1 Introduction

1.1 The Progressive Inclusion of Biodiversity Measures in Environmental Monitoring

The recognition of the importance of monitoring within ecosystems emerged only since the mid twentieth century. The concept of biological indicators, as opposed to particular target “headline” organisms and the measurement of these alongside broader environmental parameters, was adopted in ecosystem monitoring with the establishment of the United Nations Environment Programme. A formal recommendation to focus on biological diversity in biological monitoring appeared in the Brundtland Report. There followed widespread acceptance that the quality of air, water and soil can be monitored far more effectively with the use of indicator species than by environmental monitoring of chemical pollutants or climate alone. Early emphases of European monitoring programmes sought to gauge the state of marine fisheries under increasing harvesting, and forest health as affected by acid deposition, but this soon developed into surveillance of particular plant and animal species, where the conservation of biological diversity became a priority objective in certain European countries as concern mounted over habitat loss and declines in species. The CORINE Biotopes Programme was the first pan-European assessment of biotopes of major importance for nature conservation. The essential purpose of long-term monitoring was advocated in the UNEP Global Biodiversity Assessment, that such monitoring was critical “to identify human-made changes from natural changes”.

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Biodiversity Under Threat

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1.2 The Challenge of Adequately Representing Complexity

Biodiversity comprises the expression of life on earth in all its various forms and at all its relevant levels of complexity, in a hierarchy from genes to the biosphere. This richness, however, is not easily grasped and expressed in operational measures. We need scientifically well-based approaches to represent the inherent complexity and still adequately describe the diversity of life and the services provided for humanity.

In this chapter we describe the methodological challenge related to biodiversity research and monitoring. Beyond the introduction, we evaluate surrogate measures, indicator species and indices of diversity. Surrogates are used to characterise biodiversity where direct measurement of biological diversity is not feasible, whereas indicator species and diversity indices act to summarise information on biodiversity and can serve to communicate it. Terminological distinction is not always straightforward and clear, as the section will show.

Next we consider how these measures of biodiversity are best structured to identify the effect of environmental factors, namely a Long-Term Ecological Research (LTER) network, illustrated using case studies from Italy. Long-Term Ecological Research sites are equipped to continuously monitor environmental and biological variables enabling interdisciplinary experimental research. The research should provide comprehensive information on the state of biodiversity and how it responds to environmental fluctuations and trends. The comprehensive data should allow an assessment of ecosystem functions and the connection with ecosystem services for humanity. Long-Term Ecological Research sites cannot realistically represent the broad range of ecosystems represented across Europe and we consider the importance of additional monitoring in the overall landscape or “wider countryside” for gauging the status of biodiversity in a later section.

The fundamental task of communicating knowledge about the composition and state of biodiversity, and how it is measured, to the policy and public arenas is dealt with in the final section. Key stakeholder groups and the public at large must understand the observed changes in biodiversity and the future consequences for ecosystem function and the quality of human life in order to appreciate the purpose of environmental monitoring.

1.3 Complexity and Ambiguity of the Term Biodiversity

“Overall richness of life on earth” is an appealing linguistic expression, apt to convey the thought of a great natural heritage and the need for its conservation, but how to connect it to measurable quantities? Our knowledge about the “richness of life” on earth is seen to be dramatically incomplete when considering some key numbers. The total number of existing species is unknown, estimates range from 2.5 to 30 million and more. The number of actually recorded and described species is currently at 1.5–1.75 million and continuously increasing, owing to intensive taxonomic research. Hence, anything from about
5 to 60% of all species has been recorded by man, and there is no way of knowing the exact figure. Concern about an ongoing erosion and decline of biodiversity is hence based on facts other than precisely known total numbers: it is the apparent loss of some “charismatic” key species (e.g. tiger and gorilla) in particular that attracts attention and raises concern, as well as the apparent loss and degradation of many habitats in general. The presumed (and indeed very plausible) link of habitat loss and species loss is a strong line of reasoning in the biodiversity debate.

1.3.1 Hierarchical Level Model. One important consideration is that biodiversity is expressed at different organisational and spatial scales, which are hierarchically nested, and each of these scales can be an important level in its quantification. The hierarchical levels extend from bio-molecules to the biosphere, comprising genes, populations, communities, ecosystems, habitats, biogeographical regions, biomes and finally the entire biosphere. The hierarchical approach can contribute to make quantifications of biodiversity more feasible and more precise in their meaning. For instance, quantification and comparison of populations with respect to their total gene pool or the richness of variation at certain key gene loci are becoming possible with the help of recent modern molecular genetic techniques. Diversity of traits in microfauna or microbial populations, which could never be studied on the basis of counts and descriptions at the level of individuals, can efficiently be discerned by employing molecular markers. Likewise, on the large spatial scale, remote-sensing-based assessments of the change of habitat extensions and habitat quality can enable qualified appraisals of related changes in biological diversity.

1.4 Approaches to Reduce Complexity

There are several meaningful concepts and tools to handle the complexity inherent in biological diversity. Many of the established parameters date back in time much longer than biodiversity science, since diversity in general can be treated as a problem of information theory (amount of “diverse” information in a signal) and has been addressed with measures such as the Shannon Index long before biodiversity emerged as a topic in science.

The Shannon Index can be regarded as the classic in the field of diversity indicators and as the basis for the development of a multitude of further indices which are commonly used to address different facets of the numerical expression of biodiversity. The formula for the Shannon Index is:

\[ S = -\sum (p_i \log (p_i)) \quad \text{with} \quad p_i = \frac{n_i}{N} \]  

(1)

\( N \) is the total number of individuals in a sample, \( n_i \) are the individuals of species I and \( A \) is the total number of species observed. However, this expression continues to increase along with \( A \), the total species number.

\[ S_{\text{max}} = \log (A); \quad \text{(even distribution of all species assumed in this case)} \]  

(2)
To normalise it, the proportion of $S$ to the log of all species is calculated

$$E = \frac{S}{\log (A)}$$ (3)

This normalised term is called the “Evenness” of species distribution in a sample. An evenness value of 1 would hence indicate maximum evenness of the species represented in a sample, lower values indicating an increased dominance of a few species. However, it cannot be assumed that the highest observed evenness values always indicate the ecologically most favourable or sustainable conditions\(^7,\)\(^10\)

It is further important to note that the Shannon Index and Evenness only give numerical information on the sample considered and no information concerning distribution in space. However, species counts plus the Shannon Index and/or Evenness together provide a complete and quantitative set of information on how many species (of one or more taxa) there are in a sample (or habitat), and how the abundances of the those species are distributed relative to each other (see Figure 1).

Another approach to handle the complexity associated with biodiversity and the different levels on which it is expressed is the distinction of $\alpha$-, $\beta$- and $\gamma$-diversity. $\alpha$-diversity designates diversity within a habitat, $\beta$-diversity is the measure within a mosaic of habitats, including borderline effects, and $\gamma$-diversity refers to the diversity within a bio-geographical region or country.\(^11\)

This classification reflects the integrated and hierarchically nested spatial scales on which biodiversity becomes manifest. It has frequently been supplemented by further classes, designated as $\delta$-, $\varepsilon$-diversity and so on, addressing still different situations and problems of quantitative biodiversity assessments.

1.4.1 Species Numbers and Abundances. Although a number of more-or-less sophisticated indices to quantify biological diversity are available, an exploration of the literature quickly reveals that in most instances simple species numbers and abundances are the most popular measures of diversity in

Figure 1  Increasing evenness between the occurrence of four species in a sample.
practical use. This is surely resulting from the fact that species counts and abundance assessments are the very basic and intuitive way to address biodiversity-related questions. Counting and estimating would naturally be the first thing to do when exploring the biological diversity within a habitat and, in fact, most reporting is based on this simple and straightforward approach. Indicators of trend founded on combined species, like the common farmland bird index\textsuperscript{12} or the Pan-European Species Trend Index (STI)\textsuperscript{13} are commonly used in large-scale reporting schemes. They represent merely an aggregation of single observations of species numbers and abundances, but are still more frequently used than the sophisticated diversity indices of higher mathematical and logical complexity.

1.4.2 Development of Surrogates, Indicators and Aggregated Indices. Having identified that the reduction of complexity is a major problem to solve, we have to consider in which ways it could best be achieved for our purposes. Well-chosen and evident surrogates, indicators and indices, which are scientifically well founded and broadly accepted by the pertinent scientific community as well as stakeholders, political actors and decision makers, would indeed be a great accomplishment. In the next section, we focus on this challenge.

2 Surrogate Measures, Indicators and Indices

It is no secret that scientists are in pursuit of a general, unifying model to explain the universe. In this instance, it is biodiversity rather than the broader universe, but it is nonetheless extremely complex and widely unknown. Thorough studies of, for instance, the species richness of a limited area requires an intensive effort by many collaborators, using much time and money. Despite the immense effort, it is likely that many inconspicuous organisms of obscure taxa would be overlooked due to the general lack of taxonomic expertise. Additionally, the urgency to formulate conservation measures in these decades of rapid biodiversity loss demands the use of short-cuts in biodiversity assessment. Altogether, this has led to the development of indicators, indices or so-called surrogates of biodiversity.

2.1 Forerunners and First Steps in the 1980s

One can argue that some studies carried out in the 1960s are forerunners of the biodiversity indicator approach\textsuperscript{14,15}. While searching for factors that determine species diversity, they explored the importance of environmental spatial heterogeneity for species richness patterns. These studies and others were motivated by ecological theory. However, in the 1980s conservation biologists started to explore this topic. In the woodlands of Lincolnshire it was found that rare plants act as an umbrella to include the occurrence of 99% of all other plants\textsuperscript{16}. Murphy and Wilcox\textsuperscript{17} explored the usefulness of a vertebrate-based
conservation management for an insect group. They compared data on species richness on three geographic scales, partly included vascular plants in their analysis, and found reasonable support for their approach. Nevertheless, there are few quotable studies in the 1980s, but new concepts and catchwords were established at the end of that decade.

2.2  A Muddle of Terms

Besides the more general terms of biodiversity indicator or biodiversity surrogate some more focused concepts emerged. For instance, the concept of an umbrella taxon, which is defined as a “species with large area requirements, which, if given sufficient protected habitat area, will bring many other species under protection”.18,19 Or the term flagship species, i.e. a limited set of umbrella species chosen for their charismatic appearance (e.g. tiger, rhino or elephant). Many more terms and concepts are under discussion (e.g. focal and target taxon, keystone species, cross-taxon congruence) and this muddle of terms is frequently criticised and has yet to be clarified.20–24 There is some consensus that the term surrogate is the most general one. Some researchers deny this and say that the concept of indicator is good enough. However, until a taxon has been demonstrated to be an indicator/surrogate it must remain a potential indicator/surrogate.25 Mostly used in materials science originally, the word surrogate basically means a substitute. It quickly gained popularity since 1995, although already used as early as 1988 by Landres et al.20 (“the indicator is a surrogate measure”). Altogether, the number of studies on biodiversity indicators/surrogates boomed since the middle 1990s and, anticipating the summary below partly, the philosopher’s stone has not yet been found. Effectively, some indicators have been detected and developed that are suitable to represent some aspects of biodiversity, at the most.

2.3  “It Starts with the Right Question” or “the Choice of Values and Measures”

The motivation to use one of the various biodiversity surrogates and measures is manifold. In agricultural landscapes, for instance, we perhaps need biodiversity indicators for biological control, ecosystem functioning or nature conservation.26 Each mentioned aspect requires at least one indicator and the quality and reliability of potential indicators must be tested rigorously. Nevertheless, the output in the domain of biodiversity indicator research is dominated by its appliance in conservation practice. Again, what indicator would best suit our purpose? Do we need a biodiversity indicator to locate an area of raised species richness or to find the best solution for a representative reserve system?27 Or, are we searching for indicators that allow decision makers to set measures for the maintenance of biodiversity? Or, a conservation practitioner looks for an indicator to evaluate the success or failure of restoration measures
that have been carried out. To demonstrate the rapid development that took place in the last years it makes sense to focus on one practical example.

2.3.1 Deadwood as a Showcase. Forests in Europe have been heavily exploited for many centuries. Logs are harvested long before the trees reach their natural span of life. In an average managed forest only a small amount of deadwood remains. Saproxylic species (i.e., species that demand dead and decaying wood) suffered seriously due to habitat loss and fragmentation. However, about a third of the European forest species need deadwood and veteran trees to some extent for their survival. In Germany, 25% of the beetle fauna depend on deadwood and in Britain 1800 invertebrate species are saproxylic. So, the establishment of conservation sites for saproxylic species became a main issue. Additionally, discussions and recommendations focus on increasing the amount of deadwood in commercially managed forests. Immediately it is apparent that it is time consuming and costly to assess the whole array of saproxylic species. Consequently, potential indicators and surrogates were explored and the cost-effectiveness of surrogates was evaluated. There is now ample evidence that raising levels of deadwood in forests will promote abundance and richness of deadwood-demanding species. So, why not measure the amount of deadwood as a surrogate for saproxylic species richness? This was proven to be pretty successful for several taxa and it is cost-efficient when data collection is integrated in the national forest inventories. On the other hand, if there isn’t any nationally organised forest inventory it might be more efficient to concentrate on some deadwood-demanding umbrella species like woodpeckers. However, for the overall biodiversity, dead and decaying wood is not a comprehensive indicator, because other factors on the landscape- and stand-scale also play an important role. Another problem is that deadwood threshold values are poorly understood and identified only for a few species. Altogether, in the case of the saproxylic species diversity in Europe, some steps for a profound and cost-effective biodiversity surrogate have been taken, but more needs to be done.

2.4 Adoption of the Biodiversity Surrogate Approach

Some hundred studies on biodiversity surrogates with real field data from around the world have been published in the last two decades. The outcome is ambiguous and no clear picture has emerged so far. What we do know is that the scale of analysis is critical. Scale is recognised as an important issue in ecology, well documented for species richness patterns, and also the effectiveness of biodiversity indicators is markedly influenced. On average the predictive power of biodiversity indicators increases from local to global scale. Furthermore, it seems that surrogates developed in one geographical region or within a special habitat type are not easily transferable into another context. Reyers and van Jaarsveld demonstrated that the assessment techniques used also
have a strong influence on the effectiveness of biodiversity surrogates. The quality of the input data used and observation bias are at least partly a black box, and they both could have serious effects on the outcome of the analysis.

Despite these limitations some progress can be observed. So, environmental surrogates can improve how well species in a reserve system are represented. Empirical evidence grows that some taxa could be used as surrogates for a broader aspect of biodiversity. It has been shown, for instance, that vascular plants or birds are efficient indicators at least in some contexts and at certain scales. Another promising method is the so-called multi-taxon approach: while single groups may fail to serve as biodiversity surrogates, a selection of a set of taxa with different ecological requirements might circumvent this problem. This approach directly leads to the development of biodiversity indices, which are increasingly used in biodiversity monitoring.

2.5 Biodiversity Indices

Recently, especially in the light of the world-wide aim to reduce the current rate of biodiversity loss significantly by 2010, the variety of biodiversity indices is growing. Already applied in some countries (e.g. Britain, Switzerland, The Netherlands), biodiversity indices increasingly become important on a European and world-wide scale. If kept simple, they are smart enough to influence decision makers and they are valuable tools for communication with the public.

In the next section, we examine in detail which indicators of biodiversity should be employed at intensively investigated LTER sites, which are particularly important ecological research objects around the world.

3 Indicators of Biodiversity and its Change for LTER Sites

3.1 LTER Sites and Biodiversity: Basic Concepts and Keystones

Long-Term Ecological Research (LTER) sites consist of various monitoring and research facilities, creating a network across the world. Their data can be profitably used to address research questions on several environmental topics. The concept of LTER implies: (a) long data series; (b) data on ecosystem traits and processes; and (c) a shift from monitoring activities, performed on a regular basis, to research activities. The International Long-Term Ecological Research (ILTER) network was founded in 1993 by the United States of America and had 34 contributing countries by 2006, reflecting the increased appreciation of the importance of long-term research in assessing and resolving complex environmental issues. This was a means to meet a growing need for communication and collaboration among long-term ecological researchers and to provide a scientific forum to encourage data-sharing at a local, regional
and national level, co-operation on global projects, and to integrate findings and deliver sound, peer-reviewed research to decision makers and the public.

The ILTER network is not the only LTER programme but it is the only one with: (a) a global network of research sites in a wide array of ecosystems worldwide; (b) a focus on long-term site-based research; (c) a governance structure and research mandates built on a “bottom-up” rather than a “top-down” approach.58

The usefulness of the ILTER is readily illustrated by recent research to investigate the response of forests to hurricane and typhoon events along the Pacific and Atlantic coasts in the USA (presentation by Steven Hamburg, head of US LTER, Brown University, Rhode Island, USA). Data on the location, period, power category, average power/year from LTER forest sites experiencing tropical cyclones in the USA, Japan and Taiwan revealed that forests responded differently to these storms in the Old and New World.

The following environmental trends were identified by ILTER and external scientists:58 (a) an accelerating increase in sea temperature and glacial melt as a consequence of climate change with implications for ecosystems, societies and human health; (b) ILTER contributes to sustainable development, especially in the areas of human health, education and access to natural resources linked to environmental conditions, through the participation of developing countries where water scarcity, lack of electricity and environmentally induced diseases prevail; (c) biodiversity loss: biodiversity is one of the key natural resources on which human societies rely. Particularly in developing countries, biodiversity services are essential to humans, assuring survival support by agricultural production, water supply and quality, and pest control; on the other side, in developed countries, pressures on biodiversity are of great concern due to population density and over-exploited landscapes and natural resources. Modifications in biodiversity status and processes can be complicated and slow, affected by several factors, thus requiring long-term and multi-disciplinary approaches, features that ILTER can easily provide.

By 2006, LTER Europe included the Czech Republic, Hungary, Israel, Latvia, Lithuania, Poland, Romania, Slovenia, Slovakia, Ukraine, Austria, France, Italy, Germany, Switzerland and the United Kingdom. A biodiversity gradient can be discerned across Europe, increasing approximately from north to south and from east to west. Formal LTER sites with geo-referenced data are located in the United Kingdom, Switzerland and Eastern Europe59 because of their political-historical association with ILTER from its inception. If the total number of LTER-like facilities are considered, this widens the distribution of research sites to include Spain, Portugal and Greece. Further countries could contribute data collected in long-term-based research sites to the Network. Hence, biodiversity research topics are already strongly addressed at the European level. A major goal of ALTER-Net60 under the Integration Objective I3 (a network of long-term multi-functional, inter-disciplinary ecosystem research sites) is to integrate long-term ecosystem research and increase capacity at a national level.
3.2 LTER Networks at Pan-European Level in Practice: the Experience of UN-ECE CLRTAP ICP IM and ICP Forests

Whereas a dedicated pan-European network for biodiversity monitoring and research is still lacking, large and continuous monitoring schemes implementing surveys on biodiversity status and change have been in operation at a pan-European level since 1985 under the UN-ECE Convention on Long-range Trans-boundary Air Pollution (CLRTAP), in particular for the forest ecosystem. The International Co-operative Programmes (ICPs) identify air pollution effects on the environment (including biodiversity) through monitoring, modelling and scientific review. The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) collects data in close co-operation with the European Commission (under Regulation no. 2152/2003 Forest Focus) and determines cause–effect relationships of changes in forests due to air pollution and other stresses by means of large-scale monitoring. The International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM) determines and predicts the state of ecosystems or river catchments and their changes from a long-term perspective with respect to the regional variation and impact of air pollutants. Both ICPs have been co-operating closely for a number of years now, although the objects under study appear different. ICP IM is focusing on catchments in undisturbed ecosystems while ICP Forests monitors both unmanaged and regularly managed forest ecosystems. Most ICP IM sites are, however, located within forest areas and many countries have linked their plots of both programmes within one monitoring system. One result of this intensive co-operation is the harmonisation of assessment methods. Detailed information on the programmes is available on the web sites of UN-ECE ICP and UN-ECE ICP IM.

The activities of ICP IM began as a joint Nordic co-operation programme under the Nordic Council of Ministers in the mid 1980s. From 1989 to 1991 it was run as a pilot programme under the CLRTAP and became a permanent ICP in 1993. The main objectives of the ICP IM are: (a) monitoring of the biological, chemical and physical state of ecosystems (catchments/plots) over time in order to provide an explanation of changes caused by environmental factors, including natural changes, air pollution and climate change, with the aim to provide a scientific basis for emission control; (b) development and validation of models for the simulation of ecosystem responses in order to estimate responses to actual or predicted changes in pollution stress, and make regional assessments in concert with survey data; (c) bio-monitoring to detect natural changes, in particular to assess effects of air pollutants and climate change. The full implementation of the ICP IM will allow determining ecological effects of heavy metals, persistent organic substances and tropospheric ozone. A primary concern is the provision of scientific and statistically reliable data that can be used in modelling and decision making. The ICP IM sites (mostly forested catchments) are located in undisturbed areas, such as natural parks. The ICP IM network presently covers about 50 sites, with on-going data submission, in 21 countries.
ICP Forests was established under CLRTAP in 1986. In 1987 the European Commission (EC) also started to monitor forest condition in the EU Member States. However, ICP Forests and the EC merged their previous two monitoring programmes into a joint one in 1991. Since then, both have been monitoring forest condition and publishing their results jointly. Consequently most of the activities of ICP Forests are carried out in close co-operation with the EC. ICP Forests pursues the following mandate: (a) to monitor effects of anthropogenic stress factors (in particular air pollution) and natural stress factors on the condition and development of forest ecosystems in Europe; (b) to contribute to a better understanding of cause-effect relationships in forest ecosystem functioning in various parts of Europe. For each part of the mandate ICP Forests has implemented a separate monitoring intensity level. At Level I the large scale variation of forest condition is assessed by means of an extensive survey on more than 6000 plots. At Level II intensive monitoring is carried out on 800 plots in 30 countries in order to trace in detail the influence of specific stress factors in main forest ecosystem types. On these plots a larger number of key factors is measured. Apart from air pollution, ICP Forests has widened the scope of its programme to the topics of biodiversity and climate change. In view of these topics, the major objectives of the intensive monitoring at Level II are, in particular, the assessment of: (a) responses of forest ecosystems to air pollution and its changes; (b) differences between present loads and critical loads of atmospheric deposition (tolerable long-term inputs in order to protect the sustainability of the ecosystems); (c) impacts of atmospheric deposition on the ecosystem condition according to scenario analyses; (d) changes in carbon storage in forests (net carbon sequestration); (e) changes in indicators related to the various functions of forest ecosystems to assess long-term sustainability. Both parts of the programme – extensive monitoring on Level I and intensive monitoring on Level II – yield the potential to transfer process information gained on the plot-level (Level II) to the European scale (Level I). The methods for the assessment of the chemical, physical and biological parameters are harmonised throughout both ICPs and are laid down in two manuals (available on the web sites given in refs 62 and 63).

Surveys carried out in both programmes are crown condition, foliar chemistry, species composition of the ground vegetation, soil solid-phase chemistry, soil solution chemistry, tree growth, atmospheric deposition, meteorology, phenology and litter-fall. Surveys that are carried out at the ICP Forests Level II only are ozone injury and remote sensing, whereas soil biology, surface-water chemistry and bird inventories are assessed only by ICP Integrated Monitoring. The number of parameters assessed within the surveys is large; some of them are mandatory, others are optional. The responsibility for selecting the sample plots for each survey and for choosing optional parameters lies with the National Focal Centres (NFCs).

Ground vegetation has been assessed on ICP Forests Level II plots since the 1990s as a biological indicator for effects of chemical deposition, and these make a core contribution to biodiversity monitoring. Under Regulation (EC) no. 2152/2003 Forest Focus, and in line with the ICP Forests strategy, new
projects and developments have been initiated recently with the aim of contribut-
ing to monitoring some aspects of forest biodiversity. The pilot project “Forest Biodiversity Test-phase Assessments (ForestBIOTA)” aims to har-
monise monitoring methods for the assessment of stand structure, deadwood and for lichens growing on tree bark (epiphytic lichens). An ecological classification of forests has also been implemented. The new methods were successfully tested on 107 plots located in 12 European countries in the period 2004–2005. The results of the ForestBIOTA project support the EU demonstration project “BioSoil” that will be carried out on a larger number of Level I plots (6000) in the period 2006–2007. Links to the national forest inventories of many countries are also being intensified in order to provide reliable and comparable information on the biological diversity of European forests.64

3.3 Biodiversity Status and Change in Forest Ecosystems: Examples from Italy

Italy entered the International Long-Term Ecological Research (ILTER) net-
work in 2006 after a core group of scientists implemented the Network in the late 1990s. The network of sites was realised through the wider participation of researchers and scientists from public agencies, universities and research institutes coordinated by a National Steering Committee. The National Forest Service – CONEFOFOR Office (Corpo Forestale dello Stato – Ufficio CONE-
COFOR) – has been a partner in the Italian LTER from its instigation. The National Steering Committee proposed sites and research activities during 2005. In 2006, a priority list of Italian sites was produced from which ten suitable sites were finally selected after revision of the scientific methods by external experts. These sites have been grouped into five “macro-sites”, each representing a particular ecosystem (forest, freshwater, marine environment, Antarctica Ocean, Himalayan lakes). Sites are linked to each other by ecolog-
ically and biogeographically similar traits and may include more than one research station.

3.3.1 Forest Monitoring Activities within LTER-Italy. The “Forest” macro-
site includes three sites: (a) site 01 “Forests of the Alps”, where the main biotic communities are primary/secondary spruce (Picea abies)-dominated forests; (b) site 02 “Forests of the Apennines”, mainly Fagus sylvatica old-growth forests and mixed coppice stands with secondary meadows; (c) site 03 “Medi-
terranean forests”, represented by mixed high coppice Quercus ilex- and Quercus cerris-dominated forests. Sites 01, 02 and 03 include nine research stations (plots) belonging to the Italian CONEFOFOR programme (see Table 1). The Italian programme for the monitoring of forest ecosystems (CONE-
COFOR) started in 1995 within the framework of Regulation (EC) no. 1091/94 and under the UN-ECE Convention on Long-range Trans-boundary Air Pollution of the United Nations (CLRTAP).65 A typical CONEFOFOR permanent plot (Permanent Monitoring Plot, PMP) is made up of two closed
2500 m² areas: one was established to carry out the surveys while the other one was chosen as a control area; moreover, the outline of a typical analysis area includes a buffer zone, service facilities, a fence, meteorological stations and other sensors.

Several monitoring activities are carried out in Italian “Forest” sites: vegetation surveys, crown condition, soil chemistry, foliar chemistry, tree growth, atmospheric deposition, ozone, macro- and micro-climate, phenological observations, gas exchange, population dynamics, structure, silviculture, net primary productivity and nitrogen cycling. All CONECOFOR PMPs were initially selected not according to a systematic grid applied on Italian territory but on a preferential basis; that is, actively choosing specific areas among the most important forest communities in the country which were representative, on a wide scale, of all types of forest ecosystems for the particular climate gradient along Italy. As a consequence, it is not possible to infer general statements about forest ecosystem status at national level based on the results obtained from monitoring activities within PMPs; that is, each PMP is to be considered individually as a “case study” and the data obtained inside one plot cannot be related to the others in a statistical way.⁶⁵ Among the main priorities recognised by the integrated and combined strategy is the evaluation and

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quantification of: (a) the actual and potential risk status of ecosystems in the
PMPs (especially in relation to atmospheric pollution and meteorological
stress) and (b) the on-going change in the physical-chemical and biological
system and its determinants. Given the above framework for the interpretation of scientific outputs from
CONECOFOR plots, it is easy to imagine a move from monitoring issues to
the search for answers to research questions and a shift from a physical-
chemical approach to an ecological one, as a first step toward the investigation
of status and changes in forest biodiversity.

3.3.2 Biodiversity: Ethics and Science. The Italian Academy of Forestry
Science identified in nature, and consequently in biological diversity, an
economic value (the so-called “instrumental value”) but also an “existence
value” (“intrinsic value”) that is the value of forest in itself, not related to
human needs. Science can serve both views by the analysis of biodiversity
components to understand and sustain ecological processes and services (water
quality, agriculture, wood and fruits production, air quality, climate balance,
etc.), and the “curiosity” and need for knowledge of biological actors that is
“pure” research.

3.3.3 An Example: the Italian Biodiversity Research – Invertebrates. In 2003,
new additional investigations related to forest biodiversity started in some
CONECOFOR PMPs (a) epiphytic lichens, (b) deadwood, (c) invertebrates,
(d) naturalness. In forest ecosystems, the major amount of biodiversity as
regards species numbers is represented by invertebrates, especially bacteria,
protozoa, molluscs, fungi, lichens and arthropods. Insects are of great con-
cern and interest at the European level: due to mono-functional silviculture
practices and managing procedures, aimed at obtaining high-value wood
products in the shortest time, saproxylic populations have been reduced:
Cerambyx cerdo is considered a damaging species for woods in most forestry
programmes but it is, at the same time, included in the EU Habitats Directive
as end-consumer in mature forests. Twelve Italian CONECOFOR plots have
been involved in a pilot project called ForestBIOTA, including a focus on
invertebrates and with the principal aim of testing an effective and inexpensive
protocol for insects sampling. Eight out of twelve plots included in the project
are part of forest LTER-Italy facilities.

Preliminary results of the pilot project in four plots have been presented to
date. Samplings were conducted from June 2003 and June 2004, using a
Malaise trap, a window trap and four pitfall traps in each plot (see Figure 2).
Most of the collected material is still undergoing analysis, but long lists of
eleven insect families have been produced so far: 21 species of Stratiomidae, 114
of Syrphidae, 206 of Tachinidae, 3 of Lucanidae, 7 of Scolytidae and 18 of
Rhopalocera. Seven species of Diptera have been newly recorded for Italy
(together with 28 new to Sicily and 40 new to Sardinia). Moreover, three species
of Diptera Tachinidae were recorded as new to science (Pales abdita, Pales
marae and Pseudogonia metallaria), deserving special mention not only because of their discovery as newly described species but also because they seem to be strictly Mediterranean species.

3.3.4 An Example: the Italian Biodiversity Research – Vegetation. The relationship between the number of vascular species, as a component of site biodiversity, and the characteristics of the station was investigated, relying on traditional surveys conducted in 19 PMPs (vascular plant species richness, stand structure, soil and atmosphere composition), ranging from one-storied beech and irregular-stratified Norway spruce high forests to layered oak coppice, over the period 1999–2003, in order to highlight what biotic and abiotic factors influence vascular plant species richness. In fact, mean vascular species richness (including woody species) was found to be a good indicator of the total number of plant species in the plot: so, in this framework, the mean number of species per 100 m² was used as a response variable, i.e. a dependent
one, while stand, soil, meteorological and deposition data were considered as the independent variables of the research. Statistical metrics were used in order to obtain a sound interpretation, because of the large number of independent variables compared to the relatively small number of plots investigated. Regarding the response of vascular plant species to chemical composition of the soil, direct as well as indirect relationships were found. In particular: (a) species richness is relatively high where there is higher content of K in the soil, high litter-fall and a large number of woody species in the dominant layer; (b) the dependent variable seems relatively low in the presence of high levels of C, N, C/N, C/P and P in the soil and high coverage of the main tree species in the upper layer. When the largest numbers of independent variables were taken into account, different results were recorded for (a) all the plots and (b) for beech plots only. When all plots were considered, the only significant correlation was with the number of tree species in the plots (that is, the higher the number of tree species in the plot, the higher the mean number of vascular plant species); when only beech plots were studied, vascular species diversity correlated positively with longitude (and, to a lesser extent, with latitude), top height, standing volume and soil N, but, on the other hand, negative correlations were found with N deposition and exceedances of a critical level of N. The extent of vascular plant diversity with regards to N content was found to be particularly interesting: in fact, especially in southern Italy, the number of vascular species increased with soil N content, but, on the other side, the number of species decreased with the increase of N deposition and exceedances of an N critical level in most cases in plots located in beech forests in northern Italy, characterised by low content of N in the soil (see Figure 3). In order to extend this analysis, the continuation of long-term data series seems to be particularly useful.

3.4 Biodiversity Status and Change in Freshwater Ecosystems: Examples from North-Italy

The international limnological literature demonstrates that there has been little research of diversity in freshwater lakes over long periods. A uniform, long-term trend in biodiversity in the world’s lakes has been related to trophic change, and the corresponding effect on ecosystem biodiversity is now widely acknowledged, accepting that there can be different responses of species according to the compartment of the trophic web and the particular ecosystem. The general trend is represented by a bell-shaped curve, with high biodiversity values corresponding to an oligomesotrophic state. Here perhaps the optimum equilibrium between the creation of new niches is reached, brought about by the increase in range and gradients of abiotic parameters and the negative effects of an excess of nutrients, such as the critical conditions for zooplankton growth and reproduction, the reduced euphotic depth or the self-shading of phytoplankton. Data for certain Italian lakes have been collected since the nineteenth century, but are generally too sparse and irregularly collected for
comparison over time. Moreover, sampling with nets was common until the 1950s and underestimated the number of species and individuals of phytoplankton. Lack of standardisation in counting methods by different investigators made it difficult to assess general changes in biodiversity in most Italian lakes (discrete samples at different depths or integrated samples over variable water column layers). Regular monitoring and standard limnological methods were established to study “cultural” eutrophication of the lakes in the sub-alpine district in the last 30–35 years. For many lakes, there was more emphasis on the analysis of the water chemistry than of the biota illustrated by only three papers, 1950–1980, providing complete and comparable biological data for Lake Garda, Como and Iseo. This at least allowed an analysis of long-term changes of phyto- and zooplankton. The alternation of many investigators in counting the samples and the adoption of different counting techniques further complicated the picture. Therefore, studies dealing with long-term plankton biodiversity in Italian lakes are virtually non-existent, even though the sparse existing data testify to important changes in the species structure of plankton.

Figure 3  Vascular plant species richness is correlated (a) with nitrogen content of soil and (b) with exceedance of critical load for nitrogen, in seven CONECOFOR permanent monitoring plots in Italy, dominated by *Fagus sylvatica* forest (original, based on data from ref 85).
assemblages; lakes Candia, Maggiore and Orta represent three rare exceptions in this respect. All three lakes were regularly monitored, carrying out monthly (or, sometimes, fortnightly) sampling, continuously for c. 25 years. In each of these lakes the long-term evolution of biodiversity has been evaluated, in particular concerning the plankton, although in some cases other biotic compartments were considered, such as macrophytes for Lake Candia. The general pattern that emerged from these analyses points towards an increase of biodiversity after the improvement of the water quality. Since the 1960s a worsening of the water quality of Lake Maggiore was recorded, due to the increased nutrient loading. Since the end of the 1970s, thanks to recovery measures, the phosphorus availability gradually decreased. In a few years, notable changes in the food web took place. In Lake Maggiore the biodiversity of phytoplankton proved to be a good indicator of the environmental changes: following the decrease of phosphorus input, the number of algal taxa gradually increased from about 50 total taxonomic units recorded at the end of the 1980s to the almost 80 taxa found in the most recent years. The most significant increase of diversity took place among the cyano-bacteria: from two or three blue-greens usually dominant in the eighties, to seven or eight dominant species in the most recent period. A comparison of samples collected during the 1980s with those collected at the end of the 1990s shows that the biodiversity increased yearly as well as seasonally. The reliability of the above findings is confirmed by the fact that the samples were counted with the same method and by the same person for the whole time series. The calculation of Shannon–Wiener diversity and of the evenness, carried out by the late Dr Delio Ruggiu, confirmed the link between the increasing phytoplankton diversity and the improving trophic status of Lake Maggiore. An analysis of the long-term zooplankton data demonstrated the same pattern of increasing biodiversity during the gradual oligotrophication of the lake.

Summarising, the limnological research in Italy offers few examples of studies dealing with the status of biodiversity and its long-term changes. The results confirm the existence of a close relationship between biodiversity and trophic evolution, a pattern already observed in many lakes worldwide. Not far from Italy, the Swiss sub-alpine lakes offer many examples of increasing biodiversity during the oligotrophication process (L. Lucerne, L. Sempach, L. Greifensee). Their trophic evolution mirrors the processes observed in the deep Italian sub-alpine lakes: for instance, very similar changes in the phytoplankton species structure and biodiversity were recorded in both Lake Maggiore and Lake Lucerne. The comparison among Swiss and Italian deep lakes seems to indicate the existence of common patterns of ecosystem reaction to the long-term trophic changes when the lakes share similar basic features (morphometry, hydrology, climate, morphology of the catchment). In general terms, the Intermediate Disturbance Hypothesis seems to be appropriate also to describe the relationship between a lake’s biodiversity and its trophic evolution: moving from a high degree of disturbance (eutrophication) to a lower degree (oligotrophication), the biodiversity increases. This is what, in fact, is happening in many lakes around the world. After a certain degree of
oligotrophication, diversity should decrease again. However, none of those lakes seems to have reached a stable oligotrophic status yet, so we do not really know what we should expect, in terms of biodiversity, at the opposite end of the curve.

3.5 Biodiversity Status and Change in the Marine Ecosystem: Examples from the Pelagic Ecosystem in Italy

The marine environment is subject to intense human pressure and considerable changes are occurring as a consequence of over-exploitation, habitat destruction, introduction of exotic species, pollution, eutrophication and global climate change. Notwithstanding the acknowledged global importance of marine systems, the estimate of the magnitude of biodiversity at most scales is surrounded by a large degree of uncertainty. Species in the sea are far less known than on land. The major gap in the knowledge of marine biodiversity concerns those groups (prokaryotic and microbiota) that actually dominate the biogeochemical processes. Our perception of marine biodiversity is biased by the geographical distribution and focus of the research on few phyla: most published aquatic biodiversity research comes from few countries, focuses on relatively few specific regions and refers mainly to commercial (fish) or charismatic species (birds and marine mammals), while other organisms (e.g. copepods, nematodes, microbes) that play ecologically important roles are rarely mentioned.

Most research evidence and ecological theories on the effects of biodiversity on ecosystem functioning (BEF) come from terrestrial plant systems, particularly grassland. This issue has received relatively much less consideration in aquatic ecosystems. Actually, marine scientists have been very productive in research that is highly relevant to BEF issues in recent years, even though they have not placed that research within the appropriate conceptual context.

A network of excellence on Marine Biodiversity and Ecosystem Functioning (MarBEF: www.marbef.org) was established in 2004 (Sixth Framework Programme for Research and Technological Development of the EU). It comprises over 700 marine scientists from 24 countries throughout Europe and the principal aim is to support research on the relationships between biodiversity and functioning of ecosystems. The integration, in a single and unifying picture, of the mutual interactions among biodiversity changes, ecosystem functioning and abiotic factors represents the major challenge in biodiversity research. The (re-)analysis of large-scale and long-term studies, even though they were not framed in the BEF context, represents a valuable way to explore and evaluate biodiversity and ecosystem changes. In this context, ecological time-series are fundamental tools to trace the long-term variations of marine ecosystems, detect significant shifts and assess whether changes are attributable to human or natural causes. Moreover, long-term series are essential for testing ecological theories, for enhancing our limited capacity for short- and medium-term forecasting and for managing the resources.
3.6 Toward a Core Set of Biodiversity Indicators for LTER Sites

It is highly desirable to develop a core set of biodiversity indicators for LTER sites which may be applied on the basis of harmonised methods at pan-European level, across different bio-geographical regions. The Pan-European Biological and Landscape Diversity Strategy (PEBLDS) was developed to support the implementation of the UN Convention on Biological Diversity at the pan-European level, by the initiatives of the Council of Europe and the United Nations Environment Programme (UNEP). In this framework, the biodiversity resolution taken by the 5th Conference of the European Ministers of Environment “Environment for Europe” (Kiev, 2003) includes the keystone decision to develop by 2006 a core set of biodiversity indicators and to establish by 2008 a pan-European network on biodiversity monitoring and reporting, with a framework of collaboration with MCPFE (Ministerial Conference on the Protection of Forests in Europe). A pan-European Co-ordination Team, formed by the European Environment Agency, UNEP, the European Centre for Nature Conservation and the Expert Groups leaders has operated since 2004, having initiated its work collecting available information. The work plan elaborated, approved and funded by the EC provides the logical framework for the activities that need to be carried out in order to ensure European coordination of the development and implementation of biodiversity indicators. The indicators will be applied in assessing, reporting on and communicating achievement of the 2010 target to halt biodiversity loss. This activity is called “Streamlining European 2010 Biodiversity Indicators (SEBI2010)”.

The Expert Groups have started their activities; demonstration activities to be carried out in three test countries are expected in 2006; by 2007 the definition and publishing of the final revision of the indicator set; and by 2008 the establishment of a co-operative monitoring network at pan-European level. The selected “headline” indicators are based on the set currently proposed at global and European level and just included in an official EU list (Annex 2): trends in abundance and distribution of selected species, change in status of threatened and/or protected species, trends in extent of selected biomes, ecosystems and habitats, trends in genetic diversity of domesticated animals, cultivated plants and fish species of major socio-economic importance, coverage of protected areas, nitrogen deposition, number and costs of invasive alien species, impact of climate change on biodiversity, marine trophic index, connectivity/fragmentation of ecosystems and water quality in aquatic ecosystems.

A good example of results and work in progress under the SEBI2010 initiative is the overall headline indicator called “Trend in extent and composition of selected ecosystems”, currently under development by the SEBI2010 Expert Group 2. A specific “Forest Area Indicator” is ready for implementation, mainly based on quantitative data (trend of forest area, considering forest types), but for a proper understanding and evaluation it needs to be complemented by a qualitative indicator, taking into account status and trends of key characteristics of forest ecosystems, a “Forest Status Indicator (FSI)”. Development of FSI is based on detailed collection of available meta-data and
harmonised methods (EU Forest Focus and UN-ECE ICPs, National Forest Inventories, Natura2000 National Reports, MCPFE Reports, etc.). It will consist of a synthesis from surrogate measures (sub-indicators) for biodiversity (tree condition, deadwood amount and type, plant species composition, etc.) per forest type in Europe, with the aim to evaluate results provided by the Forest Area Indicator, taking into account concepts like quality, functionality and integrity of forest ecosystems. It will be based on sub-indicators identified at pan-European level (4th Ministerial Conference on the Protection of Forests in Europe, MCPFE) and implemented at pan-European (EU Forest Focus and UN-ECE ICP Forests) and National level (NFIs) as follows: (a) EU Forest Focus and UN-ECE ICP Forests Level I: tree condition data on c. 3000 points, since 1985 (continuously for 20 years); forest structure, deadwood and plant species composition on c. 6000 points, since 2007 (pilot project BioSoil); (b) EU Forest Focus and UN-ECE ICP Forests Level II: tree condition data on c. 700 plots and plant species composition on c. 500 plots, since 1995 (continuously for 10 years); deadwood data on c. 100 plots, since 2006 (pilot project ForestBIOTA); (c) National Focal Points: tree species composition and deadwood data from a number of NFIs all over Europe; (d) Natura2000 National Reports: “conservation status” of a number of SCIs (47% of them including forests) all over Europe; (e) MCPFE Reports and National data: “protected forests” amount. Data will be organised according to a revised and improved version of FTBA (BEAR Forest Types for Biodiversity Assessment), recently released to EEA. FSI development meets the requirements of SEBI2010 concerning delivering data on changes in the time of some key attributes of forest ecosystems in Europe; the emphasis on the qualitative aspects of biodiversity is policy relevant for the management of the environment. Most of the data are harmonised at pan-European level; in some cases they cover a period of 20 years, according to a systematic network well representative of all Europe and are readily available from international bodies (EU and UN-ECE). There is the possibility for up- and down-scaling of data collected at Level I and Level II sites. FSI will be based on sub-indicators broadly accepted; it is very sensitive, being able to detect changes in time frames and on scales that are relevant to the decisions. It can be updated regularly, if adopted at European level, on the basis of routine monitoring programmes. The available data are consistent in space and cover most of the EEA countries. The indicator could be represented by star diagrams, including all sub-indicators/forest types/years (each diagram per each available year). Changes in the time and “distance” from target values can be easily recognised by the change in shape of the diagrams. Some examples for beech and spruce forests in Italy are given in Figure 4.

4 Indicators of Biodiversity and its Change for the “Wider Countryside”

A convincing justification for the construction of an integrated and harmonised network of LTER sites across Europe has been presented. However, this should
not exclude the contribution of further sources of biodiversity assessment over
time, particularly those that have been established for longer periods.

4.1 Limitations of Discrete, Intensively Monitored Locations

Realistically, a future integrated and harmonised pan-European LTER net-
work will achieve only relatively few locations, and these will necessarily be
small in area. The capital and maintenance costs of infrastructure and

Figure 4  Examples of star diagrams based on same sub-indicators of Forest Status
Indicator (original data for 2005, partially from refs 85 and 86).
instrumentation and the labour costs for the collection of measurements will be high, and hence will restrict the overall coverage of habitats and regions. These detailed measurements will be restricted to a relatively discrete list of habitats and species, selected for pan-European comparison (e.g. headline biodiversity indicators; EEA 2004\textsuperscript{73}). The target habitats and species will by necessity be wide-ranging rather than restricted in range or extent; neither rare nor locally abundant, respectively. Due to the demand for regular access, LTER sites may also be selected according to factors such as ease of access or willingness of land owners to agree access, culminating in a biased rather than entirely scientifically objective stratified sampling design. A disadvantage of fixed sites of relatively small area is the effects of disturbance from the regular, continuous (sometimes destructive) sampling of various plant and animal populations and physico-chemical parameters on target organisms of interest. The lack of suitable taxonomic expertise to undertake the identification of particular plant and animal taxa severely limits the potential range of organisms that can be included in LTER monitoring.

4.2 Advantages of Supplementary Monitoring in the Wider Landscape

The measurement of ecological indicators is used either to assess the condition of the environment or to reveal the cause of environmental change.\textsuperscript{74} The precise composition of such indicators is dealt with earlier, but monitoring for ecosystem or resource management often requires data collected on such indicators at specific sites. In contrast, policy decision-makers require information across broader geographical areas and the site data may not be representative of the broader state of the environment.\textsuperscript{74} The network of proposed LTER sites can only ever cover a very minor fraction of the entire European land surface. Whilst the “wider countryside” or “landscape matrix” is clearly enormously important for supporting most biodiversity, data collected on a selected taxonomic group and collected from a broad-ranging but truly random and stratified sample may be more representative of general habitat condition than LTER sites. European countries have varied numbers of pre-existing long-term environmental or ecological datasets from numerous locations in the wider countryside.\textsuperscript{75} These often represent longer-term data and illustrate trends for a different set of organisms compared with those of the relatively restricted list under surveillance at LTER sites. These sources often contribute long-term data for rare or locally abundant species within different regions, according to nature conservation status, the availability of taxonomic expertise or special interest groups. These data allow the possibility to test the broader consistency of trends recorded for one or more of the habitats and species under surveillance at LTER sites in the broader context, which is of relevance to policy makers. There is also the potential to demonstrate such consistency of trends for a different set of species and habitats across landscapes under “real” management and a range of environmental contexts.
Examples could be the monitoring of the condition of sites under the EC Habitats Directive protected sites, namely Special Areas for Conservation (SAC), which offers the possibility to include the extent and condition of key habitats and certain associated species of conservation concern. National monitoring of aquatic pollutants and invertebrates is carried out by European national environmental protection agencies in accordance with the EC Waters Directive (e.g. Harmonised Monitoring Scheme). Natural history records of special interest groups also generate inexpensive but adequate data from across the broader countryside:

- Voluntary effort recording a broad range of habitats and species, coordinated by Local Government Record Centres.
- National surveys of major charismatic wildlife groups by volunteers with professional guidance, coordinated by NGOs, e.g. BirdLife International partners in several European countries and Butterfly Conservation in the UK.

4.3 Data Sources that could Contribute to Surveillance in the Broader Landscape

The existence of inherited data, ease of access, comparability, both across countries and with data collected from the LTER, and cost-effectiveness all are major considerations for monitoring in the broader countryside. Remote sensing offers potentially full coverage for the assessment of the pattern and extent of recognisable land cover classes/broad habitats. It may be possible to lobby for greater general vegetation survey through appropriate training of farmers to undertake self-assessment of land in receipt of agri-environment incentive payments, possibly the presence or absence of target species in agricultural land. The monitoring of charismatic/special interest groups encouraged and coordinated by NGOs (e.g. birds, butterflies, moths, dragonflies and flowering plants) has been a major contributor to time-series data and data of broad geographical coverage, although only in a few European countries. Common Standards Monitoring (CSM) is used by the conservation agencies to assess whether designated sites, such as EC Habitats Directive SACs, are in “favourable condition”. There has been an increasing emphasis on monitoring the condition of designated conservation sites, including a need to underpin the relatively superficial assessments made under CSM with more detailed, scientific measurements at a sub-set of sites. English Nature conducted a pilot study for a “validation network” to provide this function. Monitoring encouraged by Local Government, such as the National Biodiversity Network in the UK (http://www.nbn.org.uk), has only been established in recent years. However, they have also greatly improved accessibility to existing data, especially for habitats and species on lists that have been agreed for the National biodiversity strategy. The ICP Forests Level II Programme monitors a wide range of variables relating to air pollution and climate and their impacts on production...
forests, although lacks any measurement of forest habitats and species. The assessment of waterways is essential because water courses integrate pollution effects in the broader landscape, e.g. land management effects, atmospheric deposition of pollutants and the potential buffering effect of soils and geology of particular river catchments. The Acid Waters Monitoring Network includes both physical and biological variables to investigate the effects of acidifying atmospheric deposition on freshwater systems and their catchments.\textsuperscript{77}

The main challenges in using data derived from the diverse sources of measurement in the broader countryside are:

- consistency in the taxonomic groups measured
- use of comparable methods
- substantial duration and overlap of time-series data
- similar frequency of recording
- availability of associated physico-chemical measurements.

The nature of the source data, collected for a particular local or national purpose, and the need for consistency in the method of measurement for a particular time-series, makes it difficult to consider any changes. Such diverse monitoring will not attain the same degree of standardisation that should be the major characteristic of monitoring under a harmonised and integrated set of measurements carried out at a European network of LTER sites. The collection of additional biodiversity data in the wider countryside may also have the additional benefit of greater relevance and proximity to more of the European public than the selected LTER sites. Hence, it may facilitate greater public understanding and appreciation of pressures on biodiversity and their consequences. This important area is explored in the next section.

5 How to Communicate Biodiversity Assessments to Stakeholders and the Public?

The results of scientific research rarely become visible to the general public or even to decision makers. This has to be changed, as good science is not enough to halt biodiversity loss; the participation of society is indispensable.\textsuperscript{78} Awareness and appreciation of biological diversity is highly dependent on the extent to which science on this matter is perceived and accepted by the public and different user groups. Effective science communication can change society’s attitude to nature itself and the services it provides.\textsuperscript{79}

The communication of biodiversity assessment is different from other types of science communication in several respects. The aim is not just to inform people on scientific achievements, but to motivate a change in their attitudes and behaviour, such as consumption patterns. To do so, people need reasoning and convincing information, and a learning process.\textsuperscript{79} Knowledge, awareness and attitudes are not enough to effect behaviour change. Emotions and moral convictions also influence actions\textsuperscript{80} and have to be taken into consideration in
the communication process. The loss of biodiversity is rarely appreciated by the public; a lack of information and data on the change is a major element. The necessary data must be derived from existing and future biodiversity assessments and monitoring programmes. Generally, the efficiency of communication of the results from these activities to users and the public needs strengthening.

The importance of science communication and awareness raising is acknowledged by several international efforts. The Convention on Biological Diversity expressed this (Article 13. Public education and awareness) at a global level. Lately the European Commission has identified the building of public education, awareness and participation for biodiversity as a supporting measure to halt the loss of biodiversity.71 Campaigns and communication programmes have to be launched and access to information has to be ensured to fulfil the requirements. Effective communication methods can support this process. This section summarises general aspects of communication and specific methods for biodiversity assessments.

5.1 General Principles

The popularisation of science should be treated as seriously as science itself. This is the basis for success, but it is generally not happening. The reward system of scientific research, where the number and impact of papers in scientific journals are considered, does not support this approach. So the first step is to put more emphasis on science communication and popularisation in the career-building of scientists. This would automatically result in an increase in respect for the audience that could help to establish a basis for trust.

Three main communication strategies exist: values-based communication, strategic-frame analysis and social marketing.80 Values-based communications analyse personal beliefs and valuation of qualities of the target audience and try to persuade by reason and motivate through emotion. Strategic-frame analysis uses cognitive sciences to identify how messages are encoded to be interpreted in relation to existing beliefs. Social marketing considers the desired activity of a product that has a price and needs promotion. All three approaches need data and information in the process to support the message. This is where biodiversity assessment results can be used in biodiversity conservation issues.

5.2 Setting Objectives

The overall aim is not just to inform people, but to motivate change in their attitudes and behaviour, which is the most difficult activity. The task is to use the main findings of biodiversity assessment and monitoring programmes as part of the communication campaign. The results of these often have implications for policy issues, so the relation between biodiversity matters and decisions or legislation represents further information that must be communicated. In most cases the objective is to raise attention and awareness by understanding the concept and the importance of biodiversity. The ultimate target of an
increasing number of campaigns is to motivate action, change behaviour and involve people in problem-solving in order to halt biodiversity loss. Biodiversity is a complex issue, hardly understood unless elements, levels and defined aspects are communicated. A focus can be put on landscape, community, species, population or genetic levels.

When setting the objectives of communication, the message to be transmitted has to be clearly defined. General messages can be: biodiversity is life; biodiversity is declining; biodiversity is vulnerable; biodiversity loss has direct implications for human life; we are all responsible; everyone can do something about it. Data and information to support the message have to be selected and used in the campaign. Message development should be based on what the intended audience values. Key messages should be positive, simple to understand, memorable, accurate and realistic.\textsuperscript{81}

5.3 Selecting the Target Audience

To influence biodiversity loss, focus is required on communication with key actors, who make decisions at a large scale. Usually emphasis is on school children, a group with no direct influence on implementation processes.\textsuperscript{79} However, their future role and influence on consumption patterns is evident. Therefore, the scope of the target audience has to be well adjusted to the aims.

The communication approach should greatly differ for different audiences as the perception of and attitude to the message largely depends on what they value. Policy makers need links to their interests in very short messages, supported by a few numbers. Other stakeholders usually need more detail, especially if the message concerns their own subject area. For other scientists the scientific approach that generated the information is of more importance. It is hard to convince the business community to support biodiversity matters, unless beneficial to the market (biodiversity “brand” used\textsuperscript{82}). Land managers and farmers are an important component of the audience because of their direct impact on land use. Social market methodology to promote sustainable agriculture turned out to be effective to bridge the existing gap between research and managers.\textsuperscript{80}

Teachers have an important role to play in distributing the message to the younger generation. They require special support for this activity. The rural population needs a different approach from that of the urban population or the general public. Families accept messages more if all members find interesting elements. Children need age-specific approaches. The main rule is that the communicator should know as much as possible about the views and attitudes of the target audience in advance.

5.4 Selection of Appropriate Tools

Three major types of tool exist: one-way, two-way or interactive methods. One-way communication means one-way information flow from the communicator
to the audience. Such tools are printed materials, web sites, CDs, posters, exhibitions, films, comics or the media. In this case very little is known about the impact of the effort. Interactive methods are always more effective, but more labour- and time-consuming. Two-way communication can be conducted by personal encounters or by written materials. Personal meetings are more effective but generally reach fewer people. Such meetings can be open days at institutes, environmental education campaigns, field visits, training programmes, practical activities, e.g. monitoring, volunteer work, nature camps, visitor-centre activities. Larger groups can be involved through the media in international days for biodiversity or nature. The coordination of master’s theses in the field of biodiversity assessment and monitoring can also contribute to awareness-raising. The use of questionnaires, internet forums and interactive software are widely used tools for two-way communication with larger audiences; however, participation might be surprisingly low. Evaluation of effectiveness should go parallel with both types of communication tools.

5.5 How to Do It?

Two main tasks can be identified during the communication process: the first is to capture the attention of the right audience; the second is to deliver an understandable and credible message that influences the beliefs of the audience. Real-life examples help to get closer to the audience and capture attention. Difficult topics within biodiversity assessment should be related to ordinary people’s lives to maintain interest. Stressing the link of natural to cultural values is a helpful option. Story-telling and dramatic examples can also be effective if appropriate for the target group. Interactive approaches or interesting questions put to the audience are also effective means. Get people involved directly in the process, listen to their views and suggestions. Reward positive behaviour rather than punish negative behaviour. To deliver the message, the use of easily understood indicators or surrogates of biodiversity can be helpful. Never compromise the scientific credibility, avoid too much technical jargon and use simple language. Enthusiasm, personality and credibility in personal contacts are essential. Instead of details, stress principal findings and implications. Adjust the language to the target audience.79 Do not over- or under-estimate the potential of communication; consider communication barriers.83

5.6 Evaluation of Success

Two types of evaluation are required: the assessment of the communication process and the estimation of the impact of the message. Evaluation of the process itself helps to improve delivery in the future. Baseline values are required before starting the project; therefore the evaluation planning must be parallel to the planning of the communication activity, and the evaluation
should be on-going throughout the programme. Bear in mind that the best indicators of success might be the more difficult data to collect. Evaluation should be associated with the main messages and depend on the audience and the tools used.

A general method is to prepare questionnaires, not exceeding two pages, for different groups. Prizes are effective at increasing the number of respondents. Open forums and interviews can provide the opportunity for people to express their opinions if they find the topic interesting. Opinions should be assessed on what people think they can do for biodiversity before and after the programme. Organisation of competitions with the help of teachers may increase attention within the target group. Feedback can be collected through voting on the internet or phone calls from the audience (for media appearance). For large campaigns statistical data (consumption patterns/daily choices) or policy responses (new legislation) can be used as indicators of effectiveness.

5.7 Case Study: Visitor Centre in Vácrátót, Hungary

An increasing number of papers and projects deal with or give advice on biodiversity communication (e.g. Goldstein, Farrior), but no references or examples exist to our knowledge which focus on biodiversity assessment. This is usually part of the communication process providing evidence for loss of biodiversity. However, here we describe a case study that includes an assessment of biodiversity.

A visitor centre is under construction at the Institute of Ecology and Botany within the botanic garden in Vácrátót (Hungary). The aim of the centre is to provide information on the role of plants in our lives and in the functioning of global processes and to raise awareness and individual responsibility. Besides explaining biodiversity loss, the exhibition will select examples of survey, monitoring and research results from the Institute, including biodiversity assessments. The target audience is the general visitor to the garden (about 50,000 people per year). This includes school and pensioner groups, families, students, i.e. all ages of different social and educational levels.

The idea of biodiversity loss is symbolised by a balloon of the globe with a basket full of people and with sacks hanging down from the basket that represent pressures, like habitat loss, biological invasion, etc. Each sack – pressure – is detailed separately with examples and research results (see Figure 5). The National Habitat Map Database will be used to demonstrate fragmentation of habitats. Temporal changes are visible with the help of historic habitat reconstructions in the form of map series from the eighteenth century onwards.

The loss of natural habitats and their patterns are similar to old codex pages that lack certain parts of the paintings and text. This approach provides the opportunity to mention restoration methodologies for habitats and codex pages as well. Surveys on invasive plants represent species level assessments. Guidance on how to use the knowledge in everyday life will be presented.
6 Conclusions

The assessment of biodiversity status and trends is today an established component of environmental observation and monitoring programmes, performed from regional to global scales. Although the term biodiversity expresses a very complex phenomenon – the “overall richness of life on earth” – which has to be referred to at different hierarchical levels, we have demonstrated that there are adequate means and methods available to describe and quantify it. In particular, numerical indices that summarise the diversity and evenness of species distributions, environmental surrogates of biodiversity, indicator species, combined and aggregated indicators (which may comprise both species- and habitat-level information) are available and have proved useful in particular instances of the assessment of biodiversity. A substantial body of scientific literature describes the limitations, biases and pitfalls of the various measures. In practice, most assessments of biodiversity rely on the simplest and most intuitive method, consisting of species counts and abundance estimates.
Long-Term Ecological Research sites are crucially important “test laboratories” to develop and apply methods for the assessment of biodiversity. LTER sites offer the best possibility to integrate the analysis of abiotic and biotic data with the objective of identifying the relative importance of pollution or climate as drivers of change. Networking such sites across Europe and up to the global scale will reinforce and increase the certainty of such results. Our case study of the Italian LTER demonstrates the usefulness of combining continued (long-term) observation with a network of sites covering the key ecosystem types within a country or region. With this observation approach, it is possible to detect patterns which would not emerge on the basis of less intensive or temporally less-extended observation.

However, LTER sites themselves cover only a very small part of the overall landscape supporting biodiversity, and they have a bias to natural or near-natural ecosystems. It is also important to have reliable information on biodiversity status in the wider countryside. Information obtained from remote sensing offers great potential here and several processes and programmes support biodiversity assessment in the wider countryside, most importantly at the European scale the monitoring of the condition of sites under the EC Habitats Directive.

Finally, understanding and appreciation of biological diversity is highly dependent on successful science communication. We have demonstrated here that approaches must duly consider the different user groups involved. Visitor centres with a high degree of interactive exploration can be a successful means of communicating the science examining biodiversity.

References

42. A. Shmida and M. V. Wilson, *J. Biogeogr.*, 1985, 12, 1–21.


