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ECOLOGICAL SOUNDING

Scale and trends in species richness: considerations for monitoring biological diversity for political purposes

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ABSTRACT

Switzerland's governmental 'Biodiversity Monitoring' program is designed to produce factual information on the dynamics of biodiversity within the country for governmental agencies, politicians, and the general public. Monitoring a complex issue like biodiversity in order to give relevant and accurate messages to the general public and politicians within a politically relevant timescale and at moderate cost means focusing on few elements. Because relevant human impacts on biodiversity operate differently at different spatial scales, we need at least three different indicators to observe changes over time in local ('within-habitat'), landscape ('habitat-mosaic'), and macro-scale ('regional') diversity. To keep things as simple as possible, we use species richness as an indicator for all three levels of diversity, just defining three different spatial scales (10 m^2, 1 km^2, regions, respectively). Each indicator is based on a number of taxonomic groups which have been selected mainly on the basis of costs and the availability of appropriate methods.

Keywords

Biodiversity monitoring, CBD, sampling, spatial scale, species richness, Switzerland.

INTRODUCTION

To meet one of the requirements of the Convention on Biological Diversity, Switzerland is implementing the 'Biodiversity Monitoring' program (BDM). BDM is a governmental program designed to produce annual information on the dynamics of biodiversity. Information is addressed, on the one hand, to governmental offices for nature conservation, agriculture and forestry, and, on the other, to decision-makers in politics, scientists, environmental organizations and the media. The latter group is of great importance, as public opinion directly influences the support of actions based on the monitoring data. A broader description of the BDM is given by Hintermann *et al.* (2000, 2002) or www.biodiversitymonitoring.ch.

Yoccoz *et al.* (2001) show that many existing monitoring programs for biological diversity suffer from design deficiencies and appear to have been developed without paying adequate attention to three basic questions. (1) Why monitor? (2) What should be monitored? and (3) How should monitoring be carried out? We feel challenged by these questions to present and explain the concept of BDM. We would in particular like to illuminate political aspects of biodiversity monitoring in this paper, a topic that is not addressed by Yoccoz *et al.* (2001). Decision-makers or politicians have a somewhat different outlook on biodiversity than do 'pure' scientists or environmental managers. The term 'biodiversity' is probably of political origin and only secondarily a scientific (biological) concept (Gaston, 1996a).

By talking of the political motivation we want to stress the special conceptual requirements. 'Political' stands in no case for lesser scientific quality. On the contrary, the challenge of such a program is to provide over a sustained period, highly reproducible, statistically sound data, that nevertheless are easy to communicate.

We discuss our approach to monitoring changes in species diversity by means of a set of three indicators. These indicators all represent species richness, but they consider three different spatial scales (local, landscape and macro-scale according to Whittaker *et al.*, 2001). We explain why we selected these indicators and why we believe that fewer indicators would be inadequate. Although BDM also produces additional indicators, using the OECD's Pressure-State-Response model (OECD, 1994), the three indicators discussed here are clearly the essential ones, to which BDM devotes the bulk of its financial and personnel resources (Hintermann *et al.*, 2000), because species are a fundamental and well defined unit of biodiversity (Larsson & Catizzone, 1997). Although we focus on species richness, we are aware of the genetic diversity underlying within- and between-species diversity (which cannot be surveyed in a countrywide monitoring program).

Table 1 Scales of biodiversity from Whittaker *et al*. (2001) and specific human impacts. Area gives the BDM-sampling areas

Spatial scale	Local	Landscape	Macro-scale (regional)
Definition	Within-habitat-diversity	Within-habitat-mosaic-diversity	Within-region-diversity
Area	10 m^2	10^6 m^2	10^{10} m^2
Human impacts	Land use techniques	Size and distribution of different habitat (land use) types	Species extinction, influences on colonization

Table 2 Key criteria for selecting country-specific biodiversity indicators (from Cohen & Burgiel, 1997)

Indicators should:
- *Quantify* information so that its significance is apparent;
- *Simplify* information in order to help communicate complex phenomena;
- Be *user-driven* to help summarize information of interest to the intended audience;
- Be *policy relevant and based on specific targets or objectives* (to help guide decision-making and measure progress toward such objectives);
- Be *scientifically credible*;
- Be *responsive to changes* in time and/or space;
- Be *simple and easily understood* by the target audience;
- Be based on *information that can be collected within realistic capacity limits*.

Furthermore, we would like to mention the problems of labelling the three spatial scales of biodiversity that we distinguish in our program. There is still a lot of confusion in the literature about the use of the terms, and so in this paper, we follow the proposal of Whittaker *et al*. (2001) for the use of the terms local, landscape, and macro-scale diversity (see Table 1). Thus we use the term local diversity for the biodiversity within one habitat type, landscape diversity for the biodiversity in a given area with different habitat types ('habitat-mosaic'), and macro-scale diversity for the regional biodiversity, i.e. biogeographical regions or countries.

WHY MONITOR?

Yoccoz *et al*. (2001) give two possible categories of objectives for monitoring programs: scientific and management. BDM's objective, however, is neither of these, but is instead political. But what information about biodiversity do politicians and decision-makers need? Defining biodiversity indicators for BDM means making a decision about the type of information on biodiversity trends which will be given regularly to the target audience. One has to face the problem that biodiversity ('simply the variety of life', Wascher, 2000) is difficult to state in numerical terms and even more difficult to measure regularly. Or, in the words of Takacs (1996): '*Don't know what biodiversity is? You can't.*', but '*Biologists must find a way to communicate biodiversity's complexity lucidly to the public. If they fail to convey clearly what biodiversity is, … they also jeopardize the enormous amount of conservation momentum that has gathered behind biodiversity*.'

This problem is, of course, not specific to biodiversity, but is quite common when issues of socio-economic importance have to be monitored, e.g. public health, welfare, security, let alone concepts such as freedom, peace, happiness. All are simple to define and almost impossible to monitor in an objective way.

BDM is designed to provide the decision-makers with the information they need to make decisions about issues relating to agriculture, forestry, land use and the environment. At this point, it is essential to distinguish between 'baseline monitoring' of biodiversity trends in a country (the objective of BDM), and 'effectiveness monitoring' of projects and programs to enhance biodiversity (auditing the results of action taken). Decision-makers need both types of information, but often only get the latter. For example, we might well know whether the decline of orchids has been stopped by a management program within selected grassland areas, but we do not know the current trend in the species composition of the country's common meadows. A scrupulous decision on the next grassland conservation project or on the priorities in sustainable agriculture should be based on both types of information (see Hintermann *et al*., 2000).

We started the BDM project by asking target groups about their needs for baseline information on biodiversity. Taking account of the general criteria in Table 2, the BDM indicator set was then defined as the result of an evaluation taking account of the following factors: the needs of the decision-makers, data sets available from other related governmental projects, variability and sensitivity, and costs. While doing this, we were guided by the following questions (stated in order of priority):

1 What kind of information are decision-makers asking for?
2 What information do decision-makers really need?
3 How can this information be generated on a scientific basis?
4 What will be the quality (precision, variability, sensitivity) of the information?

WHAT TO MONITOR?

Statements about changes in biodiversity are usually made by conservationists who are highly motivated to select information that proves a dramatic decline of variety of life.

Table 3 Some indicators of biodiversity change over 10 years in breeding birds of the Lake Constance region, Central Europe (1212 km^2). Data from Boehning-Gaese & Bauer (1996). We have defined ‘widespread’ species as those breeding in at least 50% of the 400 ha grid cells

Indicator	1980	1990	Δ (%)	Trend
Species richness (total number of species)	141	146	+3.5%	↗
Richness of species considered threatened in Europe	29	29	±0%	→
Number of widespread species	59	53	−10.2%	↘
Mean species richness per 400 ha	59.4	58.6	−1.3%	↘
Mean evenness per 400 ha	0.78	0.79	+1.0%	↗
Mean diversity (Shannon) per 400 ha	3.19	3.33	+1.3%	↗
Total breeding pairs (thousands)	418	390	−6.7%	↘
Total breeding bird biomass (tons)	56.4	52.7	−6.6%	↘

> ‘In the term biodiversity, subjective preferences are packaged with hard facts; eco-feelings are joined to economic commodities; deep ecology is sold as dollars and sense to more pragmatic, or more myopic, policy makers and members of the public’ (Takacs, 1996).

Non-biologists will trust the figures and ignore the subjective choice of the object under consideration, e.g. ‘Over 100 species are thought to have become extinct in the UK this century’ (UK Biodiversity Steering Group, 1995), or ‘mean species richness has remained unchanged at 18.7 species, but the populations of Red List species have declined’ (Weggler & Widmer, 2000). Typically, the public is not informed about the numerous species that have (re-)colonized the UK this century (e.g. Sharrock, 1977; Nature Conservancy Council, 1984; Gaston, 1996b) or about the fact that, since Red List species are defined as species in decline, their populations will inevitably decline. Even when we do define indicators in a way that allows not only losses, but also gains in biodiversity, we must be aware that defining biodiversity indicators in our context is a directly evaluative process (e.g. Trudgill, 2001).

So, what is the ecological truth to communicate as a ‘biodiversity trend’ in a given region such as Switzerland? A look at the work of Boehning-Gaese & Bauer (1996) gives an idea of possible responses to this question. They have analyzed the changes in breeding-bird diversity in the Lake Constance region (1212 km^2) during the 1980s (Table 3). Of eight indicators, four show a decline, and three an increase for the same taxon in the same region over the same period. Species richness has increased 3.5% (5 species lost, 10 species gained within 10 years), while the total number and the biomass of breeding birds declined.

The point is that, within the same region and period of time, different things happen at different spatial scales (*sensu* Table 1, Whittaker *et al*., 2001). (1) Local diversity: there is a decrease in birds (biomass and breeding pairs), but these losses mainly relate to the common species with large populations, making up local diversity within fields, meadows, woodlots and settlements. This selective decline of frequent species interestingly leads to higher Shannon-diversity and evenness values. (2) Landscape (and macro-scale) diversity: a lot of species have either maintained or increased their populations. Their local populations are in general small and they do not contribute much to local diversity or overall bird biomass in the region. The number of such species within the region is stable, even increasing, which leads to an overall increase in macro-scale (regional) and (maybe) landscape species diversity.

Table 4 Changes in species richness in terrestrial vertebrates in Sweden (Bernes, 1994) and Switzerland (preliminary compilation of BDM)

	Switzerland	Sweden
Number of species (richness) 1900	246	311
Number of species (richness) 1950	249	329
Number of species (richness) 1995	268	338
Number of species extinct 1900–95	8	12
Number of species newly established 1900–95	30	39
Growth of richness 1900–95	8.9%	8.7%

Almost everybody seems to agree that the species richness of a country (here seen as macro-scale diversity) must be monitored in some way (OECD, 1994; Cohen & Burgiel, 1997). According to Reid *et al*. (1993) this is ‘one of the most useful indicators of status and trends’. However, looking at a country of the size of Switzerland (41,284 km^2), only slow changes over time can be expected: before a species becomes extinct, a long process of decline may have occurred, which is not reflected by simply counting species present in a given area (ten Brink, 2000). (Re-)immigration of additional species might offset the losses. At least three biogeographic theories predict a relatively stable species richness in a given region, upon which human impacts have only a slight effect:

1 the equilibrium theory of island biogeography (MacArthur & Wilson, 1967);

2 species saturation (Terborgh & Faaborg, 1980);

3 carrying capacity for species (Brown *et al*., 2001).

Parody *et al*. (2001) give a striking example of substantial land-cover and land-use changes in a 4700 km^2-region over 50 years, which has led to fundamental changes in bird community composition, but has left species richness virtually unchanged.

Available data show a recent increase in species richness at a country level in Europe [e.g. Table 4; breeding birds in Britain and Ireland show a similar increase in richness of about 0.8% per year from 1970 to 1990 (Gaston, 1996b)], which might be a worldwide trend in macro-scale species richness (Sax *et al*., 2002). This is clearly not the message conservationists like to give to the public and politicians (and to themselves). Aware of the fact that species richness at the country level actually has increased, some people have developed a special terminology to devalue gains in species richness as, e.g. '*invasions by aliens*', '*infestations*', '*outbreaks*', whereas other value-laden words are found to name species '*losses*', '*impoverishment*', '*paucity*', or '*deterioration*' (Trudgill, 2001). We decided not to do so within the BDM, but rather to generate additional information about those changes in biodiversity that are usually considered problems by conservationists. Macro-scale diversity is only one part of the story. Other changes take place in the local and landscape diversity and these changes are the problematic ones. Or, as Whittaker *et al*. (2001) write:

> 'different ecological factors exhibit measurable heterogeneity at different scales … The importance of the many ecological/biological mechanisms that have been proposed is evident mainly at local scales of analysis, whilst at the macro-scale they are dependent largely upon climatic controls …'.

As local and landscape diversity are much more influenced by human activities than is macro-scale diversity, they are also more interesting from a political point of view. Land areas in Central Europe are almost completely used (e.g. Kalusche, 1996; Harrison & Pearce, 2000; BFS, 2001) and therefore the diversity within the used areas (local diversity) makes species common, rare or endangered in the whole region. Agricultural land and exploited forests dominate continental ecosystem processes such as nutrient cycles, carbon dioxide uptake, oxygen production, water storage and soil formation in Central Europe (e.g. UNDP *et al*., 2000). At the local level it matters whether there are conifer plantations or mixed forests, whether species-rich grasslands are transformed to *Lolium*-oligocultures, or how rivers are managed. At present, there is potential for an increase in within-habitat diversity in almost every important type of land use in Switzerland (e.g. Hintermann *et al*., 1995). Recent diversity trends in used land in the developed countries are generally downwards (e.g. Heywood & Watson, 1995). Qualifying modern trends in land use from a biodiversity standpoint means looking at local diversity.

Decision-makers need information about current local diversity trends within used areas to make decisions about agriculture, forestry, and other land use issues. However, our discussions with conservationists in Switzerland have shown that not all of them are much interested in this kind of information, because traditional conservation targets are not in the used areas, but the special habitats and structures between them, e.g. hedges, small watercourses, remainders of wet and dry grasslands and orchards. A look at the countryside of Switzerland makes it clear that the bulk of species (not individuals!) survive in relatively small numbers on small patches of nonused land or in areas devoted to the conservation of species and habitats and specially managed for this purpose (Hintermann *et al*., 1995; Boehning-Gaese & Bauer, 1996). It is there that the interesting rare species can be found, and the preservation of this small but important part of the country is clearly one of the conservation movement's successes. A correct assessment of the biodiversity of the countryside cannot be made without taking account of these 'ecological compensation' strips and patches in addition to the large and relatively poor fields and meadows. BDM therefore also looks at landscape diversity, the diversity of whole habitat mosaics.

In conclusion: BDM has to produce at least three different indicators. They must describe different biological phenomena, resulting from different human impacts, leading to different conservation strategies, and addressing different target groups (see also Table 1). Local diversity is especially interesting for decision-makers in agriculture, forestry, and other land use issues; landscape diversity is the most important information for conservationists and landscape planners; and macro-scale diversity is mainly addressed to the OECD and other international organizations.

HOW TO MONITOR?

Macro-scale diversity

The best indicator for monitoring macro-scale diversity of a country for our purposes is species richness. It captures much of the essence of biodiversity, its meaning is apparently easily understood, it is often considered as measurable in practice and much data on species richness already exist (Gaston, 1996b).

However, unbiased detection of changes in species richness over politically relevant timescales, e.g. 5 or 10 years, is not as simple as it might seem: changes are due to (re-)immigration, active (re-)introduction, and extinction. This means that we are dealing with extremely rare species. While it is in most cases easy to document active introductions of species, it is sometimes quite baffling to detect and prove the extinction of, e.g. a plant species within an area of 41,284 km^2. It is quiet a challenge to detect a new species at the first places it has settled spontaneously in the country, all within one or a few years. Sample-based methods (e.g. species accumulation or rarefaction curves), as discussed by Gaston (1996b), Boulinier *et al.* (1998), or Gotelli & Colwell (2001), are no help because we expect changes of 1% or less within 10 years (see Table 4), which, by illustration, in the vertebrate group is only a handful of species, most with only few individuals. The precision of sample-based methods is not sufficient to detect such differences (allowing for reasonable sampling effort).

Unable to monitor year-on-year changes in species richness in Switzerland, we decided to monitor a surrogate (*sensu* Gaston, 1996b): changes in richness of those taxonomic groups for whom detection of immigrant species within a few years is almost certain or can be secured (as well as the detection of extinction, which is normally a lesser problem). These are groups of great interest to nonprofessional naturalists (e.g. 'birders'). We can be almost certain that they detect rare species whenever present in the country. BDM supports networks of volunteers and in addition mandates specialists to clarify critical cases (e.g. species for which there are no records). Species groups under survey are given in Table 5. Most of these taxa are also those which are of interest to the lay public, and which comprise many threatened species. It should be noted that BDM is unable to survey changes in the richness of vascular plants, which would be needed to

Table 5 List of taxa definitely applicable (+) or rejected (–) in the BDM of local, landscape and macro-scale diversity. Due to costs, not all operational taxa will be included over the coming years. (?) are undecided cases

Taxon	Local (within-habitat)	Landscape (habitat-mosaic)	Macro-scale (regional)
Mammals (without bats)	–	+*	+
Bats	–	–	–
Birds (breeding species)	+*	+	+
Reptiles	–	–	+
Amphibians	–	+*	+
Fish and Cyclostomes	?	+*	+
Butterflies (including Hesperiidae and Zygaenidae)	+*	+	+
Moths	–	?	–
Caddis flies	?	–	?
Grasshoppers	–	+	+
Stone flies	?	–	?
Dragonflies	–	?	+
Mayflies	?	–	?
Molluscs	+	?	–
Vascular plants	+	+	–
Mosses	+	–	–
Fungi (edible fungi)	–	–	?

*program not yet started.

calculate the 'World Bank/GEF's Natural Capital Indicator' (ten Brink, 2000), since the regional extinction of annuals is difficult to measure and since the appearance of new species might be undetected for a long time.

Besides pure biogeography, surveying changes in species richness within a country leads to some interesting practical questions:

1 How do we know that a species no longer occurs anywhere within the country?

2 How can we detect the arrival of a new species in the year of its arrival or soon afterwards?

3 What about species that appear in the country sporadically or occasionally?

4 How can species regularly escaping from captivity or actively released to the wild be dealt with?

5 Should we count species dependent on human care and, if not, what about species dependent on the care of conservationists?

6 And what, in practice, do we mean by a species at all (see, e.g. Diamond, 1992)?

Some of these and further questions on species discrimination, recorder effort, and species status are discussed by Gaston (1996b). Apart from selecting the least problematic taxonomic groups, we can solve the practical problems arising from these questions with subtle methodological definitions, which have been proposed by and discussed with experts and then been established as individual standards for each species. We cannot give all these definitions here. However, the most important definition is the following: We define species richness of a taxonomic group as 'the total number of species in the wild whose existence in Switzerland is highly probable during at least 9 out of the preceding 10 years'. Existence in Switzerland is defined by the fact that 'the species has successfully bred in the wild'. We do not demand proof of successful breeding in any case, but rather circumstantial evidence, individually defined for the different species.

The '9 out of 10 years' criterion is of great practical importance as it excludes a lot of occasional and erratic invaders in mobile taxa. The systematic detection of those species would require an enormous effort. Thanks to this criterion we can wait until a new species is recorded for several consecutive years until we begin to examine the case in greater detail. On the other hand, the absence of information about a rare species in a given year does not mean that we have to delete it from the list immediately; we have still one year left to check potential sites and clarify the situation.

Landscape diversity

In a cultural landscape, landscape diversity (within-landscape diversity) is the result of heterogeneity within patches (management), within habitat types (types of land-use), and between types of the land-use (land use mosaic), as shown, e.g. by Wagner *et al.* (2000) for a Swiss agricultural mosaic landscape. The mosaic concept (Duelli, 1992) predicts an increasing species diversity with increasing habitat variability and with increasing habitat heterogeneity.

Because landscape diversity cannot be precisely deduced from diversity measures at finer spatial scales (local diversity) or predicted from the habitat mosaic alone (Wagner *et al.*, 2000 and further references therein), BDM has decided to measure it by a special 'landscape diversity' program which operates with a slightly stratified systematic sample of some 520 1 × 1-km square cells all over the country. Ideally, a complete list of species in the selected taxa should be prepared for each grid unit. However, methodological and financial constraints forced the BDM to conduct the sampling with transects (between 2.5 and 5 km, depending on the species group). This does not allow us to record the total number of species in the grid unit, but it does produce a slightly smaller number that correlates closely with the total number. This surrogate of species diversity is assessed at 5-year intervals. Such sampling allows poststratification of the data set, e.g. into alpine or lowland regions of the country. Compared to similar programs like the British 'Countryside survey' (Barr *et al.*, 1993) or the German 'Ökologische Flächenstichprobe' (Statistisches Bundesamt & Bundesamt für Naturschutz, 2000) we do not survey the habitats and structures in the squares under survey, but instead directly record the species of some selected taxonomic groups living there. This means that we do not monitor the supposed impacts on or the presumed causes of landscape diversity (the habitat mosaics), but rather the resulting landscape diversity itself.

Within each 1-km^2 square, we list the species of some selected groups of organisms that are present (see Table 5). The resulting species richness of all squares is then averaged as 'mean 1-km^2 species richness', which is our indicator for landscape diversity. We have rejected other diversity indices like evenness, the Shannon index, or Simpson's index because they have some shortcomings compared to mean species richness:

1 Species richness figures are intuitively understood and can be communicated to a general audience.

2 Mean species richness can be assessed without having to undergo the difficulties of measuring population sizes or densities.

3 Evenness, Shannon diversity, and Simpson diversity increase when populations of common species decline, but species richness does not (see examples in Boehning-Gaese & Bauer, 1996; Wagner *et al.*, 2000).

4 Mean species richness is most sensitive to changes in the abundance of species that are widespread, but uncommon and rare within single 1-km^2 cells (often listed as 'vulnerable' in the red-list).

We have chosen units of 1 km^2 because this size corresponds to many existing inventories and monitoring programs, and because this standard is proposed by the IUCN for evaluating species' areas of occupancy (a by-product of our monitoring program) in order to check a species against red list criteria (IUCN, 1994). Mean 1-km^2 square richness can also be read as the sum of all single species frequencies of occurrence in the geographic unit of interest. Its variability is mainly dependent upon changes in distribution and abundance of widespread, but not too common, species. It will not or only slightly respond to increasing populations of abundant species (which are already present almost everywhere) or to the decrease of rare species (the low frequencies of which contribute only marginally to the figure). The indicator is most sensitive to changes in frequencies of species present in intermediate frequencies, which are often close to red list classification or are already listed as 'vulnerable' (see Table 6). Note that in special cases, high indicator values are not positive from a conservationist's point of view, e.g. in naturally monotonous habitats like blanket bogs.

Although raw data consist only of species present within 1-km^2 squares, only a handful of taxa fulfil the methodological requirements of this indicator (see Table 5). Considerable effort was expended to test, improve and standardize field methods until they yield highly reproducible data on species richness, only slightly affected by the person in the field. Data collection must be carried out by professionals, except for the breeding birds in a part of the sample. No final decision has been made about the taxa included in the landscape-diversity program, but the high costs will possibly not allow the inclusion of all the taxa listed in Table 5 over the coming years.

Table 6 Frequency distributions of bird, grasshopper and amphibian species in the lowlands of Switzerland. Data on grasshoppers and amphibians are only from a small part of the Swiss lowlands. Amphibian figures are without *Salamandra salamandra*. Data from Duelli (1994), Schmid *et al.* (1998), Thomas Walter (unpublished data from a survey of grasshoppers in the canton of Zurich, 1997), and Baudepartement canton Aargau (unpublished raw data from an amphibian inventory, 1997). The total sample of investigated cells (1-km^2 squares) is 857 for breeding birds, 34 for grasshoppers, and 283 for amphibians

Frequency (% of 1 km^2-squares occupied)	> 75%	25–75%	< 25%
Number of breeding bird species (all)	25	28	> 54
Number of breeding bird species (red-listed)	0	6	> 37
Number of grasshopper species (all)	4	10	> 11
Number of grasshopper species (red-listed)	0	7	> 9
Number of amphibian species (all)	1	4	6
Number of amphibian species (red-listed)	0	3	6

Local diversity

We monitor local diversity because we want to know and demonstrate what happens to diversity within the cultivated and/or exploited areas of Switzerland. These are mainly habitats shaped by human activity and devoted to food and timber production and to dwellings. At the same time, however, they are habitats for wild animals and plants (not rare species, but nonetheless valuable ones). The question is to determine how species diversity changes in fields, meadows, forests, and gardens over the country.

Like landscape diversity, BDM monitors local ('habitat-type') diversity by a special grid-sampling program with repeated sampling every 5 years. Total sample size is some 1600 units, which — with a stratification in favour of settlements — is sufficient to monitor trends in the main habitat-(land use) types of our country and its main altitudinal zones (Table 7). The systematic grid guarantees sufficient data on the most common land use types all over the country, whatever these types will be in the future. Preliminary results suggest that satisfactory precision will be achieved for strata represented by at least 50 sampling units, which translates to about 3% of the country's area.

Each sampling unit consists of a circle of 10 m^2, on which the richness of vascular plants, mosses, and snails is measured by highly standardized methods with good reproducibility, so ensuring a small and constant sampling error. The indicator calculated is 'mean species richness', as for landscape diversity.

The choice of the three taxa mentioned is mainly due to the available methods and the costs. Other taxa would be too

Table 7 Examples of habitats or land use-types for which BDM will be able to calculate reliable data for local (within-habitat) diversity change over time

Habitat (land use) type	Lowland	Montane	Subalpine	Alpine	Switzerland
Woodland	x	x	x		x
Arable land	x				x
Meadows and pastures	x	x	x		x
Settlements					x
Natural alpine areas				x	x

expensive and/or the methodological precision would not be satisfactory. However, breeding birds may be added to the system (based on an improved point-census method). It is not yet known whether and how the variability in diversity of the chosen taxa correlates to the variability in diversity of all species of animals, plant, and fungi. There are indications that plants correlate well with insects at the local scale (e.g. Duelli & Obrist, 1998; Haddad *et al*., 2001), but not with molluscs (our own preliminary data). Therefore it probably was a good idea to add molluscs to the plants (and not an insect group).

The resulting indicator of mean land-use-type diversity can be used to assess the quality of man-made habitats in the Natural Capital Index calculation (ten Brink, 2000), and to replace or complement the somewhat unsatisfactory 'indicator-species' approach used in this calculation. Kleijn *et al*. (2001) give an interesting example of the use of 'mean fine-scale species richness' to qualify the biodiversity of agriculture. Based on the same raw data, it is possible to develop the crude mean species richness indicator further towards an indicator that additionally takes account of habitat specificity (Wagner & Edwards, 2001) or other qualities of the species recorded.

As with the landscape-diversity indicator, data collection must be carried out by professionals, who are guided by very precise instructions. Data gathering is staggered, one fifth of the total sample being surveyed each year, and the survey of the first sub-sample being repeated in the sixth year. Besides an organizational advantage (giving continuous work for the professionals involved), this staggering produces yearly data, which helps to distinguish erratic fluctuations and cyclic changes from directional trends.

CONCLUSION

To measure biodiversity for political purposes, at least three different indicators are needed: local diversity for decision-makers in agriculture, forestry and other land use issues; landscape diversity for conservationists and landscape planners; and macro-scale diversity for international organizations. A good monitoring of the trends in biodiversity should be based on perfectly reproducible methods, which cope with representative taxa and which produce statistically sound data. Finally, the applied indicators need simple definitions and should be easy to communicate.

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