (Table 4). In order to meet its aims, a monitoring scheme must fulfill various criteria, including sensitivity to change, precision and accuracy of estimates, and cost-efficiency. Often a combination of different methods can better fulfill these criteria than one individual method.

Table 3: Aspects of habitat attributes that can be monitored by the two basic data acquisition methods used in habitat monitoring.

Monitoring method **Habitat attribute**	**Field mapping-based**	**Remote sensing-based**
Extent	Area of habitat	Area of habitat
Biotic composition	• Presence, distribution, and diversity of specific biotopes • Detailed species composition (relevés)	• Habitat type (generalized species composition) • Presence and distribution of (functional) species groups (e.g., coniferous trees)

	• Population size / density of characteristic species	
Biological structure	• Extent of specific biotopes • Integrity of biotopes	• Spatial pattern of habitats
Physical structure	Topography, vegetation structure, soils, chemical pollution, traffic load etc.	Land cover / land use change, topography etc.

Based on the potential combinations of schemes of different classes, integration of monitoring schemes can progress in ten logical avenues (four within-class and six between-class integration avenues, Table 3).

Non-spatial schemes are considered in detail separately from two perspectives. One perspective is the integration of non-spatial schemes with non-spatial schemes (section 2.3.), and the other is integration of non-spatial schemes with any of the spatial schemes (section 2.4.).

Table 4: Avenues of within-class and between-class integration of habitat monitoring schemes and indication of the section in chapter 2 where they are discussed in detail.

Section	Integration avenue
2.2.	Integration within scheme classes (i.e., highly similar schemes)
2.2.1.	• Integration of remote sensing-based, holistic schemes
2.2.2.	• Integration of remote sensing-based, targeted schemes
2.2.3.	• Integration of field mapping-based, holistic schemes
2.2.4.	• Integration of field mapping-based, targeted schemes
2.3.	Integration across scheme classes (i.e., highly different schemes)
2.3.1.	• Integration of remote-sensing-based and field mapping-based schemes of the holistic approach
2.3.2.	• Integration of remote sensing-based and field mapping-based schemes of the targeted approach
2.3.3.	• Integration of holistic and targeted approaches within remote sensing-based and within field mapping-based methods
2.3.4.	• Integration of schemes of opposite classes

2.2 Integration within the classes (highly similar schemes)

Integration within the classes means that rather similar monitoring schemes are to be integrated. For example, holistic schemes with holistic schemes, remote sensing-based with remote sensing-based etc. At first sight, therefore, integration appears as straightforward. However, as it will be shown in sections 2.1.1. through 2.1.4., the success of integration will largely depend on the technical details related to the specific properties of the schemes to be integrated. The next sections review the most important criteria for the integration of similar schemes.

2.2.1 Integration of remote sensing-based, holistic schemes

Remote sensing-based monitoring schemes belonging to the holistic approach, i.e., schemes that monitor all habitats within an area, are highly appropriate for integration. These schemes have a common “language” in the form of a georeferenced spatial information basis. The compatibility of such information systems depends on the technical properties of monitoring schemes. The integration of holistic remote sensing-based schemes usually involves the integration of monitoring and mapping results. However, these schemes are the most appropriate for combining the input data as well. When integrating the results of holistic remote sensing-based mapping and monitoring schemes, the following compatibility criteria should be considered:

- compatibility of habitat nomenclatures (habitat classification systems), compatible level of habitat nomenclature hierarchy,
- comparable sampling intensity in space (all parts equally measured in the focal area) and time (annually and/or according to phenological changes of the habitat types),
- comparable mapping scale or spatial precision: the minimum mapping unit (for vector maps) or the spatial resolution (for raster maps) should be similar,
- comparable mapping accuracy: the thematic accuracy (percent of correctly classified habitats) and also spatial accuracy (habitat delineation errors),
- compatible map projections, and
- comparable sensitivity to changes.

For the integration of input data, additional criteria need to be considered. When the schemes to be integrated cover disjunct areas, only data from comparable sensors can be integrated. Furthermore, data should be acquired under comparable conditions (acquisition frequency, scale, comparable phenologic stages) and should be projected in the same coordinate system. If these criteria are fulfilled, the result of integration can be an increase in the area where all habitats are monitored, which is highly appropriate for large spatial scales. Such integration is also highly desirable for a potential EU-wide habitat monitoring scheme.

When the schemes to be integrated cover the same area, the merged remotely sensed datasets might be integrated, if they match or complement each other in terms of spectral and spatial resolution, acquisition dates, scale or comparable phenologic stages. If one of the schemes covers only a part of the second scheme, but at a higher spatial and thematical resolution, it can be used as a reference source to guide data interpretation and to validate the results of the other scheme. Regardless of the area covered, however, other criteria should also be considered in the integration of input data: common data formats, compatible data management systems, costs and complexity of the mapping methodologies.

Due to their inherent common interface, holistic remote sensing-based schemes have the best chances to become part of a pan-European integrated monitoring scheme. A joint scheme integrating holistic, remote sensing-based habitat monitoring schemes could be a starting point in pan-European monitoring. A gradual extension of the system towards lower-level, increasingly field mapping-based monitoring schemes could eliminate the major disadvantage of remote sensing-based approaches, i.e., that small-scale, but relevant changes of habitats, e.g., the appearance of invasive plant species at a site, may go undetected.

Finally, it is important to list the data fields in the DaEuMon database that are relevant as criteria for integration:

- H9. Scale
- H10. Total area monitored
- H13. Frequency of monitoring
- H16. Starting year of scheme
- H17. Ending year of scheme
- H18. Has the monitoring procedure changed during this time period
- H19. Monitoring data are analyzed by
- H20. All habitats in the area monitored?
- H21. Habitat type classification used
- H22. List of habitats monitored
- H23. Remote sensing data used for sampling
- H24. Minimum annual change detected
- H28. Habitat quality criteria monitored

2.2.2 Integration of remote sensing-based, targeted schemes

Targeted schemes monitor one or a few habitat types. In this case typically schemes covering disjunct areas are integrated in order to increase the monitored area of focal habitats or habitat types. When integrating the results of targeted remote sensing-based monitoring schemes, all schemes should cover the same or at least comparable sets of habitats, in addition to the criteria presented in section 2.1.1.. If the same habitats or habitat types are monitored, integration should be rather evident, and the spatial coverage of the monitoring schemes increases. If the spectra of habitats monitored differ slightly between or among schemes to be integrated, spatial coverage will increase, but not exactly the same habitats will be monitored by the integrated schemes. Such a scenario can be interesting for certain schemes, for example, for alpine habitats in Europe. Alpine habitats are discontinuous, and monitoring schemes can target different habitat types in each major mountain range. In any case, the greater the similarity among the habitat types monitored, the higher the chances of successful integration.

Integration of the input data also makes sense among targeted remote sensing-based schemes. This can be of two kinds: (1) integration of remotely sensed input data (where criteria presented in 2.1.1 apply), and (2) using the input data and mapping results of the scheme with higher spatial and thematic resolution to support and validate mapping in the less detailed scheme, which potentially covers a larger area. A special case is when several monitoring schemes each monitoring a different target habitat type within some common area are integrated. In such cases, the aim of integration can be to broaden the spectrum of habitats monitored. A reasonable set of such schemes might sum up to form a holistic scheme for the common area.

Question H22 (habitat types monitored) in the DaEuMon database is of central relevance here. However, the same data fields as in 2.1.1. are also important for evaluating the chances of successful integration.

2.2.3 Integration of field mapping-based, holistic schemes

Field mapping-based schemes using the holistic approach are frequent throughout Europe. Many general habitat mapping or vegetation mapping endeavours belong to this class. The approaches used differ considerably among countries. As a consequence, there are many issues that make the integration of field mapping-based holistic monitoring schemes difficult. Many of the issues arise in field mapping and interpretation methodology. Some of these issues are outlined below.

The scale of habitat or vegetation mapping often varies depending on the scope of the schemes. Even national-level habitat or vegetation mapping schemes vary a lot e.g., by the size of the country involved. Based on exhaustiveness field mapping and monitoring schemes can be divided into those that are exhaustive, i.e., monitor 100% of the habitats and to those that are not exhaustive and use some kind of sampling. If each of the schemes to be integrated are 100% exhaustive, there can still be problems with observer biases, differing error rates among schemes, and so on. If any sampling is involved (which is true for most of the field mapping-based schemes, even if not made explicit), many further questions arise:

- What proportion of the focal area is actually sampled?
- What is the sampling strategy (random vs. systematic, stratified vs. non-stratified etc.)?
- Are samples collected from the same sampling unit at each sampling occasion (permanent plots, quadrats, and transects) or sampling units differ among sampling occasions?
- Is sampling intensity equal in space and time across habitats and habitat types?
- How is information obtained for non-sampled areas?
- What is the precision of the schemes to be integrated? Is precision comparable among the schemes?
- What is the ability of schemes to detect trends or changes in the habitats monitored?
- Does the sampling strategy account for the type of habitat attribute measured, the inherent variability of the attribute, the required accuracy and precision of the measurement, and the time/budget available for sampling?
- What are the exact mapping methods (vegetation only, animals also, habitat structure/quality, indicator species etc.)?
- What efforts are made to quantify errors in mapping and data processing?
- What habitat classification system is used and are there overlaps in the categories used among the schemes to be integrated?

These problems need to be addressed and solved before integration. For example, the habitat classification system may need to be recoded to that used in the other scheme(s) to achieve compatibility. If these problems are overcome, the result of integration will be that the area monitored will increase. Such integrations have a good potential to become the basis for a pan-European habitat monitoring scheme. The disadvantage may be that the results may not be generalizable or applicable over large spatial scales (a problem inherent in field mapping). Obviously, an ideal solution for a pan-European habitat monitoring system would incorporate the best of both the remote sensing approaches (large spatial scales, relatively easy integration etc.) and the field mapping-based approaches (small scales, high sensitivity, detailed etc.).

For evaluating the chances of successful integration of field mapping-based schemes using the holistic approach, the following data fields in the DaEuMon database are relevant as criteria for integration:

- H3. Environmental parameters collected
- H4. Documentation of spatial variations in habitat
- H5. Sampling stratification
- H6. Experimental design
- H7. Choice of sites to be monitored
- H8. Sampling of legally protected areas
- H9. Scale
- H10. Total area monitored
- H11. Number of sampling sites
- H12. Number of samples (eg transects, plots, quadrats) collected during a visit to a sampling site
- H13. Frequency of monitoring
- H14. Frequency of sampling per year
- H16. Starting year of scheme
- H17. Ending year of scheme
- H18. Has the monitoring procedure changed during this time period
- H19. Monitoring data are analyzed by
- H20. All habitats in the area monitored?
- H21. Habitat type classification used
- H22. List of habitats monitored
- H23. Remote sensing data used for sampling:
- H24. Minimum annual change detected
- H26. Causes of change you monitored
- H28. Habitat quality criteria monitored
- H29. Indicator species monitored
- H32. Training / expert knowledge required to take part to field/lab work?

2.2.4 Integration of field mapping-based, targeted schemes

In general, a field mapping-based, targeted habitat monitoring scheme concerns one or a few habitat types or one certain group of habitats. Monitoring is conducted in several distinct sites with either similar or different mapping methods. One example for such schemes is the monitoring of bogs. Integration of such schemes is rather straightforward, if the schemes to be integrated monitor the same habitat type or the same group of habitat types. If the same habitat types are monitored, only the extent of the differences in field mapping methods is important from the perspectives of integration. If different habitat types are monitored within some common area, integration can be used to broaden the spectrum of the habitats monitored. A reasonable set of such schemes might sum up to form a holistic scheme for the common area.

The criteria and DaEuMon data fields listed in section 2.1.3. are important in this aspect. Question H22 (habitat types monitored) are obviously of central relevance here as well. If there are no big differences either in the habitat types monitored or the actual field mapping methods, integration will become a pooling of the data on the habitat type(s) in question from several distinct locations.

2.3 Integration across classes (highly different schemes)

Integrating habitat monitoring schemes belonging to different classes is much more difficult than that of similar schemes. The integration of different schemes, however, can give highly valuable insight that within-class integrations cannot provide. For example, if different schemes are integrated (holistic with targeted) in the same area, e.g., same region/country, the integrated monitoring scheme will have an added value that the constituents do not have individually. A proper integration of remote sensing-based schemes with field mapping-based schemes within the same area will result in the ability of the integrated scheme to exploit the advantages of both approaches (e.g., ability to monitor large areas with also the ability to monitor small changes of target habitat types). After such integration, the result is increased quality and/or quantity of information on parts of the monitored area.

2.3.1 Integration of remote sensing-based and field mapping-based schemes of the holistic approach

The integration of holistic field mapping-based and remote sensing-based schemes over a common area may be advantageous when both are complementary in habitat attributes covered or when the combination is more cost- and time-efficient. It makes especially sense to use the high precision field survey data to support interpretation of remotely sensed data and to validate the remote sensing-based mapping and monitoring results.

The complementarity of habitat attributes can be envisioned in several ways. First, in terms of habitat extent, remote sensing-based habitat mapping is faster and cheaper per unit area mapped than is field mapping and requires less ecological expertise. However, remote sensing-based mapping cannot discern the lower-level habitats. Second, the biotic composition can be described more reliably and with more detail using field surveys. On the other hand, remote sensing can provide a large-scale overview (e.g., class 3.1.2 Coniferous Forests, CORINE Land Cover nomenclature). In addition, this information can be acquired more often and for larger areas than for field mapping due to the lower cost per unit area. Third, in terms of biological structure, the extent and integrity of specific habitat types, which can be reliably monitored by field survey, can be complemented by remote sensing-derived spatial patterns of the habitats (e.g., fragmentation, connectivity). Spatial patterns affect the migration and adaptation capabilities of species needed to respond to changes in environmental conditions and to climatic change (EEA 2004b). Finally, a number of physical structure aspects can be most reliably estimated in the field (e.g., soils). On the other hand, remote sensing of land cover and land use change can provide a synoptic overview of some anthropogenic pressures on the habitats (e.g., urban encroachment, deforestation, road density). Some other aspects of physical structure (topography, climate) most often have to be acquired from outside the habitat monitoring context.

Criteria for the integration of field-based and RS-based schemes:

- comparable spatial scale of monitoring,
- compatibility of habitat nomenclatures (habitat classification schemes), exhaustiveness of field mapping,
- comparable thematic precision,
- comparable monitoring / mapping accuracy,
- comparable sensitivity to changes,
- common data formats, compatible data management systems (the latter is not necessary, if a scheme is only used to validate the results of the other scheme)

It has to be noted that field mapping-based and remote sensing-based schemes can theoretically also be integrated for disjunct areas. However, while acknowledging that such integration may be important for some highly specific aims, we believe that this avenue of integration is beyond the scope of this deliverable.

2.3.2 Integration of remote sensing-based and field mapping-based schemes of the targeted approach

For the integration of targeted field-based and remote sensing-based schemes, the criteria and advantages listed in section 2.2.1. also apply. In addition, the schemes to be integrated have to be comparable or complementary in the subsets of habitats monitored. Such integration avenues may be especially advantageous in the interpretation of the results from the different monitoring schemes (please also see section 3.1 Combining input and results data). Common interpretation of results from different schemes will need to be one of the top priorities of the EU-wide monitoring of certain Natura 2000 habitat types.

2.3.3 Integration of holistic and targeted approaches within remote sensing-based and within field mapping-based methods

Integration of schemes applying the holistic and targeted approach can be advantageous for several reasons. Firstly, a targeted scheme can supplement the holistic scheme in the common area, where the latter does not adequately cover or entirely leaves out certain habitats. A set of targeted schemes that is complete enough over a common area can be combined into a holistic scheme. If the set of targeted schemes is incomplete for a common area, it can still be used to provide additional spatial and thematic detail in some important parts of the common area. For example, monitoring of the NATURA 2000 network, which, by definition, is a targeted scheme, can contribute relevant and detailed focus to a generalized, wall-to-wall, holistic scheme in a region/country or even at the EU level. CORINE Land Cover, for example, is one of the best examples of a generalized, wall-to-wall, holistic monitoring/mapping scheme at the EU level.

Secondly, the data provided by the high-precision field survey can support the interpretation of remotely sensed data and validate the remote sensing-based mapping or monitoring results. The main criteria for the integration of holistic and targeted schemes are as follow:

- habitats monitored should match or at least overlap to a great extent, i.e., habitat types monitored by the targeted schemes are a subset of habitat types monitored by the holistic scheme,
- spatial scales used in each monitoring scheme should be comparable,
- compatibility of habitat nomenclatures (habitat classification schemes),
- comparable monitoring / mapping accuracy,
- comparable sensitivity to change,
- common data formats, compatible data management systems (the latter is not necessary, if a scheme is only used to validate the results of the other scheme).

2.3.4 Integration of schemes of opposite classes

The integration of schemes of opposite classes refers to cases when remote sensing-based holistic schemes and field mapping-based targeted schemes are integrated (type A) or when remote sensing-based targeted schemes and field mapping-based holistic schemes are integrated (type B). Such combinations may be the most technically difficult of any of the major integration avenues. However, some special inquiries may warrant an attempt at integrating schemes of opposite classes. One obvious application of such integration is when within the target habitats, the high precision field survey data is used to support the interpretation of remotely sensed data and to validate the RS-based mapping and monitoring results (type A). However, such integration does not lead to an exhaustive validation of the holistic scheme as only a subset of the habitat types monitored in the holistic scheme is monitored in the targeted scheme. Therefore, the ground truthing and data validation for habitat types not present in the targeted scheme(s) need to be implemented separately.

For the integration of schemes of opposite classes, most or all of the criteria listed in 2.2.1 through 2.2.3. apply. Even though there may be some additional criteria that need to be considered, a detailed development of such criteria would lead to too much detail in this document. Because this integration avenue is probably very rarely used, we believe that the detailed criteria should be developed by the persons carrying out the integration. The criteria provided above and elsewhere in this document can provide several hints of which aspects to consider in developing such criteria.

2.4 Integration with and within non-spatial schemes

Although the majority of the habitat monitoring schemes have a strong spatial aspect, some schemes use spatial information only implicitly or do not use such a spatial basis at all. Examples include the monitoring of small, disjunct habitats types (e.g., bogs in southeastern Europe, urban parks in a country etc.), which, in extreme cases, can be in the form of species lists collected at small, point-like sites over time. The lack of spatial aspect at first sight may increase the chances of successful integration of non-spatial schemes. This is because the complicated issues inherent in spatial schemes in the form of how they incorporate the spatial aspect, do not arise with non-spatial schemes. However, this ease of use may also limit the useability of such integration.

The integration of non-spatial schemes with similar schemes then becomes a merging of the methods and/or data from monitoring. This can be optimal in rare cases, e.g., in the integration of bog monitoring and of Sphagnum community monitoring. However, the integration of non-spatial schemes leads to very limited possibilities for application towards larger-scale integrated monitoring schemes.

The integration of non-spatial schemes with spatial schemes have more potential towards the application of larger-scale integrated monitoring. In such cases, the non-spatial scheme becomes implicitly spatial, for example, at least the coordinates of sampling sites used in the non-spatial monitoring will need to be incorporated in the spatial scheme through the integration. The advantage of such integration may be the merging of information from several point-like, small habitats with information from a larger common area. For example, the monitoring of urban parks, integrated with a targeted monitoring of all urban habitats, may become an important component of the integrated monitoring scheme. The precision and accuracy of the measurements (e.g., species lists from certain points) may then be higher for the initially non-spatial scheme, and thus, this information can be used in the validation or enhancement of the spatial scheme. In any case, the attribute information from non-spatial schemes will be tied to a larger, less limited area.

2.5 Integration of habitat monitoring schemes with regard to NATURA 2000 and 2010 targets

The goal of monitoring according to (i) the reporting obligation of the member states as put forth in the Habitat Directive, (ii) achieving favourable conservation status of Natura 2000 HD Annex I habitats, and (iii) progress towards the 2010 target to halt the loss of biodiversity can be summarized as: " to quantify state and trend in the distribution and composition of habitats". This goal can be met only by explicitly addressing integration by identifying which schemes should be combined so that the distribution and composition of habitats are monitored in each corresponding habitat in each corresponding country.

2.5.1 Integration of habitat monitoring schemes and Natura 2000

At the European level, the main objective of monitoring is to determine the changes of habitat types of Community interest, i.e., habitat types in Annex I of the Habitats Directive. The specific criteria that need to be considered during the development of an integrated habitat monitoring scheme can be outlined as follows.

Firstly, an integrated monitoring should encompass all HD Annex I habitat types in the EU27. This integration needs to have a remote sensing-basis, which is important for several reasons. It assures the manageability of large spatial scales (cf. entire EU27). A remote-sensing basis provides an opportunity to detect changes in spatial properties (extent/size, shape) of HD Annex I habitat types. This may be related to creating an opportunity to detect changes early enough for environmental policy to take action at the European and/or national levels. Finally, a remote-sensing basis enables one to ask questions on multiple spatial scales.

Secondly, although a holistic approach would be ideal, an integrated scheme does not have to be holistic. It is probably appropriate if the integrated scheme encompasses those SCI areas that have been specifically designated for HD Annex I habitat types. Ideally, the integrated monitoring scheme should also include SPAs for establishing a connection point to the most frequently used species monitoring schemes (i.e., those monitoring birds). These two types of EU-protected networks often cover similar areas anyway.

Thirdly, the integrated scheme should be flexible enough to assure that it is suitable for extension to areas that are currently not covered by pSCI (or SPA) areas, but may become pSCI (SPA) in the future.

Finally, an integrated monitoring needs to be completed with field-mapping in habitat types of Community importance because remote sensing alone is not suitable to detect small-scale but relevant changes. Field mapping-based monitoring should be conducted at least in priority habitat types of HD Annex I. Field mapping needs to be a coordinated effort. Currently ongoing field mapping-based schemes can be integrated if they are suitable for this purpose (see criteria in section 2.1.3.). Coordination is necessary to evaluate the possibilities for integration (based e.g., on the criteria provided in this document) and to implement the integration of suitable habitat monitoring schemes. During the process, gaps (e.g., habitat types/regions not monitored) will need to be identified and new monitoring schemes need to be established to reduce or eliminate gaps.

2.5.2 Integration of habitat monitoring schemes and the 2010 target

A proper assessment of the achievement to reach the 2010 target may be an even bigger challenge for integration than is the integration necessary to monitor NATURA 2000 habitats. This is because the 2010 target is more general than Natura 2000 targets as it involves "biodiversity" in general. Biodiversity in general encompasses Natura 2000 species and habitats but beyond that it also includes a great deal more species and habitats that are not included in Natura 2000. From our perspectives, the greatest challenge is to establish an integrated monitoring for non-Natura 2000 habitats.

In an ideal case of biodiversity monitoring, three primary attributes of biodiversity – composition, structure, and function – should be assessed at the regional, landscape, community/ecosystem, population/species, and genetic levels (Noss 1990). Indicators of each attribute in terrestrial ecosystems should be identified at all four levels. Particular attention should be paid to specifying the questions that monitoring is intended to answer and to validating the relationships between indicators and the components of biodiversity they represent (Noss 1990).

Considering the overwhelming scope of the task, it appears inevitable that indicators will need to be used instead of direct measurements to assess achievement of the 2010 target. There is currently intense discussion on biodiversity indicators and the development of indicators is the scope of several other EU-funded research projects (e.g., BIOHAB, ALARM, BIOSCORE) and other international projects (e.g., CBD). From the perspectives of EuMon, it is necessary to emphasise that the indicators agreed should be suitable for monitoring by the currently available monitoring schemes or by an integrated monitoring scheme expected in the future.

A balanced set of indicators may be used at the global, regional, national, and local levels as tools for the implementation of the 2010 targets. They should take into consideration goals and indicators developed by other relevant international processes and use existing data sets from habitat monitoring schemes (Table 5) (CBD target 2000).

Table 5: Provisional indicators for a common evaluation system (2010 targets) (from CBD target 2000).

Focal area	Indicator for immediate testing	Possible indicator
Status and trends of the components of habitat types	• Trends in extent of selected biomes, ecosystems, and habitats • Trends in abundance and distribution of selected species • Coverage of protected areas	• Change in status of threatened species (Red List indicator under development) • Trends in genetic diversity
Sustainable use	• Land use	• Area of forest, agricultural, and aquaculture ecosystems under sustainable management • Proportion of products derived from sustainable sources
Threats to habitat type loss	• Fragmentation • Catastrophic events • Nitrogen deposition	• Climatic change • Numbers and cost of alien invasions • Ageing
Ecosystem/ habitat type integrity and ecosystem goods and services	• Marine trophic index • Water quality in aquatic ecosystems	• Application to freshwater and possibly other ecosystems • Connectivity/fragmentation of habitat types/ecosystems • Incidence of human-induced ecosystem failure • Health and well-being of people living in habitat type/ecosystems resource dependent communities

2.6 Practical aspects of integrating habitat monitoring schemes: a summary

In this section, we present a list of the most important quantitative and qualitative criteria necessary to be evaluated for the integration of habitat monitoring schemes. The higher number of criteria the schemes to be integrated are identical or similar in, the more successful the integration.

- input data needed for a scheme:
    - aerial photography
    - satellite imagery
    - ancillary GIS data
    - field sampling strategy and design (random vs. systematic, stratified vs. non-stratified etc.)
    - field sampling intensity (number of sites, number of measurements annually or across years)

- precision of a scheme:
    - mapping scale / minimum mapping unit (for vector maps)
    - spatial resolution (for raster maps and remotely sensed imagery)
    - thematic resolution:
        - nomenclature used
        - nomenclature level
        - number of classes (habitat types) mapped
        - temporal resolution: frequency of repeated measurements
- accuracy of a scheme:
    - spatial (errors in habitat boundary identification)
    - thematic (percent correctly identified habitats)
- sensitivity of a scheme to changes of habitats in:
    - extent
    - class
    - spatial pattern
    - other aspects
- spatial extent of a scheme
- costs and complexity of the mapping approach
- quality assurance of the data: common terminology, data formats, data management
- any other compatibility and potential synergies

2.7 Integrating species and habitat monitoring schemes

The integration of species and habitat monitoring schemes can be important from several aspects. Firstly, the monitoring of species and habitats within the same general area can provide the best measure of biodiversity changes available. Even if monitoring is not exhaustive, such detailed information may be used to extrapolate for the entire general area.

Secondly, the integration can greatly help in cost- and time-efficiency or can increase the scientific value of monitoring by providing a common interface to record changes in biodiversity. In several cases, the species and habitat monitoring is so closely linked that their integration can further enhance efficiency or increase information value. For example, schemes dealing with habitats of certain plant or animal species or schemes that study certain keystone species, umbrella species, or indicator species that provide general information of the habitats can be greatly enhanced by integration. Species and habitat monitoring schemes could be linked easily even in DaEuMon if the habitat preferences of species or the indicator values of the species are known. Such comparisons could identify crosslinks between both species and habitat groups. Habitat schemes containing data about indicator species and species schemes containing presence of listed species within certain habitat types could be useful for integrating data in such cases. In the Habitats Directive, species are linked to certain habitats by definition, and such species are often called typical or characteristic species. One could use such fixed species-habitat links to integrate and upgrade species and habitat schemes.

Finally, from a scientific point of view, integration may provide information on ecosystem- or community-level changes in both habitats or groups of plant and animal species and may help in understanding ecosystem functioning, community organization, and drivers influencing the habitats under study. Such complex information is highly relevant in designing and implementing measures to halt the loss of biodiversity.

Integrating species and habitat schemes or even replacing species scheme with habitat monitoring has several advantages. Habitat monitoring is often more easily implemented and evaluated than species monitoring (MacDonald and Smart 1993). Habitat indicators as indirect indices of species abundance and population dynamics are especially useful for species that are difficult to measure or monitor directly (e.g., species that are difficult to count, highly mobile animals, annual plants, long-lived species). Assessing changes in habitats can often be done on an annual basis (or even more often), whereas measuring the response of species population to change may take several years (Elzinga et al. 2001). Monitoring populations using habitat indicators often relies on methods that are relatively familiar, such as vegetation measurements, whereas monitoring the populations themselves may require more elaborate and unfamiliar techniques (e.g., mark/recapture methods for animal species) and therefore people with highly specialized skills needed. Therefore, motivations for habitat monitoring by amateurs could be considered here.

In exchange for ease, low cost, and immediacy, one need to be aware of limitations and risks. The risk of monitoring habitats as indicators of species condition is that the selected indicator may not really be indicative of changes in the species population. For this reason, when habitat attributes or abiotic variables are used as surrogates for tracking individual populations, it is advisable to monitor the population itself, integrate both, habitat and species monitoring, to ensure validity of the surrogate relationship. Habitat monitoring is most effective when research has demonstrated a relationship between a habitat parameter and the abundance/presence of a species.

Established connections could be fully relevant for integration guided by environmental policy, but should be handled with caution, since some are questionable according to the ecological processes behind them. Several of the Annex species are widely roaming species which cannot be directly linked to a certain habitat type in view of being a typical species characterizing the habitat type. Furthermore, integration of species and habitat monitoring scheme requires standardized definitions of habitats and habitat types throughout Europe. In addition, standard indices of specialization would allow attribution of species to given habitats at the European scale. Since species – habitat relationships differ across bio-geographical regions (Böhme, 1978, Fielding and Harworth, 1995; Diekmann, 2003), it would be questionable to apply such an approach on the habitat type level.

The integration of species and habitat monitoring schemes can be relevant for member states, which will have to report on state and trend in the distribution and population size of species and their habitats and will explicitly need to combine information from schemes monitoring species and those monitoring habitats. Integration would allow to test if it is more appropriate to monitor a set of species to evaluate habitat status, or to monitor habitat quality criteria to evaluate species status. “Appropriateness” here can be defined as more time- or cost-effective or having higher scientific value (sensu D20). This is particularly relevant when evaluating species conservation status: if habitat distribution decreases by more than 5% per year, then it is not necessary to gather data for species: according to Natura 2000 guidelines, the only conservation status possible is ‘bad’.

3 Methods for integration

From a practical point of view, the goal of this chapter is to aid the design of a tool that identifies which schemes could be integrated and how. Such a tool may be envisioned as an interface that basically works as a filtering tool, analogous to the Auto-filter function in MS EXCEL. This filter defines constraints on one or several fields in the database. Every time a new filter is introduced, the resulting subset of records will show higher similarity than the subset immediately before the introduction. The more constraints are introduced, the more similar the resulting subset of schemes will be, and the easier it will be to integrate the resulting schemes. Then one may release some constraints, increasing the list of schemes that could be combined, but also increasing difficulties to combine information since schemes will be gradually less similar. However, their complementarity will increase.

For instance, imagine that an EU-wide programme that monitors grasslands is to be set up. Highly similar, easily combined schemes would be identified by filtering schemes monitoring ‘at least grassland’ (habitats types monitored, H22 in DaEuMon contains ‘grassland’), at least at the ‘regional, national or international or EU’-level (field geographical scope, question 6. contains this information), using an experimental design (using experimental design, H6 contains ‘yes’). Such filtering would yield a limited list of schemes, and that would be the basis for building an EU-network, based on schemes that are rather easy to combine. Actually that yields a list of two schemes from two countries (France, Hungary).

Then, some constraints may be released to find other schemes, the integration of which may be less straightforward, but would benefit from each others through complementarity. For instance, the constraint on experimental design could be released to increase the number of schemes matching the fewer constraints. These suggestions for the design of an ‘integration tool’ are rather trivial, and will be considered within WP5-WP6 to produce a user-friendly browser of DaEuMon, which also allows use of advanced filtering criteria.

A major avenue for integration is to identify which monitoring schemes are implemented in several European countries, but are still lacking in some other European countries. For instance, DaEuMon suggests that wetland habitats are monitored in seven EU countries (United Kingdom, Hungary, France, Greece, Poland, Estonia, Switzerland). The design of national habitat monitoring schemes for wetlands could thus be recommended in countries that lack such monitoring schemes, based on collaboration with experienced countries.
This kind of gap analysis could be a useful tool for national officers designing environmental policies, as well as for any institution to justify that some monitoring is still lacking in their country and that it is worth developing them.

3.1 Combining data

An intuitive recommendation is to unify all existing sampling designs. However, in practice, this is far from realistic, because schemes will differ in sampling design, methods, etc. and data from monitoring are rarely, if ever, similar and compatible. Separate schemes often have different goals, which translates into different sampling designs applied, or have different amounts of manpower, which translates into sampling designs with differently optimized sampling effort. When unifying existing sampling designs is not possible, then methods for integrating data are necessary.

Integration of data can be of two kinds: either the input data are integrated or the results are integrated. Input data are either remotely sensed imagery or field-collected quantitative and/or qualitative data. The latter can result from exhaustive measurements or from field sampling (mapping). Input data integration is meaningful when the focal areas overlap at least partially. The three possible combinations integration of input data and their main characteristics are shown in Table 6.

Table 6: Potential combinations and main characteristics of cases when different input data are integrated from overlapping focal areas.

Combination	Motivation for combination	Methods for combination	Requirements for combination
Remotely sensed with remotely sensed data	Improving separability of habitat features by enhancing their spectral signature and by providing mult-itemporal and multi-resolution coverage	- Imagery is used in various combinations for visual photo-interpreter or it is being automatically classified by a computer. - Visual interpretation of multi-spectral, multi-temporal, multi-source imagery combined into true- or false-color composites. Image data of dissimilar spatial resolutions used for interactive visualizations in a GIS framework. - Automated supervised and unsupervised image classification	Same image geometry (map projection, spatial resolution, image extent), except for some techniques of visual photo-interpretation.
Field-collected with field collected data	Increasing the spatial or thematic coverage of monitoring by including information from larger area, from longer time or from additional habitat types	- Merging data on species composition and abundance, and on habitat properties and measurements from several observation points, transects, relevés etc.	- Same measurement units - Compatible measurement accuracy and precision - Weighting issues to adjust for representativity
Remotely sensed with field collected data	Data, provided by a high precision field survey can support interpretation of remotely sensed data and validate the RS-based mapping and monitoring results	- Ground-truthing the remotely sensed data, i.e., spatially co-registering ground samples with image segments to calibrate the classification model - Independently validating interpretation or classification results using an error matrix	Reference field data need to be representative for the remotely sensed area of interest; adequate coverage of inter- and intra-habitat variability

The integration of input data may in some cases require the homogenisation of the data types across schemes. Homogenisation involves the transformation of the data to have the same data type in all monitoring schemes. This can happen in several ways, the easiest of which is to degrade information to the lowest complexity level available in the datasets to be combined. For example, habitat types precisely defined at some lower level can be transformed to a group of habitat types at a broader, higher level. Such homogenisation obviously results in the loss of information, but it may be the only way to progress when different data types are to be integrated.

The integration of results most often involves combining the habitat maps. The habitat maps are the results from the interpretation, processing and evaluation (checking) of the data obtained either by remote sensing or field mapping. The advantages for such combinations differ when maps from overlapping areas or maps from spatially disjunct areas are merged.

- The advantage of combining spatially coincident maps is to improve or enhance monitoring results for the given area (e.g., more spatial or thematic detail for some of the habitat types, extended temporal coverage if comparable maps from different dates are combined).
- In contrast, the main advantage of combining spatially disjuncted maps is to extend the spatial coverage of monitoring to other areas.

The most important data requirements for combining maps are:

- same map projection,
- compatible dates of validity,
- comparable nomenclature / set of habitat types,
- compatible map precision (spatial, thematic),
- compatible map accuracy.

There are many methods for combining habitat maps, belonging to the domain of raster and vector GIS analyses. Since these methods are too numerous to mention here, we recommend that the reader consult some standard GIS text for an overview (e.g., Longley et al. 2005).

3.2 Combine estimates

In many cases, the integration of some derived measure istead of the data is of interest. These derived measures will be referred to commonly as "estimates" and can range from relatively simple statistics (e.g., averages, sums) to highly complex measures (e.g., spatial statistics, pattern indices etc.).

One advantage of combining estimates is that measurement units do not need to be the same. However, for meaningful comparisons, the same habitat quality criteria need to be monitored (e.g., for H28: fragmentation, structural changes, species composition, physical-chemical environment, indicator species). After producing estimates for the same habitat quality criteria, weighting issues and intensity of monitoring have to be considered.

When combining estimates, a general issue is the relative importance of each separate scheme. This issue is usually solved by attributing different weights to estimates from different schemes, based on sources of the difference among schemes. These differences may include spatial extent of a scheme, percentage of habitat coverage per scheme, temporal and spatial monitoring intensity (i.e., frequency of monitoring and sampling density, respectively), thematic accuracy (e.g., percentage of correctly detected units, Kappa index of agreement – Lillesand and Kiefer 1994), and spatial precision (i.e., scale of mapping or minimum mapping unit).

The appropriate estimate for use in analyses, comparisons, evaluations, and integration depends on the questions posed (please see examples in Table 7). In general, two types of statistics are used in such evaluations, univariate and multivariate statistics. Univariate statistics involve the selection of a single habitat variable, for example, abundance of an indicator species, an environmental parameter, or a habitat structural measure. Univariate approaches can be used in several evaluation procedures, e.g., to calculate simple descriptive statistics, to conduct exploratory data analysis, and to test biological hypotheses through significance tests. Hypothesis-testing is a major application of univariate statistics to analyse monitoring data, for example, to discover significant changes in one parameter over time.

Table 7: Examples of estimates and potential ways of combining them.

Estimate	Methods for combination
Habitat extent (change)	Sum of individual habitat areas
(Change of) diversity of biotopes within habitat	Weighted sum of biotope diversity percentages
(Change of) species composition within habitat	Weighted sum of species composition percentages
(Change of) spatial pattern	Weighted average of spatial pattern metrics

Another frequently used group of estimates are the various indices developed to characterize different habitat attributes. In habitat monitoring, indices of biodiversity are especially frequently used. These can be relatively simple, e.g., species richness is most often given as the total number of species occurring within a habitat, but can also be complex, e.g., diversity indices that measure the relative abundance of species compared to other species, are sensitive to certain distributions, and can be ordered to study their applicability to characterize species composition and abundance. Indices are often treated as normally distributed and are analyzed using standard statistical methods (e.g., ANOVA, t-test, confidence intervals). As biological phenomena often do not follow a normal distribution , randomization tests based on resampling to estimate sampling error for the indices often will be requied (Elzinga et al. 2001). Indices calculated from different sets of data could then be compared.

In contrast to univariate measures, multivariate methods evaluate several habitat variable simultaneously. Multivariate methods, simply put, can be used in integration and in habitat monitoring

- to calculate a similarity or dissimilarity (distance) measure between each sampling unit and each of the other sampling units by comparing each of the variable pairs within the sampling unit and
- to group the sampling units into classes (classification techniques) or arrange them in relation to each other (ordination) based on their similarity.

Classification, or putting samples into classes, is often useful when one wishes to assign names to habitats or to map habitats. However, given the continuous nature of habitats, ordination can be considered a more natural approach.

A special case of statistical estimates related to integration of habitat monitoring schemes is to judge the quality or condition of habitats. In most cases, habitats monitored are too diverse for a simple common measure of quality and many different measures of condition can be used to characterize their status. Thus, in most cases, data for a range of attributes has to be considered together in order to assess the condition of a habitat or habitat type. All attributes must attain their target value for the condition of the habitat or habitat type to be considered favourable. Even the listing of these attributes would be well beyond the scope of this deliverable, therefore, we will not go into much further details here. However, it is important to stress the need for baseline data for all attributes that characterize the condition of habitats. Another complication is that data should be available from different sampling times for all attribute information, because the determination of the status of the habitats requires repeated measurements to detect any trend.

3.3 Ability to detect trends

The ability of a monitoring scheme to detect any trend is analogous to the power of statistical tests. Statistical power is the probability of getting a statistically significant result given that there is a real biological trend in the habitats under investigation. In statistical terms, power is defined as 1 – ß, where ß is the probability of wrongly accepting a null hypothesis when it is actually false, known as type II error. When a statistical test returns a non-significant result, it is important to distinguish whether there is no biological effect, or whether it is because the sample design is insensitive to a real biological effect. Power analysis can distinguish between these alternatives and therefore is an important component of experimental design (Davies et al. 2001).

In monitoring terms, careful consideration of the power of a sampling programme can make the difference between insufficient sampling for conclusive decision-making and wasting resources by over-sampling beyond that necessary to achieve significant results. For the monitoring of quantitative attributes of habitats (extent, shape, diversity etc.), type II error will be directly linked to how large of an effect size a scheme is able to detect. Question H24 in the DaEuMon database ("The minimum annual change you think you can statistically detect is") provides a rough and potentially biased estimate for this statistical power. For monitoring the quality of habitats, a type II error results in a feature being considered favourable when it is actually unfavourable. Unfortunately, the DaEuMon does not contain specific information on whether the favourable status can be judged by the coordinator or by the monitoring scheme.

However, information present in the DaEuMon database offers a way to estimate statistical power of the monitoring schemes (please see D20 for further details). The estimation of statistical power of the consituent schemes and the integrated scheme can provide useful information on whether the integration resulted in a higher ability of the integrated scheme to detect trends than it was for the single monitoring schemes.

4 Example of a possible habitat monitoring scheme integration

It should be mentioned that monitoring of habitats is still at an early stage and are less often carried out by non-professional people compared to the monitoring of species. Consequently, the habitat monitoring database (DaEuMon) is less exhaustive than the species monitoring database.

Two systems of Habitat Types Monitoring have been analyzed and compared, where focus of both is oriented towards forest habitats: Plant community monitoring - Forests in Hungary and Slovenian Forest Inventory.

4.1 Plant community monitoring - Forests in Hungary

The example is a part of the wider Hungarian Biodiversity Monitoring System (HBMS – Demeter et al. 2001). In the establishment of HBMP the following key areas were given priority:

- the monitoring of endangered and protected natural values,
- the observation of elements with a diagnostic value in assessing the general state of the biota and communities, and
- the study of the direct and indirect effects of human-induced changes and changes of the environment.

To carry out the national obligations under the Convention on Biological Diversity, biologists and nature conservation experts joined forces to find the reasons for the decline of biodiversity in Hungary. The Hungarian Academy of Sciences (HAS) first drafted a biodiversity conservation strategy, which identified the accomplishable tasks and stressed the importance of continuous national monitoring. The design of the Hungarian Biodiversity monitoring System was initiated and organized by the Authority for Nature Conservation of the Ministry of Environment and Regional Policy. This program will enable the creation of a national monitoring network that might serve as a reference for other countries. The different sampling and data-collecting methods of the Hungarian Biodiversity Monitoring System were tested in an experimental site in the floodplain of the River Tisza in 1995. On this area the characteristics of the different plant communities have been described and the occurrences of the targeted animal and plant species were recorded. Therefore, the information recorded at different organizational levels (populations, communities or associations, landscape) became comparable. The distribution of the proposed network of 5 by 5 km sampling quadrates in Hungary has been used. Mapping in these quadrates at landscape level yields the framework within which the more detailed community-oriented repeated investigations can be carried out.

4.2 Slovenian Forest Inventory

Slovenian Forest Inventory has been adopted in view of habitat type monitoring and is a part of forest management planning, assessed by the Slovenian Forest Service. As a public institution, established by the Republic of Slovenia (The Act on Forests, 1993), it performs public forestry service in all Slovenian forests, irrespective of ownership. It is organized in 14 regional units, 93 local units, and 408 forest districts. It employs 688 forestry experts.

The main tasks of forest management planning are the elaboration of forest management plans, collecting data on the state and development of forests, monitoring of biotic diversity of forests, giving consent for interventions in the forest and forest space and co-operation in open-space planning.

Forest management plans, elaborated for a period of ten years, describe the state of forests and their development trends and set the goals of management in the future (also by taking into account the analysis of management in the past) together with guidelines and measures for the rational implementation of these goals. Objectives are related, apart from timber production, to important forest functions, such as protective, biotopic, water protective, recreational, etc.

In making plans the Slovenia Forest Service also co-operates with environmental organizations. Full attention is given to forests with a special purpose and to all forests located in NATURA 2000 regions. It means that all planned guidelines and measures are especially carefully discussed, also considering wider interests of nature preservation.

4.3 Comparison of the two habitat monitoring schemes

Comparison between the two schemes of monitoring of forest habitat types using DaEuMon shows that the Hungarian monitoring is assessing the total state area of 93.000 km^2. Within this area a network of 34 sampling quadrates (5 by 5 km in size) is analyzed, whereas monitoring in Slovenia Forest Inventory includes forest areas only, 11.692 km^2, which is almost 60% of the total state area. Sampling is performed on a total of 100.000 sampling sites (permanent plots), whereas the complete forest area is covered by the Forest Management plans and more detailed silvicultural plans, which link planning with implementation work in forests (H10, H11). Up to 1/10 of silvicultural plans are updated or renewed annually in Slovenia, (approximately for 100 thousand hectares of forests); in Hungary the frequency of monitoring is four (4) years (H13).

Slovenian spatial variation in habitats is documented by field mapping (H4). Remote sensing (orto photo plans in 1:5000 scale - DOF 5) and field methods (permanent sampled plots) are combined in Slovenia. On the stand level a different density of grids is applied. In Hungary frequency of plant species sampling ranges from 1 to 3 sampling quadrates/site (size of 50x50 m) selected per plant communities (H23).

Estimate of minimal annual change of parameters that could be statistically detected in Hungary is more than 20% and in 10% Slovenia (H24).

Both schemes provide data on species abundance (H2); in the case of the Slovenian Forest Inventory most information is based on tree species, whereas in Hungary monitoring is targeting different groups of plant and animal species. In both countries no further environmental parameters are collected (H3).

In both schemes sampling sites are chosen/defined according to expert knowledge (H7) and partly located in legally protected areas (H8). In Slovenia the starting year of monitoring was 1971. In the year 1990 the scheme covered nearly 25 % of forests, whereas today it covers 100 % of forests (H16, H35). In Hungary the scheme has started in the year 2000 (H16). Monitoring data are analyzed by graphics and descriptive statistics in Slovenia and with some advanced statistics (GLM, GAM, mixed models and time series analysis) in Hungary (H19).

All habitats mentioned in the habitat list (H22) are presented in Table 10, whereas in the Slovenian scheme also all forest habitats not listed in Annex 1 are monitored (H20, H35).

Table 8: Comparison of habitat types monitored in Slovenia and Hungary. Some of the listed habitat types in Hungary are not classified as forest habitat types (Annex 1) but are nevertheless presented in the table (2340*Pannonic inland dunes and 7140 Transition mires and quaking bogs) (source: DaEuMon).

List of habitat types monitored	SLOVENIA	HUNGARY
Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	**YES**	**YES**
Bog woodland	**YES**	NO
Dinaric dolomite Scots pine forests (Genisto januensis-Pinetum)	**YES**	NO
Illyrian *Fagus sylvatica* forests (Aremonio-Fagion)	**YES**	**YES**
Illyrian oak-hornbeam forests (Erythronio-carpinion)	**YES**	NO
Luzulo-Fagetum beech forests	**YES**	NO
(Sub-) Mediterranean pine forests with endemic black pines	**YES**	NO
Asperulo-Fagetum beech forests	NO	**YES**
Euro-Siberian steppic woods with *Quercus* spp.	NO	**YES**
Pannonian-Balkanic turkey oak -sessile oak forests	NO	**YES**
Pannonian woods with *Quercus pubescens*	NO	NO
Pannonic inland dunes	NO	**YES**
Pannonic woods with *Quercus petraea* and *Carpinus betulus*	NO	**YES**
Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris)	NO	**YES**
Tilio-Acerion forests of slopes, screes and ravines	**YES**	**YES**
Transition mires and quaking bogs	NO	**YES**

Both countries mention land use, invasive species, fragmentation, and catastrophic events as the causes of change that are monitored. Climatic change and ageing of habitats as the additional causes are also mentioned for the Slovenian scheme (H26).

Species composition is monitored in both countries. Fragmentation and structural changes are included in Slovenian Forest Inventory (H27, H28).

In the Slovenian scheme there are 600 professionals and 40 volunteers and in Hungary 20 professionals involved (H30, H31). Training or expert knowledge is obligatory in both countries (H32). In Slovenia 8800 persons-days and 20 persons-days in Hungary are necessary yearly for data collection, coordination, and analysis of the presented schemes (H33). 250.000 € are spent on material and equipment in Slovenia and 2520 € in Hungary (H34) per year.

Due to the vicinity and geographical similarity, the object of monitoring in both countries are similar forest habitat types. However, the methodological approach, monitoring intensity, spatial scale and application of monitoring results, differ between the two countries. Plant community monitoring - Forests scheme in Hungary has been established exclusively for the purpose of habitat type / community assessment, whereas the Slovenian Forest Inventory is part of a wider frame of Forest Management. Nevertheless, integration of both schemes into a unified framework for habitat monitoring could yield not only a spatial extension of the area monitored, but also a synoptic overview of biodiversity loss in forest habitat types for the two countries. In order to achieve this a common set of habitat types monitored should be defined, as well as a homogenisation of each estimate to be integrated. For instance, integrating land use change estimates would entail harmonizing definitions and minimum mapping unit of each land use class monitored, setting common data quality standards, reference dates etc.

5 References

Bailey, J.A., 1984. Principles of Wildlife Management. 373 p.

Blondel, J., 1979. Biogeographié et ecologié. Paris, New York, Masson.

Blondel, J., 1995. Biogeographié. Approché ecologique et evolutive. Paris, New York, Masson.

Böhme, W., 1978: Das Kühnelt`sche Prinzip der regionalen Stenözie und seine Bedeutung für das Subspezies-Problem: ein theoretischer Ansatz. - Z. zool. Syst. Evolut.-forsch. 16: 256-266.

Bossard, M., Feranec, J. & Otahel, J., 2000. CORINE land cover technical guide – Addendum 2000. European Environment Agency, Copenhagen.

Caughley, G., Sinclair, A.R.E., 1994. Wildlife Ecology and Management. 334 p.

Connor, D.W., Brazier, D.P., Hill, T.O., & Northern, K.O., 1997. Marine Nature Conservation Review: marine biotope classification for Britain and Ireland. Vol. 1, Littoral biotopes; Vol. 2, Sub littoral biotopes. Joint Nature Conservation Committee, Peterborough.

CORINE Biotopes - Technical Handbook, volume 1, p. 73-109, Corine/Biotopes/89-2.2, 19 May 1988, partially updated 14 February 1989.

CORINE Biotopes manual, Habitats of the European Community. EUR 12587/3, Office for Official Publications of the European Communities, 1991.

Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora, O.J. L206, 22.07.92

Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C., Vincent, M., (Eds), 2001. Marine Monitoring Handbook. UK Marine SACs project. Joint Nature Conservation Committee, English Nature, Scottish Natural Heritage, Environment & Heritage Services, Countryside Council for Wales, Scottish Association for Marine Science

Demeter, A., Török, K., Fodor, L.: Hungarian Biodiversity Monitoring System 1998-2001, c/o Department of Nature Conservation, Budapest, 28 p.

Devillers, P., J. & Devillers-Terschuren, 1996. A Classification of Palearctic habitas. Council of Europe, Strasbourg: Nature and environment, No 78.

Devillers, P., J. Devillers-Terschuren & Ledant, J.-P., 1991. CORINE biotopes manual. Vol. 2. Habitats of the European Community. Office for Official Publications of the European Communities, Luxembourg.

Diekmann, M. (2003) Species indicator values as an important tool in applied plant ecology – a review. *Basic and Applied Ecology*, 4, 493-506.

Dierschke, H., 1994. Pflanzensoziologie. Stuttgart, Verlag Eugen Ulmer.

EEA, 2004a. EUNIS web application. http://eunis.eu.int/index.jsp

EEA, 2004b. Impacts of Europe's changing climate: An indicator-based assessment, 2/2004. European Environment Agency, Copenhagen.

Elzinga, C., Salzer, D., Willoughby J.W., Gibbs J. 2001. Monitoring Plant and Animal Populations. State University of New York, Blackwell Science, 360 pp.

European Commission 2003. Interpretation Manual of European Union Habitats, EUR 25. DG Environment, Brussels.

Fielding, A.H., P.F. Haworth, 1995: Testing the generality of bird-habitat models. - Cons. Biol. 9: 1466-1481.

Hennëkens, S.M., Schaminée, J.H.J. & Stortelder, A.H.F., 2001. SynBioSys. Een biologisch kennissysteem ten behoeve van natuurbeheer, natuurbeleid en natuurontwikkelig. Versie 1.0. Alterra, CD-ROM, Wageningen.
Hunter, M. L. 1996. Fundamentals of Conservation Biology. 482 p.
Lillesand, T.M., Kiefer, R.W., 1994. Remote Sensing and Image Interpretation. John Wiley & Sons, New York, p. 616.
Longley, P. A., M. F. Goodchild, D. J. Maguire, D. W. Rhind, 2005. Geographic Information Systems and Science. Wiley.
MaDonald, L.H., Smart, A.W. 1993. Beyond the guidelines: practical lesson for monitoring. Environmental Monitoring and Assesment 26: 203-218.
MAFF (Ministry of Agriculture, Forestry, and Food of Slovenia), 2004. A land use monitoring system for Slovenia.
Nordic Council of Ministers, 1994. Vegetation types of the Nordic Countries. Nordic Council of Ministers, Copenhagen.
Noss, R. F., 1990: Indicators for Monitoring Biodiversity: A Hierarchical Approach Conservation Biology, Vol. 4 Issue 4 p. 355.
Noss, R. F.; Cline, S. P.; Csuti, B.; Scott, J. M., 1992: Monitoring and assessing biodiversity. S. 67–85 in Lykke, E. Achieving Environmental Goals. Belhaven Press, London.
Ozinga, W.A. & Schaminée, J.H.J., 2005. The development of ecological information systems, a new tool in biological research. Recent. Res. Environ. Biol., 1 (2004): 531-551.
Udvardy, M. D. F., 1975. A classification of the biogeographical provinces of the world. IUCN Occasional Paper no. 18. Morges, Switzerland: IUCN.