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Salient Points on the Assessment and Monitoring of Forest Biodiversity

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ABSTRACT

A general analysis and overview of forest biodiversity is presented. Some important current topics will also strengthen the overall overview of assessment and monitoring of biodiversity. Emphasis has been given to the three main components related to biodiversity. Analysis, assessment and monitoring of forest biodiversity have been presented. A list of processes generating and maintaining biodiversity have been presented as well. Main key factors and indicators of forest biodiversity have been described. Silvicultural and management treatments creating disturbances and mimicking natural processes are highly important for preserving high quality of forest biodiversity. Management of biological diversity (including genetic diversity) has also been highlighted as an important part of silviculture and forest management. Finally, some important concluding remarks have been presented.

Keywords: biodiversity, ecosystem, forest, forest management, indicator

CONTENTS

DEFINING BIODIVERSITY

Biodiversity is composed of the total biological variation, ranging from within-species genetic variation, through species, communities, and landscapes (CBD 1992; Spanos and Feest 2007). Genetic diversity is the raw material from which all other aspects of biodiversity are built. The ecosystems in which genetic diversity resides are rarely at a stable status, are open to exchange of materials and energy with the surrounding environment and are influenced by periodic biotic and abiotic disturbances affecting their internal structure and function. The cellular basis of diversity is difficult to observe directly, and this variation complicates the assessment of genetic diversity in populations (Mullin and Bertrand 1998).

Environmental factors (e.g. climatic or edaphic), genetic diversity and competition among species, along with other biotic and abiotic factors are important elements of biodiversity. Three main components of forest biodiversity have been widely recognised (Huston 1979; Franklin 1988; Noss 1990; Perry 1994; Spies 1997; Larsson 2001; Spanos *et al.* 2006): composition, structure and function. These three components have been used as a basis to identify key factors and develop indicators for forest biodiversity.

Biodiversity is not a fixed term (despite the widespread use of the Convention on Biological Diversity (CBD definition where the operative word "variability" is not defined) and it is rather complicated in definition (but see below for a useful working definition?), it is not a standard status but rather a dynamic cluster of components, functions and human impacts (Spanos *et al.* 2006). Kaennel Dobbertin (2001) for example lists more than 17 different definitions for forest biodiversity. Biodiversity levels can change periodically (fast/slow) due to catastrophic natural processes, long-term ecosystem evolution and human activities. Therefore, in many cases it is better to talk about biodiversity dynamics and the monitoring should take into account this dynamic status by reference to baseline measurements. Monitoring of biological diversity is not only the recording of the reduction/increase of the rating levels of the study indicators but also includes the dynamic status of biotic and abiotic components and functions/processes and their relation with the human activities (including cultural components) should always be considered (Spanos and Feest 2007). Man has been born in and lived for millions of years with the nature, and being a part of the nature has deve-

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loped strong relations with the mother earth (scientific, cultural and religious aspects).

Feest (2006) introduced the concept of biodiversity as a quality described by the balance of a variety of measured properties that then allowed a more precise statistical analysis of change. Feest (2006) gives seven different indices that can be calculated from well surveyed data and it is the relative balance of these that indicates the characteristics of the biodiversity quality and can be used to compare sites temporarily and comparatively. In this way baseline indices can also be set for further reference. In a scenario of attempting to halt the loss of biodiversity, the establishment of baselines in this way allows change and its degree of significance to be measured. This seems to answer some of the problems related to the use of biodiversity as a concept as indicated above.

ANALYSIS, ASSESSMENT AND MONITORING OF FOREST BIODIVERSITY

Processes generating and maintaining biodiversity

The main processes generating and maintaining biodiversity are described as follows (Hansson 1997; Angelstam 1998a, 1998b; Larsson 2001; Spanos *et al.* 2006; Spanos and Feest 2007):

1. Natural disturbance regimes

Disturbance is a key process affecting natural forest ecosystems. Disturbance agents may be endogenous and/or exogenous, caused by biotic and/or abiotic agents/factors, and may cover a broad range of temporal and spatial scales (Angelstam 1998b). Disturbance is the driving force for forest dynamics and regeneration initiating structural changes, microclimate variation, secondary succession and creating habitat diversity. Disturbance of random and periodic occurrence is known to maintain high species richness and productivity and limit competitive exclusion (Huston 1979). The maintenance and restoration of the full range of natural habitats, disturbance regimes, tree and keystone species, successional stages, stand size diversity and certain processes found or occurring in natural ecosystems are therefore very important to biodiversity (Hunter 1990; Angelstam 1997).

2. Dispersal/migration

The dispersal and migration of species determines the future ecosystem composition and pattern (Hart and Clark 1997; Lowe *et al.* 2001). Human activities may cause changes in the landscape pattern (e.g. fragmentation) and can influence migration and dispersal and hence alter the pattern of gene flow causing genetic impacts. The effects of fragmentation vary widely from species to species and from habitat to habitat.

3. Reproduction and reproductive biology

The reproduction process determines the future ecosystem composition. Differences in reproductive biology (gender effects, pollination and fertilisation systems) and impacts on the process of reproduction (increased selfing and poor seed production as a result of habitat fragmentation) can result in rapid, direct and dramatic changes on biodiversity (Larsson 2001; Lowe *et al.* 2001; FRAXIGEN 2005). In the case of species with short generation periods, non-overlapping generations, or highly specific mutualisms, changes can be devastating (e.g. habitat loss, even-aged forests susceptible to insect/fungal attacks or fires).

4. Regeneration/succession

Spatial (gap-phase) dynamics promote successional diversity and determine the natural patterns of ecosystem dynamics. Natural regeneration by seed or the vegetative spreading of clones (e.g. *Tilia* trees in the UK hardly ever seed but spread – very slowly – by suckers or layering; root sprouting of *Populus termula* in Greece) is a fundamental aspect of sustainability. After disturbances (e.g. felling, windthrowing, wild fires) seral communities develop in different stages (e.g. replacement of parts of mature forest stands by communities dominated by pioneer or early successional species). Silvicultural management regimes that alter ecosystem parameters beyond a critical limit can cause permanent changes to the ecosystem, leading to an arrested climax. Therefore, the preservation of biodiversity in forest ecosystems requires all successional stages to be maintained (Franklin 1988).

5. Trophic dynamics

Refers to processes in which species from different trophic levels interact, including predation and herbivory. Each trophic level is dependent on other levels, and therefore impacts on trophic dynamics can seriously affect ecosystem functioning. The role of fungi in cycling nutrients either as saprotrophs or mycorrhiza is of critical importance despite their largely cryptic nature. Many forest biodiversity assessments fail to include the role of fungi. The macrofungal fruit-bodies are a significant source of nutrition and create a specialized habitat in most woodlands (Feest 2006; Spanos and Feest 2007).

6. Ecosystem processes

A full operational set of ecosystem processes is essential for ecosystem functioning and stability. Such processes include photosynthesis, nutrient and hydrological cycles, dynamic aspects of food webs, succession, evolution, migration, and disturbance across landscapes. The keystone role of fungi in ecosystems is usually missed. For example we know that ectomycorrhizal fungi control soil moisture in forest soils and through this the saprotrophic fungal wood decomposition and thus (control) decomposition and nutrient cycling (Koide and Wu 2003). Removal of disturbance or other processes reduces the ability of an ecosystem to function efficiently.

7. Local extinction - loss of genetic diversity

Local extinction refers to the disappearance of a population or metapopulation (Larsson 2001; Lowe *et al.* 2004). It is a process (rather than an event) and today is mainly caused by rapid human-induced environmental changes (Angelstam 1998a, 1998b). It results in elimination of species populations that potentially contribute to ecosystem functioning. Populations with very low or critical sizes (N_e) become vulnerable to extinction because of both demographic and genetic factors, leading to inbreeding depression and loss of genetic diversity (Hart and Clark 1997; Lowe *et. al.* 2001; FRAXIGEN 2005) although some species seem to specialise in being rare (e.g. Eagle Owls). The population size necessary to maintain viable populations varies widely, depending upon species (different reproductive biology) and environment. Preserving a sufficient number of individuals of a given species requires an adequate habitat size to be maintained, including all ecosystem components on which the species depends (directly or indirectly) (Perry 1994). Loss of keystone species can have cascade effects (i.e. leads to the loss of other species or the disruption of processes) (Larsson 2001; Lowe *et al*. 2001; Dimopoulos *et al.* 2005; Spanos *et al.* 2006).

Key factors of forest biodiversity

Important parameters (such as stand age, wood volume, species number, soil microbial activity) of biodiversity may be defined as key factors that influence (directly or indirectly) the biological diversity within forest ecosystems. The main key factors can be categorized according to the different ecosystem components (as described previously) as follows (Angelstam 1997; Larsson 2001; Spanos and Feest 2007): a) structural (physical characteristics), b) compositional (the biological component), and c) functional (biotic/abiotic disturbance factors and management). Compositional and structural factors determine and constitute the biodiversity quality of an ecosystem (Noss 1990; Feest 2006), and are essential for productivity and ecosystem sustainability. Functional factors (i.e. the functions performed by different species, evapo-transpiration, soil microbiology, etc.) contribute to ecological integrity (Gaston 1998; Hansson 1998).

Development of indicators for biodiversity assessment and monitoring

A review of the concept of biodiversity indicators and methodology development is presented in this section. An indicator may be a species, a group of species (e.g. butterflies, macrofungi, lichens, bryophytes), a structural component (e.g. dead wood) or a process of a biological system (e.g. photosynthesis, evapo-transpiration), the occurrence of which insures the maintenance of the most important aspects of biodiversity (Hansson 1998; Spanos *et al.* 2006; Spanos and Feest 2007). They may be based on socio-economic factors that recognize the dominant influence of human activity in many ecosystems. Indicators can provide useful information on the status of and trends in biodiversity. When measured, they can demonstrate ecological trends and assess the state or quality of an ecosystem. Indicators can be quantitative or qualitative.

A good indicator should be (Noss 1990; Feest 2006; Spanos and Feest 2007):

- Validated to be relevant to ecologically significant phenomena (e.g. species indicating early succession, species indicating ecosystem maturity).
- Able to differentiate between natural cycles and/or trends and those induced by human pressure (e.g. soil organic matter, microbial activity).
- Capable of providing a continuous assessment over a wide range of stress (e.g. species resistant to drought, species indicated acidity).
- Sufficiently sensitive to provide an early warning of changes (e.g. presence and abundance of particular lichens or bryophytes sensitive to air pollution/acid rain).
- Distributed over a broad geographical area (widely applicable) (e.g. soil acidity, nitrogen deposition).
- Easy and cost effective to measure, collect, assay and calculate (e.g. number and frequency of macrofungi).

The Convention on Biological Diversity Decision IV/1 and Recommendation III/5 (Handbook of the Convention on Biological Diversity) set the overall target in setting indicators that they should address matters such as (CBD 1992; Feest 2006; Spanos and Feest 2007):

- the way indicators relate to management questions;
- the ability to show trends;
- the ability to distinguish between natural and human-induced change;
- the ability to provide reliable results (i.e. through the establishment of standard methodologies and validation processes);
- the degree to which indicators can straightforward interpretation;
- the question of baselines for measurement, in the light of the fact that the application of a pre-industrial baseline may often prove problematic as might be expected in the definition of “good ecological status” in the EU Water Framework Directive.

Indicators can therefore be individual species or groups of species (CBD 1992; Larsson 2001; Dimopoulos *et al.* 2005; Spanos *et al.* 2006; Feest 2006; Spanos and Feest 2007) or socio-economic factors. Biodiversity indicators can be chosen and developed in two ways:

1) Indicators can be based on parameters (e.g. bird species richness, tree species richness) of a particular component of biodiversity. The indicator to be chosen depends upon many factors but there should be a correlation between the indicator and the component of biodiversity (examples of butterfly and bird trends can be found in SEBI indicators referenced as follows: EEA Report: No 4/2009 Progress towards the European 2010 biodiversity target p. 17-21. ISSN 1725-9177, EEA Copenhagen, Denmark). Indicators usually measure species diversity (Gaston 1996; McGeoch and Chown 1998). These indicators are most commonly developed by counting the number of plant or animal species which exist in a particular area (species richness), or additionally, by their relative abundance and evenness as a part of a diversity index (species diversity as measured by the Shannon-Wiener, Simpson or Berger-Parker Indices, etc.). Data collected in a structured sampling process (e.g. Pollard and Yates 1993) can be used to add far more information when subjected to a statistical assessment (Feest 2006).

2) The second way of developing of biodiversity indicators is based on the assumption that, in the forest context, biodiversity depends upon structure of stands and landscapes, the species and the management and disturbance regimes. As a consequence, biodiversity indicators may be developed from the analysis of key factors affecting biodiversity (Larsson 2001; Spanos and Feest 2007). Thus, an indicator based on key factors of biodiversity may be as before: a) structural (total wood volume and dead wood), b) compositional (species, etc.), and c) functional (management or disturbance). These factors in turn are often the consequence of human socio-economic activities and these latter activities can therefore presumably function also as indicators albeit somewhat remote.

Structural indicators: It is known that a more complex ecosystem will support a greater variety of species. Forest trees and stand structure have major impacts on other components of the forest ecosystem (e.g. birds, mosses, lichens, insects). Stand structure, the dynamics and development of forest stands, can play a key role in the development of biodiversity indicators in forest ecosystems (undisturbed and managed). Structural changes for example may increase ecosystem’s susceptibility to various disturbances and encourage the loss of native species through the establishment of invasive species. Canopy structure controls the quantity, quality, spatial and temporal distribution of light, precipitation and air movement. All these factors combined, determine air humidity, temperature and soil moisture (Jennings *et al.* 1999), which ultimately influence the microclimatic suitability of particular flora and fauna and the adaptation to climatic changes (Spanos and Feest 2007). The structural component of amount of dead wood in forest ecosystems has a major influence on biodiversity in temperate ecosystems for some of which this component may rival the living in terms of mass (Humphrey *et al.* 2003; Petrakis 2007; Daskalakou *et al.* 2009). The rapid decomposition of most tropical ecosystems removes this component as a major source of biodiversity.

Compositional indicators: Compositional indicators are usually empirical indicators. However, a functional relation may exist as most species depend (at least to some extent) upon the presence of other species. For example, tree diversity is a key factor affecting the diversity of many other taxa, and therefore, can be used as an indicator of biodiversity (Hansson 2000; Spanos *et al.* 2006).

Functional indicators: For evaluation and assessment of different scales of biodiversity in a forest ecosystem, an

Table 1 Proposed list of 26 biodiversity indicators as described by the EEA (European Environmental Agency, Technical report 11/2007).

Biodiversity indicator	Indicator applicability to forestry
1. Abundance and distribution of selected species	✓ [a]
2. Red List Index for European species	✓
3. Species of European interest	✓
4. Ecosystem coverage	✓
5. Habitats of European interest	✓
6. Livestock genetic diversity	0 [c]
7. Nationally designated protected areas	✓
8. Sites designated under EU Habitats and Birds Directives	✓
9. Critical load exceedence for nitrogen	✓
10. Invasive alien species	✓
11. Occurrence of temperature sensitive species	✓
12. Marine trophic index of European seas	0
13. Fragmentation of natural and semi-natural areas	✓
14. Fragmentation of river systems	0
15. Nutrients in transitional, coastal and marine waters	0
16. Freshwater quality	0
17. Forest growing stock, increment and fellings	✓✓ [b]
18. Forest: deadwood	✓✓
19. Agriculture: nitrogen balance	0
20. Agriculture: area with biodiversity friendly management	0
21. Fisheries: European commercial fish stocks	0
22. Aquaculture: effluent quality from finfish farms	0
23. Ecological footprint of European countries	? [d]
24. Patent applications based on genetic resources	0
25. Financing biodiversity management	?
26. Public awareness	?

[a] ✓ Applicable to forestry biodiversity
[b] ✓✓ Directly related to forest biodiversity
[c] 0 Not related to forest biodiversity
[d] ? Connection with biodiversity tenuous

integrated approach is required that includes, apart from species abundance, also their functions, size, spatial distribution and other information. Indicators of function or process (e.g. decomposition, evapo-transpiration, etc.) are particularly valuable when assessing biodiversity in full sense. For example measurement of the biodiversity quality of macrofungi would indicate the status of either the mycorrhizal symbiosis or decomposition (Koide and Wu 2003) depending on the predilections of the individual species (see Feest, 2006 for an example).

The European Environment Agency in response to calls to halt the loss of biodiversity by 2010 has produced a candidate list of indicators many of which are socio-economic and also applicable to the forestry. **Table 1** lists these indicators and suggests those that are applicable to forestry.

Examples of widely used compositional biodiversity indicators expressed as measurable indices are the following (Magurran 1988; Rosenzweig 1995; Begon *et al.* 1996; Spanos and Feest 2007):

A) Simpson's Diversity index (Magurran 1998): It is often used to quantify the biodiversity of a habitat. The index takes into account the number of species present and the abundance of each species as well and is a measurement of evenness.

B) Shannon-Wiener's H and E Diversity indices (Magurran 1998): The Shannon index (H) is commonly used to characterize species diversity in a community. Like Simpson's index, it accounts for both abundance and evenness of the species present.

C) Berger-Parker Dominance Index (Magurran 1998): It is very easy to calculate and is an expression of the dominance of the most common species.

Since the publication of the above commonly used indices other indices have been developed that add further information such as biomass, population and valuation of organism conservation interest (see Feest 2006; Spanos and Feest 2007).

FOREST MANAGEMENT, SILVICULTURE AND BIOLOGICAL DIVERSITY

Management of genetic diversity

Management of genetic diversity (an important issue of applied silviculture) is an essential component of the forest management practice (Andersson *et al.* 1997a, 1997b; Spanos and Andersson 1997; Andersson *et al.* 1998; Mullin and Bertrand 1998) since: a) it can provide continuing ecological and economic values, b) can conserve the capacity of forests to adapt to changing environmental pressures, and c) can be a source of valuable genetic material for forest tree breeding and further utilization. Three approaches can be used to evaluate genetic diversity at the individual and population levels: (1) biochemical/molecular methods to assess allelic variation (e.g. use of isozymes or DNA markers to assess genetic diversity and inbreeding), (2) quantitative analysis of variation in metric traits (e.g., use of morphological characters to calculate inter- and intra-population diversity and heritability of traits), and (3) effective population size (N_e), based on relatedness of genes, individuals and groups (e.g., to study population genetics – diversity level and inbreeding). Within populations, evolution maintains and adapts genetic diversity through five processes (Hartl and Clark 1997; Mullin and Bertrand 1998; Lowe *et al.* 2004): (1) selection, (2) mutation, (3) migration, (4) genetic drift, and (5) mating system (reproductive biology). Gene frequencies can change by the first four mentioned processes, while mating system can change only genotypic frequencies.

Reproductive biology and genetic diversity of trees in forest ecosystems

The reproduction process determines the future ecosystem composition. Differences in reproductive biology (gender effects, pollination and fertilization systems) and impacts on the process of reproduction (increased selfing and poor seed production – such as in very small and isolated populations of coniferous species, e.g. *Cedrus* spp.) can result in rapid, direct and dramatic changes on biodiversity (Larsson 2001; Lowe *et al.* 2001; FRAXIGEN 2005; Spanos and Feest 2007). In the case of species with short generation periods, non-overlapping generations, or highly specific mutualisms, changes can be devastating (e.g. habitat loss, young even-aged forests susceptible to insect/fungal attacks or wild fires). Reproductive biology processes (flowering, sex development, pollination, fertilization) are ultimately responsible for how gametes are formed and united within a population, and tree species vary highly in this respect (FRAXIGEN 2005; Verdu *et al.* 2007). Temperate and boreal forest trees typically have mechanisms (e.g. type of flowers, receptivity, timing) that promote outcrossing, highly effective gene flow, and high heterozygosity. This allows them to carry a large genetic load of deleterious alleles that are expressed under inbreeding conditions (e.g. increased selfing/homozygosity) and result in inbreeding depression. On the other hand, some other plant species have been adapted to natural hazards and environmental/ climatic stresses through alternative regeneration systems (e.g. resprouting - oaks) or through increased selfing (high inbreeding – herbal species) (Hartl and Clark 1989; Lowe *et al.* 2001).

Almost any silvicultural or management system will have some kind of impact on the way evolutionary processes operate in the management of genetic diversity through changes in population structure and size, soil conditions and regeneration system (Murphy *et al.* 1991; Halpern and Spies 1995; FRAXIGEN 2005; Spanos and Feest 2007). In assessing the potential impact on forest tree populations, it is important to assess the ways that silvicultural activities affect each of the evolutionary processes. Further research should focus on: (1) identifying priority or rare/ threatened species (e.g. *Quercus* spp., *Ulmus* ssp., *Castanea sativa*, *Prunus* ssp., *Populus nigra*, *Sorbus* spp., *Acer* spp. – valuable noble hardwoods, *Abies* spp, *Sorbus torminalis* – threatened species) and populations (e.g. geographically isolated, soil dependent, marginal at distribution range) where efforts should be concentrated on conservation of genetic resources (*in situ/ex situ*), (2) effects of natural and human disturbance on the evolutionary forces acting in forest ecosystems, and (3) development of better assessing/ modeling methods overtime. Throughout the forest management process, it is less important to focus on preservation of rare alleles, but essential to enhance methods close to natural conditions for adaptation (particularly under climate change) and future evolution of the populations (Lowe *et al.* 2004; FRAXIGEN 2005).

Forest management activities and evolutionary processes

It is clear that forest management activities (e.g. harvesting, thinning, regeneration system) have an impact on evolutionary processes operating in forest ecosystems (e.g. compare seedling forests to coppice forests). Gap-phase dynamics (e.g. case of high forest with shelter-wood cuttings or group selection cuttings) promote successional diversity and determine the natural patterns of ecosystem dynamics. Natural regeneration by seed (e.g. most conifers) or the vegetative spreading of clones (e.g. *Tilia*, *Salix*, *Populus*, *Ilex aquifolium*, *Prunus avium*, *Ulmus*) is a fundamental aspect of sustainability. After disturbances (e.g. felling, wind-throwing) seral communities develop in different stages (e.g. replacement of parts of mature forest stands by communities dominated by pioneer or early successional species). Silvicultural management regimes that alter ecosystem parameters beyond a critical limit can cause permanent changes to the ecosystem (e.g. cases of coppiced forests, frequently burned bush-lands), leading to an arrested climax (Spanos *et al.* 2006; Spanos and Feest 2007). Therefore, the preservation of biodiversity in forest ecosystems requires all successional stages to be maintained (Franklin 1988; Spanos and Feest 2007) thus prolonging the mature and overmature phases of the keystone species is highly important. Mature and old grown forest stands represent a more natural ecosystem state for forests and as such, therefore, preserve a high biodiversity quality (e.g. woodpeckers, rich lichen/ bryophyte/fungal diversity, rare insects, ground flora) that to some extent reflect that of primeval forests (Petrakis 2007; Daskalakou *et al.* 2009). Within these ancient woodlands many species are those requiring special conditions such as very rotten wood, wet rot holes, ample deadwood, environmental stability, short distance propagule distribution (primeval forests will have been more or less continuous). As a result of these properties, primeval and old grown forests harbour many insect taxa which may include either common or rare species (Topp *et al.* 2006) including important bioindicators. Saproxylic insects and insects inhabiting tree hollows predominate and have been extensively sampled by many authors (Ranius *et al.* 2005; Topp *et al.* 2006; Alinvi *et al.* 2007; Petrakis 2007). The characteristics of ancient woodland that are very difficult to reproduce such as those above and for example continuity of habitat, long-standing mycorrhizal association, specific plants and a rich snail fauna mean that once lost they cannot be replaced (Read and Frater 1999; Rackham 2003; Petrakis 2007).

Silviculture, forest management and genetic diversity

The fact that a silvicultural treatment creates a disturbance is not the reason to consider that a negative impact on genetic resources will result. Indeed, most temperate and boreal tree species are highly dependent on disturbances (e.g. fire, flooding, wind, snow, decay) to maintain healthy and variable ecosystems (Namkoong and Bishir 1989; Hunter 1990; Spanos and Feest 2007). What then should be the objective of sustainable forest management for preserving genetic diversity? Should the management be directed to preserve rare alleles existing within populations (possibly for their future economic value) or for adaptation to local conditions and changing environments (including environmental pollution and global warming)? It is known that many discussions of genetic variation in tree populations focus on the loss of rare alleles, but it must be emphasized that it is impossible even for nature to preserve all existing genetic variation and therefore losses will inevitably occur as the population regenerates and evolutes (Hartl and Clark 1989; Namkoong 1991; Mullin and Bertrand 1998). Furthermore, populations respond to selection by substituting alleles that have additive effects, and the greatest response is caused by alleles that are neither very rare, nor very common (Eriksson *et al.* 1995; Mullin and Bertrand 1998). It has been emphasized that ecosystems are dynamic, and it follows that the objective for management of genetic resources should not be to preserve rare alleles/genes, but rather to favor methods close to nature conditions for future evolution of genetic resources (Eriksson *et al.* 1995) and to preserve viable population sizes (N_e) (Andersson *et al.* 1997a, 1997b; Spanos and Andersson 1997; Andersson *et al.* 1998; Mullin and Bertrand 1998). Equally important is the conservation of genetic resources of non-commercial taxa (flora and fauna) with emphasis on rare and threatened ones (e.g. bushy species, important herbal taxa, macro-fungi, rare insects), for which habitat conditions must be maintained under sustainable forest management to serve the multi-functional services (Feest 2006; Petrakis 2007; Spanos and Feest 2007).

CONCLUDING REMARKS

Objectives of monitoring: An important strategy when monitoring forest biodiversity is the objectives of monitoring. A well-defined monitoring of biodiversity needs a well planned methodology and defined objectives. Why we monitor biodiversity in natural ecosystems and compare to that in agroforestry systems and also to that in urban environments? Different ecosystems/systems require different monitoring objectives (scientific, environmental, economic). Well defined objectives of biodiversity monitoring will save time, will be relatively cost effective and will give scientifically based answers to policy and decision makers (Tucker *et al.* 2005).

Evolution and biodiversity: Evolutionary factors and processes (gene flow, mutations, immigration, environmental changes, catastrophic events) are in continuous change and can strongly affect biodiversity levels. In the long history of life on the Earth, many species have been lost and new species have developed. Evolutionary factors and processes may increase or reduce biodiversity, and therefore in many cases loss of biodiversity might be due to such factors/processes. Biodiversity monitoring should always consider the history of the ecosystems/systems and the possible future evolution (dynamics, succession, environmental changes, human activities).

Genetic diversity monitoring: Genetic diversity (species, sub-species/races, varieties, genotypes) and genomic diversity (genome) is the material upon which all other forms of biological diversity are built. Intra-specific genetic diversity (calculated as heterozygosity levels, allele frequencies, relatedness) and the factors/processes affecting it (pollen flow, seed dispersal, reproductive biology including sex ratio, pollination, mating system and incompatibility, inbreeding and genetic drift) are possible to estimate/monitor in natural ecosystems and human made or affected systems. Genetic and gene diversity is not a stable status but rather represent a dynamic status. It is important in monitoring biodiversity always to start from the study/monitoring of genetic diversity. We know that the number of species is an important indicator in evaluating biological biodiversity, but is important to know the intra-specific genetic variation too. Many subspecies/races, varieties or genotypes locally adapted to different environments, covering a wide range of uses, have been lost or have been substituted by a few commercial varieties or clones (narrow genetic base) (e.g. substitution of lowland riparian natural ecosystems by poplar, eucalyptus or *Robinia* plantations). It is known that loss of some part of genetic diversity will inevitably be lost, but sustainable management of biological resources with close to nature management actions will preserve most of the existing diversity.

Biodiversity and human activities: Biodiversity monitoring is urgently needed in natural and managed (including plantations) ecosystems, which are much affected by human activities (air and water pollution, climatic changes, global warming, including war impacts). In such cases monitoring of biodiversity seems rather easy due to large differences in the indicator-levels. However, it is highly important when these systems are compared (using various indicators- emphasis given on micro-flora and micro-fauna) with the close to natural or less affected ecosystems (for monitoring biodiversity levels). Such a well-defined comparison (based on biodiversity quality assessment – see Feest 2006; Spanos and Feest 2007) will give scientifically based information on the negative impacts of human activities on biological diversity.

Economics of monitoring: From the practical, scientific and realistic point of view, biodiversity monitoring should be well planned and be applied to specific sites/ecosystems defined by the objectives of monitoring. It is not possible to monitor all natural ecosystems/habitats and all agroforestry and urban/peri-urban systems. It is more advisable to establish a net of experimental plots representing different cases. A well-defined strategy, planning and methodology with widespread experimental plots, statistically designed and determined, will be much more useful and cost effective (see Feest 2006). Additionally, such a strategy of monitoring will be much easily passed to the policy and decision makers.

Biodiversity and National/International policy: It is the duty of scientists working on biodiversity to highlight and pass their knowledge and scientific conclusions to the responsible policy makers and politicians (at national and international levels). We know that for decision and policy makers it is worthy to relate biodiversity with the human activities and man's life. Monitoring of biodiversity should always be based on a sustainable development, giving the first priority on quality of human life.

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