MONITORING OF BIODIVERSITY CHANGES IN THE LANDSCAPE SCALE

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ABSTRACT

The monitoring and evaluation of changes in biodiversity is a subject for many biological and ecological disciplines. Biodiversity loss has become a social and political issue over the last few decades, and protection of biological diversity has emerged as one of the main subjects within national nature conservation policies as well as international conventions, conservation targets and political programmes (e.g. the Convention on Biological Diversity, Target 2010, SEBI 2010, CITES, Ramsar Convention, European Landscape Convention). The establishment of a monitoring scheme based on an appropriate set of indicators is vital for precise assessment of the effectiveness of measures applied within biodiversity protection (e.g. action plans for endangered species, agro-environmental and landscape protection programmes). Many indicators of biodiversity change have been proposed, but their representativeness and applicability frequently suffer from poor available data or local circumstances. The concept of species and landscape diversity evaluation using a fixed set of indicators has been developing in other European countries for some two decades, but this approach is still sporadic in the Czech Republic.

This paper provides a review of the current state of this topic in the Czech Republic, discusses the concept of establishing a future national biodiversity monitoring network, and proposes a self-contained set of indicators covering all organizational and spatial levels. These proposals will enable scientifically based and sufficiently accurate evaluation of existing trends in biodiversity and its projection into the future based on foreseeable land-use changes.

Keywords: indices, biodiversity monitoring, landscape changes, biodiversity indicators

INTRODUCTION

The term biodiversity, which is generally understood to mean the diversity of organisms and their environmental factors, has seen increasing use over the last few years, and its excessive use is typical of the public administration or political sphere. Nevertheless, it is worth emphasising that biodiversity is not represented only by numbers; diversity relates to the ranges of genes, species and ecosystems at all of their organizational and spatial levels and, therefore, diversity can be distinguished at the genetic, species or ecosystem level.

Loss of biodiversity is currently considered one of the most important of environmental problems. This has led many countries and international institutions to sign conventions and to implement programmes of biodiversity protection, the most important of which is the Convention on Biological Diversity (CBD), 1992. The Czech Republic has been a contracting party to the Convention since 1994 and has created a mandatory government document entitled the "Strategy of Biodiversity Protection", which has been integrated into the policies of the National Programme of Nature Conservation and Landscape Protection and National Environmental Policy. According to this document, biodiversity protection requires that specific aims and tasks be addressed.

The means of biodiversity monitoring have already been addressed in the Czech Republic (Absolon, 1994) and, at present, progress has been made as regards species and biotope monitoring due to the need to define the limits of Special Areas of Conservation and Special Protection Areas within the NATURA 2000 network. Only recently, however, have more comprehensive attempts been made to tackle this subject, based on a compact set of indicators (Vačkář, 2005). The activities of the Agency for Nature Conservation and Landscape Protection of the Czech Republic and the Bioplatforma organization have contributed to this to a considerable degree. Nevertheless, the absence of a leading coordinating authority with a clear specification and time schedule, a financial deficit, and a shortage of national and long-term monitoring programmes focused on different aspects of biodiversity remain vital problems (Vavřinová, 2007).

At this stage, it is necessary to compare existing biodiversity monitoring programmes and methodological approaches, suggest indicator organism groups, indicate possible data sources or possible connections between monitoring programmes currently ongoing, propose suitable sets of indices of biodiversity change that would help to clearly assess the impacts of anthropogenic activities on species and habitat diversity, and arrive at a concept for a comprehensive monitoring network.

INDICES OF BIODIVERSITY CHANGE

The cultural landscape of Central Europe has been exposed to two contradictory processes over the last few decades. On the one hand, the environment is influenced by increasing pressure in the form of urbanization processes, traffic network development, recreation, as well as intensification of industrial and agricultural production (EEA, 2005; 2007). On the other hand, vast areas have been subject to marginalization due to the abandonment of traditional land-use processes. In both cases, there have been changes in biotope character, landscape and ecological function, and biodiversity level. For the purposes of assessing change in biodiversity at all spatial and organizational levels, therefore, different sets of indicators might serve as suitable tools. These use easily qualifiable variables that characterize species' abundance and diversity, their biotopes, and other related phenomena over a given time interval. Although indicators regarding species diversity have been in use for a long time, they have only been under development over the last decade in the field of assessing habitat diversity change.

The indicators should be applied to homogenous units (i.e. to single taxonomy groups of organisms, formation groups of biotopes or landscape types), as this is the only way to interpret the existing development and assess time trends (Lipský et al., 2006; Haines-Young et al., 2005).

A number of indicators and approaches to their application in specific areas have been introduced in foreign literature. There exist, however, considerable methodological fragmentation a lack of lucidity, and numerous methodological shortcomings in this relatively new direction in geo-ecological research (Bastian et al., 2006; Dale et al., 2001; Haines-Young et al., 2005; Müller et al., 2006). Interpreting the results of such indicators can be complicated, as the various indicators applied often coincide as to content and, hence, correlate with one anther (McGarigal, 2007; Wascher, 2002). Further, there is no unified terminology and typology for indicators (Müller et al., 2006; Wascher, 2002). Not usually taken into account are such facts as that the rates of various indices are sensitive to the number of land-use classes, species or habitat types (Baldwin et al. in Bailey et al., 2007), as well as to the format of the data entered (Bailey et al., 2007; Lausch et al., 2002). It is very difficult to come up with a suitable ratio that provides a professional conception of indicator theory as regards simplicity (which is necessary for its practical application) and complexity (which is indispensable in order to guarantee the scientific quality of the indicator system) (Müller et al., 2006).

COMPARATIVE ANALYSIS OF MONITORING PROGRAMS

Many monitoring programmes (see Appendix 1) have already been planned and implemented, as the need for long-term monitoring of the environment and populations has long been recognised by various nature protection or scientific institutions. In their simplest form, these provide counts of the individuals of particular groups of interest (e.g. birds, bats, butterflies). Monitoring programmes with a medium level of coverage and complexity observe more groups and factors (e.g. Ontario's Niagara Escarpment Monitoring Program). The most sophisticated monitoring programmes, which cover large territories, assess biodiversity at many levels (e.g. Biodiversity Monitoring of Switzerland, Alberta Biodiversity Monitoring Program, United Kingdom Biodiversity Action Plan, US Environmental Monitoring Assessment Program, and Hungarian Biodiversity Monitoring System).

As part of a pan-European initiative launched in 2004, the Streamlining European 2010 Biodiversity Indicators programme (SEBI 2010) provides a set of indicators that are the most appropriate for the situation in the Czech Republic. The aim of the programme was to develop a set of European biodiversity indicators to facilitate the undertaking of the European Union (EU) to halt significant biodiversity loss by the year 2010 (EEA, 2007). As the Czech Republic is a member of the EU, and as the indicators within SEBI 2010 are connected with those used in existing EU monitoring projects (e.g. for the monitoring of NATURA 2000 habitats and species), this set of indicators represents an important model for a potential national programme of biodiversity monitoring.

Despite the high variability in systems used for monitoring biodiversity in different countries, five common priorities stand out in comprehensive monitoring programmes:

1. Monitoring of species diversity
2. Monitoring of the ecosystem
3. Monitoring of genetic diversity
4. Monitoring of biodiversity threats
5. Monitoring of biodiversity and socioeconomic ties

Monitoring of species diversity

Monitoring of species populations of particular interest groups (e.g. birds or butterflies) does not provide a complex view of the topic at first glance; with regard to the length of the time series of observations, however, high-quality results can be extracted. These data can be supplemented with data on landscape changes (such as type of agricultural or forest management, fragmentation, water pollution or soil degradation) and their influence on populations of organisms subject to long-term monitoring. The monitoring of species abundance and distribution has, therefore, immense importance as a primary data source, through which we can monitor biodiversity development back in time and often reveal the cause of relations between particular types of environmental change and changes in biodiversity.

Comprehensive monitoring programmes always imply an observation of abundance and distribution of various organisms of interest, together with observation of other supporting factors. Among the most monitored groups are birds (Biodiversity Monitoring Switzerland, Alberta Biodiversity Monitoring Program, UK Biodiversity Action Plan, SEBI 2010 Plan, Ontario's Niagara Escarpment Monitoring Program, US Environmental Monitoring Assessment Program), butterflies (Biodiversity Monitoring Switzerland, UK Biodiversity Action Plan, SEBI 2010 Plan, Hungarian Biodiversity Monitoring System), mammals, or at least numbers of their species or some of their groups (Biodiversity Monitoring Switzerland, Alberta Biodiversity Monitoring Program, UK Biodiversity Action Plan, SEBI 2010 Plan, Hungarian Biodiversity Monitoring System), higher plants (Biodiversity Monitoring Switzerland, Alberta Biodiversity Monitoring Program, UK Biodiversity Action Plan, SEBI 2010 Plan, Ontario's Niagara Escarpment Monitoring Program, US Environmental Monitoring Assessment Program, Hungarian Biodiversity Monitoring System). Lower plants (Biodiversity Monitoring Switzerland, Hungarian Biodiversity Monitoring System), molluscs and orthoptera (Biodiversity Monitoring Switzerland), as well as different components of water ecosystems, such as zooplankton, phytoplankton, fish, benthic algae and macroinvertebrates (Alberta Biodiversity Monitoring Program), have also been the subject of monitoring.

Monitoring of the ecosystem

Monitoring of changes in ecosystem diversity is the second keystone of comprehensive monitoring programmes operating at several spatial scales. In these programmes, both qualitative and quantitative indicators of particular ecosystem types have been monitored. Indicators of biotope quality focus most frequently on particular ecosystem functions, the rate of anthropogenic degradation and overall health of the ecosystem. In the case of quantitative indicators, these usually consist of assessment of structural and metric parameters, such as changes in the area, shape, heterogeneity, fragmentation and connectivity of individual biotope patches. Programmes that have covered such a complex scope include Biodiversity Monitoring Switzerland, Alberta Biodiversity Monitoring Program, UK Biodiversity Action Plan, SEBI 2010, Hungarian Biodiversity Monitoring System, and the US Environmental Monitoring Assessment Program.

Monitoring of genetic diversity

Monitoring of genetic diversity has been implemented in Biodiversity Monitoring Switzerland, the UK Biodiversity Action Plan, and the SEBI 2010 Plan. This type of diversity is especially important as a potential source of genes for economic use. In practice, this is a matter of monitoring the numbers of particular animal breeds and plant varieties, assessing their current proportion in overall number of animals or in cultivated areas, and defining appropriate measures to be adopted should some rare genetic variety become endangered. It is obvious that some qualities of older breeds and plant varieties, which cannot compete with modern varieties, may still be valuable and useful for the future. Their values include especially resistance to infection or to other environmental factors (e.g. cold or moisture) that modern genetic varieties often lose.

Monitoring of biodiversity threats

The following processes are currently considered to be fundamental threats to biodiversity: 1) eutrophication and acidification of ecosystems, 2) the spread of invasive species, and 3) climate change. As a consequence, present monitoring systems and data collection are designed in order to collect and quantify these aspects and their causes. A comprehensive biomonitoring programme that aims to monitor the influence of these aspects cannot work, however, without high-quality supporting data that quantifies atmospheric deposition of nitrogen, nitrogen leaching from the watershed, the spread of invasive species or climatic data. These data, in the context of monitoring the expansion of nitrophilous plants, their representation in ecosystems and penetration into what were originally mezo- or oligotrophic habitats, provides valuable initial data for assessing the influence of eutrophication on biodiversity.

Whereas the influence of eutrophication and the spread of invasive species are monitored in detail in a majority of the aforementioned monitoring systems, only the UK Biodiversity Action Plan, Biodiversity Monitoring Switzerland, SEBI 2010 Plan and US Environmental Monitoring Assessment Program are attempting to assess the impact of climate change on biodiversity.

Monitoring of biodiversity and socioeconomic ties

The topic of biodiversity and its protection represents a complex subject that intervenes in many fields of human activity. Impacts might include, for example, the implementation of legislation for biodiversity protection, the volume of financial resources for biodiversity protection, the extent of protected areas, the scale of integrating biodiversity protection goals into regional programmes and strategies, expert activities, and time spent by volunteers on biodiversity protection.

SOLUTION METHODOLOGY

Based on a comparative analysis of recent monitoring programmes, we found that the most comprehensive of these programmes monitor and assess biodiversity changes in terms of the five general priority topics mentioned above.

A. Monitoring of species diversity

Most people consider the concept of biodiversity to mean the number of each species at a particular site, in a certain habitat, or in a region or country. As changes in species' abundance and diversity, or changes in their distribution, are currently the subject of many biological disciplines, we have at our disposal a relatively long time-series of interesting data. The most valuable data are those gathered together with environmental data that are intended to establish a link between population changes and environmental factors, and to reliably prove causality between an environmental change and a change in the abundance or species structure of a monitored community. These environmental data can be divided into three basic groups:

- Data on habitat quality, e.g. the ratio of natural habitats, the abundance of alien organisms, forest area dominated by non-indigenous trees or deadwood per hectare.
- Data on landscape structure, e.g. measures of fragmentation, richness of types of land cover, patch heterogeneity and diversity, or edge density.

- Data on quality of the abiotic environment, e.g. nutrient supply in the soil, soil degradation, climate change, or air and water pollution.

If these findings are to prove useful for the study of biodiversity, it is important that the collection of data be undertaken using a sophisticated and standardized methodology and that a given group works as an indicator, i.e. that a given group must be sufficiently reactive to environmental change in the habitat, and that the rate of change in species richness of this monitored group can be interpreted and extrapolated as a rate of change in the total biodiversity of the studied site. In addition to the suitability of the methodology used for monitoring, it is also important that organism groups used as biodiversity indicators be popular with the wider public. Finally, if we want to monitor a wide region, or even a whole country, an enormous number of study sites will need to be examined. This will usually exceed the personnel capacity of academic institutions and, therefore, part of the work will have to be entrusted to methodically trained volunteers from non-governmental organizations.

Proposed groups

Based on a comparative analysis of existing and planned monitoring programmes from around the world, several groups of organisms have been chosen for future gathering of data, based on their bioindicative characteristics, ease of data gathering and ease of determination. These groups are: higher plants, molluscs, butterflies, dragonflies, ground beetles, fish, amphibians, reptiles, birds and mammals.

The aforementioned taxa cover a significant part of the biodiversity of the country and, together with data from the NATURA 2000 monitoring programme, which includes data on species from the missing groups, and data obtained by examination of local fauna and flora studies, they should provide a very satisfactory database for an assessment of the state of species diversity in the Czech Republic.

Databases

The results of current monitoring programmes (species monitoring within NATURA 2000, Breeding Bird Monitoring Programme of the Czech Society for Ornithology – ČSO, monitoring activity of the Czech Butterfly Conservation group – SOM, bat censuses at wintering sites by the Czech Bat Conservation Trust – ČESON), the database of the Agency for Nature Conservation and Landscape Protection of the Czech Republic, updated distribution atlases (Moravec, 1994; Anděra and Hanzal, 1995, 1996; Anděra, 2000; Anděra and Beneš, 2001, 2002; Horáček, 2001; Mikátová et al., 2001; Anděra and Červený, 2004; Hanák and Anděra, 2005, 2006; Hůrka et al., 1996; Šťastný et al., 2006), hunting statistics, results of local fauna and flora research, and others, are all potential sources of data for the monitoring of biodiversity changes in particular species groups. A further source of data will be the very large hydrobiological monitoring programme being prepared as part of implementing the EU Water Framework Directive. In addition, the latest versions of the lists of vertebrates, invertebrates and plants listed in the IUCN’s Red Data Book are also available (Procházka, 2000; Plesník et al., 2003; Farkač et al., 2005; Kučera and Váňa, 2005).

Proposed types of indicators

Trends in abundance and distribution of selected groups

This type of indicator is based on analysis and interpretation of currently available data on abundance and distribution of particular species (mainly birds, bats, day butterflies and species monitored within NATURA 2000).

Changes in status of endangered species (e.g. Red List Index)

With the help of Red Data Lists based on differences in region, time and habitat, we can produce a Red List Index (Butchart et al., 2004; 2005) that allow us to analyse changes in status against abundance and distribution trends. Using this method, problems can be analysed from different perspectives, providing answers to such questions as which systematic group is most at danger, or which habitats will enable the survival of the most endangered species? The Red List Index methodology, therefore, can be used both for amphibians over the whole of the Czech Republic, and for analysis of birds in the open landscape of the South Moravian Region (i.e. at both a national and local level). Analysis by functional group, habitat and region will bring both essential benefits and provide an interesting new viewpoint to this matter.

The IUCN Red Data Book is widely recognized as the most objective and thorough list of species in danger of extinction (Lamoreux et al., 2003; Hambler, 2004). Species are divided into several categories according to their risk of extinction by means of a relatively subtle methodology (IUCN, 2001). As regards their use for data, both the available Red Data Lists (Procházka, 2000; Plesník et al., 2003; Farkač et al., 2005; Kučera and Váňa, 2005) and additional expert statements can be used.

B. Monitoring of the ecosystem

Among the topical subjects of recent research has been the assessment of changes in ecosystem diversity and species richness as regards the intensity of human induced land-use changes. Monitoring of changes in biodiversity at the ecosystem level requires the use of existing digital databases and their subsequent processing using GIS geostatistical methods. These databases not only provide information on the type, distribution and state of biotopes, they also differentiate them according to their state of preservation or, more precisely, according to the impact of anthropogenic influences on the original biotope, fragmentation or protection level. The CORINE Land Cover database for 1990 and 2000 and the NATURA 2000 biotope-mapping layer were chosen as the most suitable vector layers.

Databases

CORINE Land Cover currently represents the only database in the Czech Republic that describes both the present state and changes in land use for the whole country, including its relationship with other EU countries. The regular updating of these data (1990, 2000 and 2006) using remote sensing methods is a big advantage of this system. As this enables landscape change assessment through the use of objective procedures, it is an indispensible source of information for an integrated assessment of the state of the natural environment and for spatial analysis at different levels.

The Czech NATURA vector database, which has no analogy in any other European country as regards the area covered, is probably the most important information source for the character and state of natural and semi-natural biotopes in the Czech Republic. In a similar manner to the CORINE database, NATURA is continuously updated on a 12-year cycle and will, therefore, become an invaluable source of information on the dynamics of mapped biotopes. The range of mapping corresponds with the environmental significance of each territory. Only protected areas have been mapped in detail, therefore, and large areas of cultural landscape were only mapped contextually or not at all. The categories of the NATURA 2000 database were maintained in their original form and additional segmentation of biotopes was carried out according to their level of preservation listed in an attribute table.

The synthesis of the aforementioned data resulted in a qualitatively new database, which covers the whole of the Czech Republic and, at the same time, provides information on the level of degradation of the original biotopes. The creation of this data layer is an essential condition for calculating one of the key indices – the Biodiversity Intactness Index (BII) – needed for an assessment of changes in biodiversity within a range of degraded environments in the cultural landscape. On the basis of expert statements for particular taxonomic groups of indicator species, their biotope needs, and their sensitivity toward biotope degradation, new basic biotope groups were determined and divided into five categories, according to their level of degradation. These were then classified on the basis of spatial distribution, either according to the categories of the NATURA 2000 database or the adapted nomenclature of the CORINE Land Cover 2000 programme.

The map of potential natural vegetation, produced by Neuhäuslová et al. (1997), provides a reference layer for the initial biotope situation. In addition, it can be used for the formulation of indices as regards changes in particular biotopes, and especially in the case of model studies. A database of all the protected areas of the Czech Republic, at all hierarchic levels (national parks, protected landscape areas, nature reserves, NATURA 2000 network sites, natural parks, territorial system of ecological stability – ÚSES, UNESCO Biosphere Reserves, etc.) provides a further useful layer. This can be used to formulate an average representation of protected biotopes and for the calculation of some essential indices (e.g. the proportion of protected land in an area, the level of protection, compactness and connectivity of protected areas of related biotopes).

Proposed indicator types

An assessment of changes in biodiversity at the landscape or ecosystem levels is a complex topic and requires the involvement of various thematic groups of indicators. On the basis of a search of international studies, and with respect to the possibilities for local data collection, the following groups of indicators were proposed:

1. Indicators of changes in the range of selected ecosystems and biotopes

The determination of these indicators requires the analysis and processing of currently available digital data on the distribution and development of ecosystem range in the Czech Republic, i.e. vector layers of biotope mapping from the NATURA 2000 and CORINE Land Cover 1990 and 2000 databases.

2. Indicators of change in the size of protected areas

The tracing of states and size trends of protected areas is based on gathering and processing the available digital data on protected areas of all types in the Czech Republic, and on determining the proportions of protected area within defined spatial units (e.g. administrative units or mapping squares). Layers of particularly protected areas, areas with general protection (natural parks, ÚSES), sites within the NATURA 2000 network, UNESCO biosphere reserves, Important Bird Areas, and important wetlands within the Ramsar Convention are all used as input data. The incorporation of the databases of the Czech Union for Nature Conservation (ČSOP) and other non-governmental organizations, from a range of non-state protected areas in the Czech Republic, is also indispensable.

3. Indicators of change in ecosystem connectivity and fragmentation

This set of indicators determine the basic metric parameters for fragmentation and connectivity within the main ecosystem types through the use of specialized software packages (FRAGSTATs and Patch Analyst for the ArcGIS extension) on existing data recording the state of the biotope (NATURA 2000) and on the type of landscape cover (CORINE 1990 and 2000).

4. Indicators of areas of forest, agricultural and water ecosystems under sustainable management

Analysis of the area covered by agro-environmental subsidies within agricultural production, assessment of differences in forest production, and the provision of information on water and fisheries management is probably one of the most time-consuming tasks within such projects. As no unified system has been developed for the collection and assessment of such information, the final proposal for the determination of particular indicators must be adapted to the character of the data available. Statistical databases from the appropriate departments of the Czech Ministries of Agriculture and the Environment, the Forest Management Institute, and the Hydroecological Information System map servers are considered to be initial information sources.

C. Genetic diversity monitoring

Genetic diversity is one of the significant levels at which biodiversity is monitored. At present, most genetic diversity monitoring programmes are focused on the genetic diversity of domesticated animal breeds, cultivated plant varieties, and fish of socioeconomic importance (Biodiversity Monitoring Switzerland, UK Biodiversity Action Plan, SEBI 2010 Plan). As regards the genetic diversity of wild organisms, a number of studies are being carried out that examine the genetic diversity of endangered species; however, no overall methodical framework for monitoring the diversity of the genetic fund of wild animals presently exists.

Databases

Statistics of the Ministry of Agriculture, and annual reports from the National Program for the Maintenance and Use of Genetic Resources of Livestock, Fish and Bees can both be used as data sources. Specialised expert studies from institutions such as the Uhříněves Research Institute of Animal Production, the Ruzyně Crop Research Institute, or the National Focal Point for Conservation and Utilisation of Farm Animal Genetic Resources can also provide important information.

Proposed types of indicators

1. Genetic diversity of domesticated animal breeds and cultivated plant varieties

The definition of the categories monitored is important such that data collection can be repeated over particular periods. The basic indicators, which should be monitored, are a number of breeds of the livestock and plants varieties and their proportion.

2. Genetic diversity of wild organisms

The assessment of genetic diversity in wild organisms is usually assessed through the determination of such factors as the influence of genetic drift, genetic “bottlenecks”, undesirable hybridism, etc. This matter is currently being dealt with only at specialised institutions and using model organisms. The results should indicate which species within particular groups, as well as what proportions of the species, are endangered by a lack of genetic diversity.

D. Monitoring of threats to biodiversity

The proposed set of indicators would not be complete unless the indices covered all levels of endangered diversity. We therefore propose that the following sets of indicators be also included into the monitoring system.

Databases

The databases and statistics of the ministries of Agriculture and the Environment, ČSOP, and the Czech Geological Survey are considered as fundamental. A more detailed overview, however, requires the inclusion of data from species monitoring of taxa that are sensitive to eutrophication and acidification within the ecosystem, as well as of taxa that are endangered due to invasive species. Both data from phenological observations and from zoological and botanic research that includes a phenological aspect can be used to assign indicators for changes in biodiversity as a result of climatic change, as can data from inventories (and re-inventories) of protected areas where a strong impact of climate change is expected. Vegetation surveys and specialised studies on the most significant and dynamic invasive species can provide complementary data sources.

Proposed indicators

1. Indicators of eutrophication rate

Eutrophication is one of the fundamental factors in Central Europe that has a global impact on all ecosystems. One of the goals of this programme should be the creation of a list of species sensitive to eutrophication and their future detailed monitoring. It is further necessary to monitor indicators of habitat eutrophication using the open sources of the ministries of Agriculture and the Environment, the Czech Geological Survey, and the Watershed Companies.

The output of this work will provide lists of nitrophilous and nitrophobous species, assessment of trends in eutrophication based on their expansion or recession, and determination of the biotope types most in danger from eutrophication.

2. Invasive species

Monitoring of the number of invasive species, damage caused by such invasive species, and the distribution or abundance of individual invasive species is an essential part of any comprehensive monitoring effort for changes in biodiversity. For spatial determination of the extent of the problem, we suggest that an assessment of the presence of invasive species in particular regions, as well as specification of the number of occupied mapping squares, would be a suitable approach.

This should produce a list of the most significant invasive species and of the most affected biotopes, as well as an analysis of the distribution of invasive species and the dynamics of this process.

3. Impact of climate change on biodiversity

An assessment of this topic is possible using the results from species monitoring. It is essential that phenological trends over longer time periods be identified (e.g. on the occurrence of particular butterfly species by repeated transects). The use of climate and meteorological data (changes in temperature and precipitation distribution) in combination with changes in abundance and distribution of the more sensitive species (e.g. decline in cryophilic species or movement of thermophilous species to higher altitudes) would provide another view of this issue.

Suitable outputs of climate change impact studies are lists of species for which a change in territory occurs or, potentially, a change in abundance in accordance with climate change; a list of species in which such changes are predicted, but which have not yet shown any change; further lists of species which react to climate change; and a comprehensive expert assessment of the issue based on data indicating changes in distribution based on assessing phenological data.

E. Socioeconomic relations of biodiversity

Species and, especially, ecosystem diversity are related to human activities in the landscape and to the economic level and cultural character of a country or region. For meaningful monitoring of changes in biodiversity, therefore, it is essential that processes be monitored that affect the state of diversity in the short term. In particular, it is essential that commitments to various legal regulations, agreements and conventions, as well as the functioning of various programmes and a range of grant resources for protection of biodiversity, are both met and fulfilled. In addition, it is essential that the engagement and integration of expert and volunteer organizations in the process of biodiversity understanding and protection be maintained.

This part of the subject is focused entirely outside of biology and ecology. It is necessary to say, however, following a comparative analysis of monitoring programs, that this aspect is applied in all comprehensive schemes, as no monitoring programme would be complete without involving this issue. As for funding for biodiversity and its protection, this requires a precise but sufficiently wide definition of which items can be included in this issue. As such, this data analysis could be undertaken by a specialist or processed from open sources (e.g. the State Budget Act or budgets of particular ministries) and repeated after some time using the same standardized method.

Other parts of this topic require cooperation with a socio-demographic body and need to be addressed using a questionnaire among non-governmental organizations, and possibly among ordinary citizens.

Data sources

Legal regulations (such as the State Budget Act), budgets and the statistics of particular ministries (especially the Treasury Department, the ministries of Environment, of Agriculture, and for Regional Development) serve as fundamental sources of data.

Proposed types of indicators

- Investments in biodiversity protection
- Public awareness and participation in biodiversity protection and research
- Patent applications for inventions based on genetic resources
- Implementation of environmental regulations

Suitable outputs of this theme might include a methodological instruction manual for data collection for particular indicator species, or the implementation of a representative and methodically well-designed data collection programme for each indicator species that is carried out in such a way as to allow re-acquiring of representative data, comparison of the results and identification of any differences recorded.

SYNTHETIC ATTITUDE TO THE ISSUE

The issue of biodiversity is also a subject of political discussion as regards the international commitments of the Czech Republic and the EU. For this reason, it is necessary to tackle the problem with the help of well-defined, scientifically supported synthetic indices that summarise the dynamics of biodiversity development into a few general numbers. In order to promote biodiversity priorities, it is essential that these complicated problems be introduced to political representatives in a simple and clearly defined way through the use of highly aggregated indices (Brink, 2006).

We see the Red List Index (which is based on the endangered status of particular taxa and is mentioned in section 4.1) and the BII (which provides a wider and more detailed view) as the two most basic and well-designed tools for the monitoring of species diversity through which communication with the wider public and politicians will be made possible (Scholes and Biggs, 2005).

Biodiversity Intactness Index (BII)

This index is designed to establish species richness within particular biotopes and relative changes depending on the status of degradation or management of the biotope. The BII was first applied in the vast areas of southern Africa, with the results being published in 2004 and 2005 (Scholes and Biggs, 2005).

The index describes general rates of biodiversity in particular ecosystems (forests, wetlands, etc.), in particular land-use classes (e.g. intact and protected areas, moderately used, degraded, intensively cultivated plantations, and urban habitats), in terms of particular taxonomic groups (plants, birds, amphibians, etc.), and in defined geographical areas (particular countries, regions). It is counted as an area-weighted index of reduction in species populations of a given ecosystem at a certain level of the land-use class in comparison with the reference population (intact population from protected area) in a given ecosystem.

The advantage of the index lies in its ability to be properly disaggregated according to different axes. Also important is that it has the same meaning at all scales and that it can be modelled back to the past or projected to the future according to various scenarios.

Work on calculation of the index is very much connected with existing monitoring programmes. By means of this index, and with the aid of suitably sophisticated input data, it is possible to quantify biodiversity loss of native species; evaluate, to a certain degree, differences in habitat biodiversity; and assess both past and future scenarios of landscape change in terms of biodiversity.

A. Concept of a general system of biodiversity monitoring in the Czech Republic

A possible monitoring programme for the Czech Republic has been developed based on a comparative study of previous monitoring programmes, their critical assessment, and the context of this issue within the Czech Republic.

Spatial Scale:

It is clear that the system has to work at more than one spatial scale, i.e. at the:

- National,
- Regional, and
- Local and biotope levels

Monitoring priorities

Three value systems have been identified as regards monitoring (Duelli and Obrist, 2003): 1) conservation (protection and enhancement of rare and endangered species), 2) ecology (ecological resilience and functioning based on species diversity), and 3) biological control (diversity of antagonists of potential pests). Our monitoring priority is naturally that of ecological monitoring.

Biotope stratification

Aside from a territorial hierarchic structure, the monitoring system must include biotope segmentation in order to assess trends in particular biotopes. Based upon expert statements on various groups of organisms, we have divided the landscape into the following categories: 1) still waters; 2) water streams; 3) wetland and shorelines; 4) springs, fens, mires and bogs; 5) cliffs, screes and caves; 6) subalpine and alpine areas; 7) meadows and pastures; 8) other grasslands; 9) heaths; 10) willow carr and riverine scrub; 10) tall mesic and xeric scrub; 11) low xeric scrub; 12) deciduous and mixed forest; and 13) coniferous forest. From a botanic point of view, this partition is extremely simplified. In a traditional classification of vegetation, which involves all important characteristics, several dozens of community groups may be used. From a zoological point of view, this division does not strictly cover those factors that have an effect on animals. It is, however, the inevitable compromise of having to work with these two groups of organisms together.

B. Proposed comprehensive set of indicators of changes in biodiversity

An output of this programme has been the proposal of a comprehensive set of indicators of changes in diversity from the genetic to the ecosystem level. The set of indicators presented here is structured such that it reflects both the complexity of the topic as regards the current possibilities for provision of data and, at the same time, records current trends in changes to biodiversity. Actual indicators are grouped into the following categories:

1. Species monitoring

- 1.1. Trends in abundance and distribution of the selected species (or groups)
- 1.2. Number of species at a national and regional level, and changes in number
- 1.3. Species diversity in a region
- 1.4. Species diversity in a habitat
- 1.5. Changes in endangered status (e.g. Red List Index)
- 1.6. Proportion of endangered species in a particular taxonomic group

2. Ecosystem monitoring

- 2.1. Indicators of changes in the area of selected ecosystems and biotopes
- 2.2. Indicators of changes in the size of protected areas
- 2.3. Indicators of changes in ecosystem connectivity and fragmentation
- 2.4. Indicators of area of forest, agricultural and water-utilization ecosystems under sustainable management

3. Genetic diversity monitoring

- 3.1. Genetic diversity of domesticated animals and cultivated plants
- 3.2. Genetic diversity of wild organisms

4. Fundamental biodiversity threats monitoring

- 4.1. Eutrophication
- 4.2. Invasive species
- 4.3. Impact of climate change on biodiversity
- 4.4. Acidification

5. Biodiversity socioeconomic ties

- 5.1. Financing of biodiversity management
- 5.2. Public awareness and participation in biodiversity protection and research
- 5.3. Patent application for invention based on genetic resources
- 5.4. Implementation of environmental regulations
- 5.5. Size of protected areas
- 5.6. Integration rate of biodiversity protection goals into regional programmes and strategies
- 5.7. Attendance at protected areas
- 5.8. Volunteer time spent on biodiversity protection and scientific activities
- 5.9. Membership of societies engaged in biodiversity protection

CONCLUSION

Biodiversity, its protection, and the monitoring of changes currently comprise a highly discussed scientific and social topic, which is reflected at the worldwide level (CBD, Target 2010 etc.), the European Community level (contractor CBD, SEBI 2010), and at the national level of the Czech Republic (Strategy of Biological Diversity Protection in the Czech Republic). The scientific community's task is to investigate the problem of changes in biodiversity by means of well-defined and scientifically based synthetic indices, which summarize the dynamics of biodiversity development in a few general numbers, and then to introduce this complicated issue to our political representatives in a simple and clear way.

The results of current comprehensive monitoring programmes (the Biodiversity Monitoring Switzerland programme in particular) not only show the excellent scientific and theoretical contribution of these projects, but also provide priceless science-based data for the determination of priorities in biodiversity and environmental protection. They also show a high rate of adoption for conservation measures, the cost-effectiveness of money spent on biodiversity management, and the efficiency of adopted environmental regulations.

The situation as regards the fulfilling of commitments to biodiversity protection in the Czech Republic is far from satisfactory. Any solution will prove to be an obligatory, long-term and financially demanding task and we cannot expect that a scientific institution without clear political and financial support on the part of the state will be able to rise to this challenge. The absence of a main coordinating body with an accurately defined description of the required tasks and timetable, as well as insufficient financial support, remains the main obstruction to raising research into changes in biodiversity to a qualitatively higher level in the Czech Republic.

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Appendix 1. A comparison of existing monitoring programmes

Monitoring criteria▼	Biodiversity Monitoring Switzerland	Alberta Biodiversity Monitoring Program	UK Biodiversity Action Plan	Streamlining European 2010 Biodiversity Indicators	The National Bat Monitoring Programme (UK)	Bird Monitoring Programme JPSP ČSO	Bat censuses in wintering sites ČESON	Ontario's Niagara Escarpment Monitoring Program (ONE) - Canada	US Environmental Monitoring Assessment Program (EMAP)	Hungarian Biodiversity Monitoring System
Data	New data collection and evaluation of older data	New data collection	New data collection	New data collection – planned for future	New data collection	New data collection	New data collection	New data collection and evaluation of older data	New data collection	New data collection
Monitoring focus	Terrestrial and freshwater ecosystems	Terrestrial and freshwater ecosystems	Terrestrial, freshwater and marine ecosystems	Terrestrial, freshwater and marine ecosystems	Terrestrial ecosystems	Terrestrial ecosystems	Terrestrial ecosystems	Terrestrial ecosystems	Agroecosystems, Great lakes, arid ecosystems, forest, terrestrial and freshwater ecosystems	Terrestrial and freshwater ecosystems
Focus of data collection	Detailed monitoring: higher and lower plants, molluscs, butterflies, birds, orthoptera. Other groups – only numbers of species	Mammals, birds, fungi, lichens, trees zooplankton, phytoplankton, fish, benthic algae, macro-invertebrates	Birds, butterflies, plants, fish Detailed monitoring of priority species	Butterflies, dragonflies, birds, fish, large carnivores, large herbivores, bats, amphibians, plants, cetaceans, pinnipeds	bats	birds	bats	The biodiversity of forest ecosystems in general, birds, lichens	Broad-spectrum focus – depending on the particular project Fish, birds, amphibians, algae, zooplankton, phytoplankton, etc.	Small mammals, bats, reptiles, fish, butterflies, orthoptera, epigea, macrofungi, alien plant species, macrozooplankton
Design of data collection	Regular network of monitoring sites – once per 5 year data collection	Regular network of monitoring sites – once per 5 year data collection	Random and selective monitoring	Random and selective monitoring	Random detection, others – selective monitoring	Selective monitoring	Selective monitoring	Random and selective monitoring	Random monitoring	Selective monitoring
Standardized data collection	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Scientific credibility	High	High	High	High	High	High	High	Partially high	Unknown	High
Investigat-ing or monitoring	Both	Both	Mainly monitoring	Both	Mainly monitoring	Both	Both	Both	Both	Monitoring
Time scale	Long-term monitoring, 1/5 of study sites monitored each year	Long-term monitoring, 1/5 of study sites monitored each year	Long-term monitoring	Long-term monitoring	Long-term monitoring. Annual control	Long-term monitoring. Annual control	Long-term monitoring. Annual control.	Long-term monitoring. Partly annual control, partly once per 5 years.	Long-term monitoring, frequency depending on particular project	Long-term monitoring
Spatial scale	Switzerland – the whole territory (41,000 km^2)	Alberta - whole province (661,848 km^2)	UK - the whole territory (244,820 km^2)	EU (4,324,782 km^2)	UK - the whole territory (244,820 km^2)	Czech Republic - the whole territory (79,000 km^2)	Czech Republic - the whole territory (79,000 km^2)	5 study sites of 1 ha area	6% of state territory	Hungary - the whole territory (93,000 km^2)
Public availability of primary data	Yes	Yes	Yes	Unknown	Yes	No	No	Yes	Yes	Unknown
Publica-tion of results	Yes	Yes	Yes	Planned in future	Yes	Yes	Irregularly	Annual report	Yes	Yes
Use of GIS and remote sensing	Yes	Yes	Yes	Yes	No	No	No	Minimally	Yes	Yes
Permanent employees	Yes	Yes	Yes	Planned in future	Yes	Yes	Ne	Yes	Yes	Yes
Financing	Federal government 3,000,000 CHF/year	Federal and provincial government 1,600,000,- CAD/rok	Ministry of Environment, DEFRA	European Commission	Volunteer organization (Bat conservation trust)	EU, grants, volunteer organizations	Grants, volunteer organizations	Ministry of Environment of province ofOntario	Federal government, state government	Government
Evaluation of biodiver-sity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monitoring of birds	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No

Monitoring of butterflies	Yes	Ne	Yes	Yes	No	No	No	No	No	Yes
Monitoring of mammals	Only number of species	Yes	Yes	Yes, some	Yes	No	Yes	No	No	Yes
Monitoring of plants	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Monitoring of others species groups	Orthoptera, lower plants, molluscs	Yes	Yes	Dragonflies, fish, amphibians	No	No	No	Yes, lichens	Amphibians	Yes
Monitoring of ecosystem diversity, fragmen-tation etc.	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes
Monitoring of genetic diversity	Yes	No	Yes	Yes	No	No	No	No	No	Unknown
Monitoring of climate change impact	No	Indirectly	Yes	Yes	No	No	No	No	Yes	Unknown
Monitoring of eutrophic-ation impact	Yes	Yes	Yes	Yes	No	No	No	Indirectly	Yes	Yes
Monitoring of invasive species impact	Yes	Indirectly	Yes	Yes	No	No	No	Indirectly	Yes	Yes
Monitoring of socioecon omic ties	Yes	No	Yes	Yes	Yes	No	No	No	No	No