AN OBJECT-BASED GIS / REMOTE SENSING APPROACH SUPPORTING MONITORING TASKS IN EUROPEAN-WIDE NATURE CONSERVATION

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ABSTRACT:

The implementation of the European Union (EU) Directives on the conservation of natural habitats (92/43/EEC – Flora-Fauna-Habitat FFH) and wild birds (79/409/EEC) will require standardized scientific monitoring of the resulting Natura-2000 network to a previously unknown extent. It has been estimated that up to 15% of the EU land area will need systematic and repeated monitoring due to these legal commitments.

We describe the extended monitoring requirements as far as they concern the FFH Directive and outline existing approaches to comply with standardized reporting obligations. On the methodological side we illustrate an innovative technique to derive a relevant baseline geometry for further analysis termed MSS/ORM (Multiscale Segmentation- Object Relationship modeling by Burnett & Blaschke, 2003). The Polygons derived by means of this hierarchical object based image analysis approach can be further used to comply with the EU monitoring tasks. We evaluate the role of structural assessment by means of landscape metrics and subsequent development of Structural Indicators and assess the role of different spatial resolution EO data for nature conservation.

Key words: Monitoring, European nature conservation, Natura-2000, object-based image analysis

1. Introduction

Increasing global concern on Biodiversity loss has led the European Union to formulate the EC Biodiversity Strategy and the Pan-european Biological and Landscape Diversity Strategy (PEBLDS). The Flora-Fauna-Habitat Directive (FFH, 92/43/EEC) with its strong focus on scientific and standardized monitoring and success control constitutes one of the most important components of an envisaged pan-european ecological network and contributes towards a standardization of European nature conservation. It is also the EU's main legal instrument for the implementation of the CBD (Convention on Biological Diversity, 1992). The priority of biodiversity issues in European policy was further highlighted with the EU strategy for sustainable development agreed on in Gothenburg (2001) and its aim to stop the deterioration of European biodiversity by 2010 and to fully implement the Natura-2000 network for monitoring purposes.

The monitoring requirements that follow from the Directive concern large areas (up to 15% of the EU land area) and prescribe a regular update (every 6 years starting 2007[1]). One of the main tools considered to support parts of such a large monitoring task is the use of EO (Earth Observation) data. In general the utilization of EO data for biodiversity science and conservation (Turner et al., 2003) as well as in ecology (Kerr & Ostrovsky, 2003) is

[1] Mid-2007 is the deadline for the reporting period 2000-2006

becoming more and more accepted as an appropriate data source to supplement and in some cases even replace field-based surveys. This increasing acceptance in ecology and nature conservation is partly driven by the availability of very high spatial resolution EO data from satellite platforms like IKONOS or QuickBird that provide spatial resolution of about 1m. However the potential of high resolution data can only be fully realized once (semi-) automated image analysis tools are available that ideally combine the advantages of statistical per pixel approaches and human interpretation (Lang et al., in press).

2. Monitoring requirements and existing concepts

Although monitoring standards do exist for some countries (e.g. the Common Standards Monitoring for the UK (Joint Nature Conservation Committee, 1998)), a pan-european standard is still elusive. In general the implementation of the FFH Directive was greatly delayed with regard to the timeframe originally envisaged. Currently the lists of pSCIs are evaluated by the EU and the adoption of final lists of SCIs (sites of community importance) is expected to be published by the EU in 2004.
One of the central monitoring requirements of the FFH Directive concerns the notion of "conservation status" of a habitat type or species. Although the meaning of conservation status is defined in the Directive, there are no detailed monitoring guidelines and methodologies provided that would allow a standardized and consistent estimation of the conservation status of habitat types and species and would help to tackle the monitoring obligations of Art.16, 17 and 11. Several monitoring concepts have been suggested and implemented in the German Länder and other EU member states as described below. Table 1 compares some first estimation of scientific standard and costs connected to the use of each of them. Additionally the table gives hints to the potential inclusion of the methods described in Chapter 3.1 and 3.2.
For Natura-2000 monitoring EO data is often required to cover local to regional scales (<1:5000 -1:25000) and therefore needs to be of very high spatial resolution. Aerial photographs and derived orthophotos are still the standard data product providing sufficient spatial resolution and being established and operationally integrated in the workflow of many nature conservation agencies.

2.1. Two stage-monitoring

In the absence of detailed guidelines from the EU, first monitoring concepts and reporting procedures for Natura-2000 were developed by the German BfN (Federal Agency for Nature Conservation) for the continental biogeographic region (Rückriem & Roscher, 1999). These monitoring concepts were mainly referring to requirements that follow from Article 17 (FFH). For a number of habitat types detailed questions were suggested that would have to be answered to justify any judgement on conservation status of the particular habitat type. For each of these questions one or several parameters (and respective methods) were selected.
In order to minimise the monitoring expenditure the concept is designed as a two-step monitoring approach. In case an initial rating indicates a favourable conservation status of the habitat type only a basic set of parameters needs to be monitored. Only in case one of the (given) threshold values is exceeded, a more detailed monitoring with additional parameters and methods is required. However these suggestions were widely regarded as scientifically sound but to ambitious for practical implementation.

2.2. Minimum requirement monitoring based on standard data form

The German federal states (Länder) are responsible for reporting and monitoring obligations on the local and regional scale, while the results need to be summarized for a national report to the EU. Therefore it was agreed on standardized minimum requirements for the evaluation of the conservation status within Germany (LANA, 2001). These requirements are based on the standard data form for Natura-2000 monitoring (European Commission, 1994a).
As a consequence a much simplified and less work intensive monitoring concept is currently being implemented within the German Länder. This monitoring concept rates the conservation status of each habitat type in only three categories (A, B or C) according to three main criteria: 1) habitat structure and quality, 2) species composition and 3) disturbances. The single parameters that are used to determine these main criteria partly remain subjective and without transparent and repeatable quantification. In line with explanatory notes of the EU regarding the standard data form, a ranking is based on the "best expert judgement" (European Commission, 1994b).

Table 1: Monitoring approaches suggested or currently implemented in Germany with the proposed inclusion of indicator supported monitoring as described in Chapter 3.

Monitoring Approaches	Implementation	Scientific monitoring standard	Costs
2 stage Monitoring (Rückriem & Roscher, 1999)	Detailed evaluation of conservation status of habitat types according to specific questions and parameters for each habitat type.	**Medium to high:** large set of questions and quantifiable parameters for every habitat type	**High:** Even if 2-stage approach is implemented
Minimum requirement monitoring	Three criteria are rated on a three level scale (A, B and C): habitat structure, species composition and disturbances. According to this rating an overall score is given for each habitat type. This relatively coarse method is currently being implemented in the German federal States.	**Low:** Only few quantifiable parameters, mostly subjective ranking using best expert knowledge	**Low:** Apart from the initial assessment relatively low costs (no extensive indicator and/or EO-data use)
Change and/or Structural Indicator supported monitoring	Additionally applied on the monitoring concepts summarized above (2-stage or minimum requirement monitoring). In either cases change indicators can be used to detect change hotspots prior to more detailed investigations. Quantification of habitat structure though Structural Indicators can support those parts of both approaches where landscape pattern is otherwise only subjectively ranked.	**High:** Quantifiable indicators and EO data used to support monitoring. Standard depends on extent to which implemented.	**Medium to high:** Indicators and EO data use replace some of the fieldwork. Costs depend on extent of EO data and indicator use, as well as on concept used.

3. Object based GIS/RS approaches

VHR (Very High Resolution) data such as aerial photographs are still predominantly classified manually by a human interpreter using methods that range from manual digitising on translucent drafting film to fully digital photointerpretation using a digital photogrammetric workstation and stereovision glasses (Campbell, 2002). Alternatively pixel based (semi)- automated approaches developed for medium to coarse spatial resolution EO data are being improved by implementing complex rules and context-based information, as well as ancillary data in the classification process (see Campbell, 2002, Ehlers et al., 2003 and Abkar, 2000) for an overview of approaches).

3. 1. Baseline geometry: MSS/ORM

In recent years hierarchical methods of contextual classification that combine the use of multiscale image segmentation with the inclusion of contextual information and ancillary data by fuzzy clustering provide promising new approaches towards the (semi)-automated classification of VHR data.
Recently, many new segmentation algorithms and applications have been tested in GI science applications, but few of them lead to qualitatively convincing results while still being robust and operational (Blaschke and Strobl, 2001). The Multiscale segmentation / object relationship modelling (MSS/ORM) methodology suggested by Burnett and Blaschke (2003) performs image segmentation as a first step and bases any further analysis or classification on derived image objects. As one of the main advantages of segmentation over per pixel classification approaches, the aggregation of pixels generally results in a significant decrease in image units. MSS/ORM is designed to utilize information from different scales within a single image and to integrate external information from auxiliary data sets. It can provide various representations of the image content in a flexible manner. Consequently one may say, it offers candidate discretizations of space. The initial GIS database building stage can be considered as quasi-independent of specific research questions. By slightly changing the parameters the same system can be tuned for a variety of different needs. This way, MSS/ORM is very flexible and can embrace any kind of spatial information. The technique is also relatively reproducible, compared to human interpretation. Within the object relationship modelling step, the ‘within patch heterogeneity’ measure (mean spectral difference between all sub-objects) was successfully applied to characterize shrub encroachment on pastures of a European cultural heritage landscape in Germany. Burnett et al. (2003) extended MSS/ORM to mire mapping and monitoring. The five components of MSS/ORM and the corresponding subsequent working steps are described in Table 2 and the general workflow proposed here is depicted in Figure 1.

Table 2: The MSS/ORM methodology for landscape analysis of Burnett and Blaschke (2003) after Blaschke (in Press).

Step ① **GIS building**	The main prerequisite is the collating of geographic information into a database (geo-referenced survey, sample and auxiliary data). - Survey data includes any systematic and continuous assay of landscape, e.g. digital aerial photograph mosaics, airborne spectrometer swathes and satellite images. - Sample data may include all kind of distribution and habitat data. - Auxiliary data include other data sets for instance derived vector data such as topographic contours, road network and cadastral information, and raster digital elevation models (DEM).
Step ② **Segmentation**	MSS searches for the gradient of flux zones between and within patches. It equates to searching for changes in image object heterogeneity/homogeneity.
Step ③ **Object relationship model building**	A model of the relationships between the segmented image objects is built. - Some object relationships are automatically derived. For instance, the characteristics of level –1 objects (such as mean spectral values, spectral value heterogeneity, and sub-object density, shape and distribution) can be automatically calculated and stored in the description of each level 0 object. - Other relationships are semantic, requiring the knowledge of the expert on the

	landscape in question.
Step ④ Classification and Visualization	Image objects are assigned to categories according to the relationship model. The output is usually a map which visualizes the results of the classification. Depending on the research question the visualization rules can be designed to show different levels of the object hierarchy in different parts of one map (e.g. a broad level for settlement classes while showing more detailed levels within ‘forest’ and ‘agriculture’ super-objects.
Step ⑤ Quality assessment	Quality assessment is essential, both at the final stage when a visualization (map) has been derived from the system, and at each of the preceding stages. Derived data sets, e.g. those generated by algorithms that search for dominant tree crown positions, must also be assessed for error.

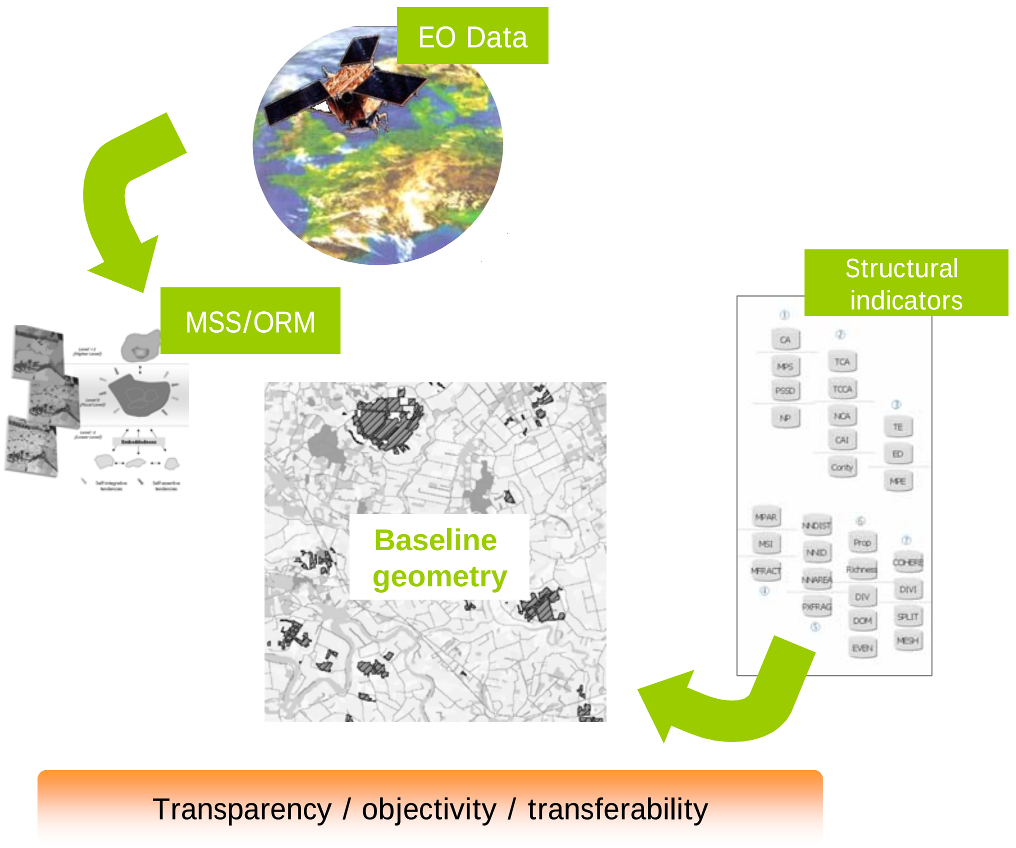

Figure 1: This Figure illustrates the workflow from EO data segmentation and classification using the MSS/ORM methodology (see Chapter 3.1.) to the creation of a categorical map (the baseline geometry). This geometry is central to all further analysis steps like the application of Structural Indicators (see Chapter 3.2.). Both the classification step and the further analysis are ideally transparent, objective and transferable.

3.2. Structural Indicators

A principal assumption in landscape ecology concerns the influence of landscape pattern on function. As Turner (1989) states: “Quantitative methods are required to compare different landscapes, identify significant changes through time, and relate landscape patterns to ecological function".

Within the framework of increasing monitoring needs for European nature conservation, a search has begun for methodological and technical tools with which to support monitoring across the large range of European habitat types. The premises underlying this search are that regardless of Natura-2000 site variability some common procedures and indicators should be identifiable. Important questions remain as to the types of indicators that would support this

monitoring, which EO-based technologies could under-pin the indicators and the universality of indicator application, EO-based or otherwise derived. These questions have been addressed within the SPIN project (Spatial Indicators for European Nature Conservation, www.spin-project.org), one of 26 EU-funded research projects linked to EO technologies in the Fifth Framework Programme (FP5).
One of the indicator groups developed in SPIN is based on landscape metrics and aims to derive Structural Indicators that quantify ecologically important aspects of landscape structure and use them to assist in evaluating conservation status.
From the large set of landscape metrics potentially available a small subset was selected and grouped according to ecologically meaningful criteria. In order to use landscape metrics as Structural Indicators, issues regarding interpretability, necessary data input and knowledge need consideration. A categorization of these issues mainly refers to the following points:

- **Ambiguity** (the metric value can indicate either favourable or unfavourable states of a habitat type). For example a high value for edge density can be judged as positive in areas where structural richness and edge habitats imply high quality, in other areas the same value could be judged negative from an ecological point of view if a large continuous patch is required for edge-sensitive species.
- **Species data required for interpretation.** In many cases the results of a metric calculation do not make sense as a pure numeric value. They need to be interpreted in the context of a certain species or habitat type (or recorded for comparative reasons only).
- **Dependant on thematic resolution.** Most indices are sensitive to the thematic resolution of the underlying base geometry (classification). Only results obtained at a certain thematic depth (e.g. level 2 EUNIS or FFH habitat types) can be compared. Interpretation has to take this into account.
- **Parameterization required.** Some metrics (like core area and proximity) need initial parameterization *before* calculating the metric. To set a core area distance either the relevant core area distance is known for a certain species or an estimated core area is extracted from literature and used to give a general picture of the sensitivity of the class to fragmentation processes.

More detailed examples for the testing and application of Structural Indicators are reported on in Langanke et al. (submitted) and Lang & Langanke (in press).

4. Discussion

Advances in European nature conservation such as biodiversity protection implemented with the FFH Directive lead to a growing need for standardized monitoring methodologies from local to national scale. To comply with these monitoring and reporting needs an increasing usage of EO data is suggested as an invaluable tool to supplement traditional methods used by nature conservation authorities. The monitoring concepts for Natura-2000 currently being implemented in Germany are scientifically less ambitious then those originally envisaged due mainly to cost considerations. With a subjective ranking largely based on “best expert knowledge” there is ample opportunity to include methods that would quantify and objectivise this monitoring concept in the future.
Medium resolution EO data (10 - 30m pixel size) might be suited to assist with the monitoring for rather stable and large natural habitat types, but not for complex, heterogeneous and small area sites. The scale domain of the local site level has traditionally

been dominated by field-based surveys and the use of manual interpretation of aerial photographs.
This situation changes slowly with the advent of very high resolution satellite imagery and the development of (semi-) automated classification methodologies for these images. With the MSS/ORM methodology one such new approach based on image segmentation and subsequent classification in a hierarchical framework has been briefly described here. This approach, we believe, holds potential for an improvement of classification quality, transparence, transferability and objectivity (as compared to manual interpretation). As categorical maps form the baseline geometry for any further detailed assessment, their quality and consistency is of great importance. We described one possible avenue of such further analysis using Structural Indicators. The utilization of landscape metrics as Structural Indicators needs consideration of several issues like ambiguity of results, the availability of species or habitat type data, the thematic resolution and the successful parameterization needed for some metrics. There is no universal and absolute set of Structural Indicators applicable on all Natura-2000 sites. Instead there is a need for local/regional adoption of thresholds based on expert knowledge and site-management decisions.
In general we see an increasing potential of EO data in combination with advanced classification methods and indicator schemes to contribute to monitoring tasks for European nature conservation. However in some cases where species related information is necessary, field-based surveys will not be completely replaceable by the use of EO data.

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