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The Austrian Forest Biodiversity Index: All in one

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ABSTRACT

Forest biodiversity cannot be measured and monitored directly. Indicators are needed to tackle this task and must be based on scientifically valid relationships concerning different levels of biodiversity. In addition, indicators must provide tangible goals for forest policy and other relevant stakeholders. Here, we propose a single aggregated measure – the Austrian Forest Biodiversity Index (AFBI) – which is composed of different indicator values being weighed depending on their significance for the maintenance of forest species richness and genetic diversity. The AFBI consists of nine state and four response indicators. Selection of state indicators was based on the general hypothesis that forests which mimic natural conditions or are characterised by structural elements of old-growth forests maintain a high number of forest dependent species and a high genetic richness therein. Among the response indicators we considered the establishment of natural forest reserves, genetic reserve forests, seed stands and seed orchards as most relevant. Proposed operational tools, especially for state indicators, are mainly based on the Austrian forest inventory. The sum of all weighted indicator measures is rescaled as a total score that may vary from 0 to 100, so that the AFBI is simple to communicate and straightforward to apply. The AFBI gives certain weight to genetic parameters which are often neglected in previous approaches.

1. Introduction

Conservation of biodiversity is an important issue of the environmental policy in Europe. Presently, the most urgent task is the "2010 biodiversity target" (Balmford et al., 2005), which aims at halting the loss of biodiversity at all levels by the year 2010. Assessment of the status of biodiversity requires both suitable indicators and suitable monitoring. Evidently, such an assessment is a great challenge both for science and policy (Mace and Baillie, 2007). Many national and international governmental and non-governmental organisations promote biodiversity indicators in the context of global as well as pan-European processes and initiatives. Sound basic data on the status of forest biodiversity can be derived from national monitoring programs (Puumalainen et al., 2003).

Austria signed the Convention on Biological Diversity (CBD) in 1992 and ratified it in 1994. Consequently, in 2004 a conceptual project, called "MOBI-e" (Monitoring, Biodiversität, Entwicklung) was initiated by the Federal Ministry of Agriculture, Forestry, Environment and Water Management (Bogner and Holzner, 2006). MOBI-e is expected to provide a set of indicators for assessing the state and trends of biodiversity in Austria and to fulfill the reporting requirements/obligations to the EU, particularly with reference to the "2010 target". The MOBI-e project team consisted of five expert groups participating in eight workshops. Additionally an advisory board consisting of 43 persons from the Federal Ministry of Agriculture, Forestry, Environment and Water Management, Federal State Governments, governmental and non-governmental agencies, universities and research organisations was implemented to review the outcomes of these workshops. Experts of the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) were assigned to develop and propose indicators – on condition to consider the ongoing international indicator finding processes – to be used in the forestry sector.

The present paper reports on indicators of biodiversity in Austrian forests in the fields of management, game impact, fragmentation, conservation and genetics for use by policy makers and other relevant stakeholders including strategic planners. We propose an Austrian Forest Biodiversity Index by making the resulting data as useful as possible to both science and policy. Since the decline of genetic diversity is recognized as a major threat to long term conservation of all forms of organisms (Geburek and Konrad, 2008) we give – as an innovative element in biodiversity monitoring – certain weight to genetic parameters. We are well aware that our proposed index has not been used in practice since not all necessary data have been made available yet. Therefore, this

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paper is primarily intended to define baselines and targets that may help to convince policy makers implementing this index and to stimulate international discussion in this field. However, this proposal is neither intended to evaluate sustainability of multi-functional forestry nor to comprehensively survey the existing literature and review the current state of existing indicator processes because that task would go far beyond the scope of this paper.

2. Background

Many indicators have been proposed to assess sustainable forest management including its influence on biodiversity at different levels (Noss, 1999; Lindenmayer et al., 2000; Gough et al., 2008). While for political reasons a harmonized approach seems to be needed at the European level (Delbaere, 2004), political belief systems, government structures, available inventory systems among many other reasons ask for country specific solutions in order to create an adequate domestic monitoring programme (cf. Hagan and Whitman, 2006; Geburek and Konrad, 2008). Such monitoring is a great challenge and requires a large amount of coordinated efforts at different levels with broad stakeholder involvement in the development of objectives and implementation. From a conservation perspective, the key issue regarding forest management is not primarily what has caused the decline in biodiversity, but to find the most effective remedy for it (Nichols and Williams, 2006). A targeted monitoring approach designed and based on scientifically sound *a priori* hypotheses should meet both the objectives of forest policy makers and conservation practitioners (Lindenmayer et al., 2006).

Indicators are tools to assess key factors of forest biodiversity. We define an indicator as a quantitative or qualitative parameter which can be assessed in relation to the criterion maintaining of a certain biodiversity level which should be monitored periodically (Hagan and Whitman, 2006). Here, we distinguish between state and response indicators (e.g., EEA, 1999). For state indicators, we concentrate on scientifically well elaborated and undisputed relationships between forest inhabiting species and underlying environmental factors. For response indicators, we focus on countermeasures that have been proven in the past to preserve forest biodiversity elements through active involvement of policy makers, landowners and stakeholders.

3. The Austrian Forest Biodiversity Index (AFBI)

The proposed AFBI is an aggregated index. First single indicator values are calculated ranging from 0 to 100; then each indicator is weighed depending on its relevance for the maintenance of forest biodiversity. Selection and weighing of indicators has been done in accordance with the advisory board of MOBI-e (see above). The weight factor is scaled from 1 to 5 (1 being minor and 5 major). Finally, the sum of all weighted indicator measures is rescaled as a score theoretically varying from 0 to 100, so that the AFBI is straightforward to apply (Fig. 1).

The maximum value of the AFBI is obtained when the following conditions are fulfilled: biologically sustainable managed forests consist exclusively of trees species typically found in the potential natural vegetation; they have more than 10% deadwood volume in relation to the total standing volume; they harbour veteran trees; they have a sufficient natural regeneration layer, if the forests are in the regenerative phase, they have been established with genetically appropriate forest reproductive material, if artificial regeneration is unavoidable; regeneration is not negatively affected by game stock. Furthermore, forest types are sufficiently represented in natural forest reserves, and the gene pool of indigenous forest tree species is sufficiently conserved by genetic reserve forests; all forest tree species are safeguarded through an adequate number of seed stands; all rare and/or endangered forest tree species are conserved in seed orchards and the use of their seed is promoted.

We propose to collect adequate field data for a representative assessment of forest biodiversity within the framework of the Austrian forest inventory (AFI) (see also Newton and Kapos, 2002). This sampling scheme is characterised by quadratic tracts systematically distributed across Austria in a regular grid system of 3.89 km × 3.89 km. Sampling units relevant for biodiversity assessment are four sample plots each of 300 m^2 located at the four vertices. In total, 11,000 sample plots can be considered (Gabler and Schadauer, 2008). For most indicators that are not based on the AFI, raw data can be provided by existing BFW databases.

Indicators that are not exclusively used in forests, such as the Austrian soil inventory (http://bfw.ac.at/rz/bfwcms.web?dok=2966) or monitoring by laypersons for birds (http://www.birdlife.at/), will not be mentioned here, because they are considered to be implemented independently (see Bogner and Holzner, 2006).

In the following, each AFBI indicator is described in detail.

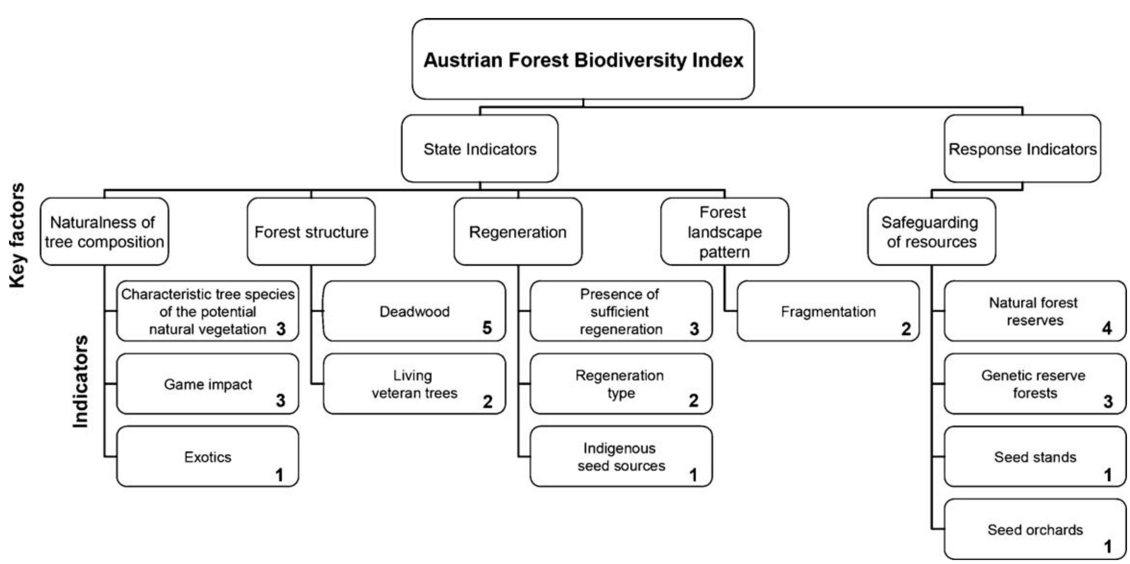

Fig. 1. Components of the Austrian Forest Biodiversity Index (AFBI); 13 indicators are linked to their key factors; indicator weights are given as numbers (minimum 1, maximum 5). Maximum AFBI = 13 indicators × 100 value points × 31 weighing points = 40,300 points (=100%).

4. Indicators

The AFBI consists of nine state and four response indicators. Selection of state indicators on forest stand was based on a general hypothesis how the indicator would measure richness of forest dependent species and genes therein, respectively (cf. Vellend and Geber, 2005). This "untested" hypothesis assumes that forest biodiversity is comparably high in forests that mimic characteristic natural processes or contain characteristic elements of old-growth forests. Among the response indicators we considered the establishment of seed stands, orchards, natural forest reserves and genetic reserve forests as most relevant. Response indicators have been especially chosen to include measures to conserve forest genetic resources. In the following for each indicator basics, target, measure, assigned values, the respective weight, and the monitoring period are given.

4.1. Naturalness of tree composition—characteristic tree species of the potential natural vegetation (PNV)

Basics: The degree of naturalness of forest ecosystems reflects the intensity of human interventions, especially by the selection of tree species or tree species composition in managed forests. Naturalness of tree species composition is expected to reflect the degree of anthropogenic alterations in forest ecosystems directly (e.g., Wulf, 1997). The potential natural vegetation (sensu Tüxen, 1956) is defined as a climax to be expected at the respective site under present environmental conditions and exclusion of past and present human disturbance (for Austria see Kilian et al., 1994; Lexer, 2001).

Target: In all AFI plots characteristic tree species of the potential natural vegetation (PNV) are found.

Measure: Assessment of PNV characteristic tree species both in the tree layer (tree height > 1.3 m, degree of canopy closure of the forest characteristic tree species > 50%) and, if appropriate, in the regeneration layer (tree height < 1.3 m) (Table 1).

Assigned values: Characteristic tree species are (1) present in the tree and – if applicable (see Section 4.6) – in the regeneration layer, value = 100; (2) either exclusively present in the tree layer or in the regeneration, value = 50; (3) characteristic tree species are not present, value = 0. In case of more than one PNV characteristic tree species, the values are averaged.

Indicator weight: 3.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.2. Naturalness of tree composition—game impact

Basics: Game stock can have a profound effect on the vegetation by feeding on seeds, seedlings and twigs, by fraying and peeling (Côté et al., 2004). In many European forests, the density of, for instance, roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) and, in consequence, browsing has significantly increased in recent decades (Reimoser, 2003). Highly affected tree species such as silver fir (*Abies alba*) are not able to withstand browsing impact. Usually, game stock does not alter tree species composition indicated by trees exceeding a height class of 130 cm. Those trees are no longer affected by browsing in their further development and, hence, are considered to build up the next tree generation.

Target: All AFI plots have no significant impact of PNV characteristic tree species during the juvenile stage (if applicable).

Measure: Record and/or assessment of PNV characteristic tree species in juvenile stages.

Assigned values: The number of damaged terminal buds of the five tallest saplings of each PNV characteristic tree species in the regeneration layer (>10 and <130 cm) is recorded. If four to five terminal buds are intact, then the value equals 100; if two to three, then the value equals 50, if zero to one terminal buds are

Table 1

Natural forest types in Austria; forest characteristic tree species of the potential natural vegetation (PNV) must be present both in the adult stand and in the regeneration; "or" means that either the first or the second tree species must be present, "and" means that all tree species must be present simultaneously. Living veteran trees of the characteristic forest tree species are defined by a minimum diameter at breast height (=dbh, measured in cm, 1.3 m above ground).

Forest type	PNV characteristic forest tree species (incl. minimum dbh of living large veteran trees)
Larch—Swiss stone pine forest	*Pinus cembra* (80 cm) or *Larix decidua* (80)
Larch forest	*Larix decidua* (80)
Subalpine spruce forest	*Picea abies* (80)
Montane spruce forest	*Picea abies* (80)
Spruce—fir forest	*Picea abies* (80) and *Abies alba* (80)
Spruce – fir – beech forest	*Abies alba* (80) and *Fagus sylvatica* (80)
Beech forest	*Fagus sylvatica* (80)
Oak—hornbeam forest	*Quercus petraea* (80) or *Quercus robur* (90) and *Carpinus betulus* (70)
Acidophilous oak forest	*Quercus petraea* (80) or *Quercus robur* (90)
Thermophilous oak forest	*Quercus pubescens* (70)
Manna ash—hop hornbeam forest	*Fraxinus ornus* (70) or *Ostrya carpinifolia* (70)
Scots pine—oak forest	*Quercus petraea* (80) or *Quercus robur* (90)
Mixed lime forest	*Tilia platyphyllos* (80) or *Tilia cordata* (80) or *Acer platanoides* (80) or *Fraxinus excelsior* (80)
Sycamore forest	*Acer pseudoplatanus* (80)
Sycamore—ash forest	*Acer pseudoplatanus* (80) and *Fraxinus excelsior* (80)
Black alder—ash forest	*Alnus glutinosa* (70) and *Fraxinus excelsior* (80)
Black alder forest marsh	*Alnus glutinosa* (70)
Grey alder forest	*Alnus incana* (60)
Mountain pine forests (Scots pine and Swiss mountain pine)	*Pinus mugo* subspecies *uncinata* (60)
Swiss mountain pine forest	*Pinus mugo* (–)
Scots pine—marsh	*Pinus sylvestris* (70) or *Betula pendula* (60)
Calcareous Scots pine forest	*Pinus sylvestris* (70)
Acidophilous Scots pine forest	*Pinus sylvestris* (70)
Austrian black pine forest	*Pinus nigra* ssp. *austriaca* (60)
Riparian poplar forest	*Populus nigra* (90) or *Alnus incana* (60) or *Populus alba* (90)
Riparian willow forest	*Salix alba* (80) or *Salix fragilis* (80) or *Populus nigra* (90)
Riparian mixed forest with ash, oak, elm	*Fraxinus excelsior* (80) or *Quercus robur* (90) or *Ulmus minor* (80) or *Ulmus laevis* (80)
Ash forest	*Alnus glutinosa* (70) or *Fraxinus excelsior* (80)
Green alder	*Alnus viridis* (–)

undamaged, then the value is zero; in the case that there are less than five saplings, the indicator is not calculated.

Indicator weight: 3.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.3. Naturalness of tree composition—exotics

Basics: Exotic species are considered to be detrimental to autochthonous forest communities (Richardson, 1998; Engelmark et al., 2001); exotics are defined as tree species intentionally or accidentally transported and released by humans into Austria beyond its present native range.

Target: None of the AFI plots harbour exotic tree species.

Measure: Presence of exotic trees in the AFBI plot.

Assigned values: No exotic tree species found in a plot, value = 100, otherwise, value = 0.

Indicator weight: 1.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.4. Forest structure—deadwood

Basics: Deadwood as a key indicator of biodiversity in European forests (Humphrey et al., 2004). It is crucial for wildlife habitat, carbon and water storage, nutrient cycle, humus formation, soil development, as well as natural regeneration of trees. Many species of vertebrates, invertebrates, lichens, bryophytes, polypores and other saproxylic fungi use decaying wood as shelter, as substrate and as an energy source thereby creating different niches (e.g., McComb and Lindenmayer, 1999; Grove, 2002). For example, in Finnish spruce forests, Ranius and Jonsson (2007) found that deadwood amounting to about 30 m^3/ha might allow the persistence of 73% of the saproxylic species, and stated "whether this is a reasonable goal is a question for policy makers rather than for scientists". While in Switzerland 30 m^3/ha of deadwood was found by the most recent national forest inventory (Böhl and Brändli, 2007), in Austria the current volume of logs (lying deadwood) and snags (standing deadwood) accounts for 12.8 m^3/ha, i.e., 3.8% of the total standing volume of wood (325 m^3/ha) (Mehrani-Mylany and Hauk, 2004).

Target: All AFI plots have 10% (standing and lying) deadwood volume in relation to the total standing volume.

Measure: Deadwood volume (dbh > 10 cm) in AFI plots is related to the respective target value (10% of the standing living wood volume).

Assigned values: Standing and lying deadwood volume is expressed as a percentage to the target varying theoretically from 0 to 100%.

Indicator weight: 5.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.5. Forest structure—living veteran trees

Basics: Large and very old living trees (veteran trees) are characteristic for old-growth forests. These veteran trees generally host to a high number of species by being structurally diverse, offering deadwood at different stages and by providing stable niche conditions for species with low dispersal ability (e.g., Read, 2000).

Target: For each tree species and forest type the minimum percentage of veteran trees is set to 1%.

Measure: Veteran trees are defined as characteristic tree species with a minimum diameter at breast height (dbh) defined in Table 1, since dbh differs among species, forest types, and altitudes, respectively.

Assigned values: To reach the final maximum value of 100, at least 1% of all individual trees recorded by the AFI in Austria must be large trees according to the criteria given in Table 1. The final value is then averaged over all tree species and forest types.

Indicator weight: 2.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.6. Regeneration—presence of sufficient regeneration

Basics: From an evolutionary point of view, the long-term existence of tree species is not threatened, provided they are able to reproduce themselves successfully over generations. Indicators that directly or indirectly assess the reproductive system of forest tree species by means of gene flow, detection of pollination barriers and the assessment of pollen and seed dispersal guilds have been identified (Boyle, 2000).

Target: Presence of natural regeneration in all AFI plots. This indicator is only applicable in forests with at least 30% coverage of trees with a height above ground exceeding 1.3 m, and a dbh exceeding 35 cm in order to exclude forest stands that do not possess a regeneration layer because of natural reasons (Schieler and Hauk, 2001).

Measure: Record of a minimum number of saplings depending on plant height per plot (Fig. 2).

Assigned values: Plots with a minimum plant number in regeneration, value = 100; otherwise, value = 0.

Indicator weight: 3.

Monitoring period: Every AFI (i.e., every 5–7 years).

4.7. Regeneration—type

Basics: Usually forest stands which are allowed to regenerate naturally over several seeding years are genetically more diverse than stands with planted trees (e.g., Finkeldey and Ziehe, 2004). We assume that naturally regenerated forest stands are better adapted to the local site conditions, have a higher structural complexity due to irregular distribution of the young plants and are richer in tree species and genetic diversity than artificial afforestations of the same age.

Target: All AFI plots – if applicable – are naturally regenerated.

Measure: Assessment by experts whether regeneration is completely natural, completely artificial or a mix of natural and artificial regeneration at the respective plot.

Assigned values: Plot with exclusively natural regeneration, value = 100; a mix of natural and artificial regeneration, value = 50; and with exclusively artificial regeneration, value = 0.

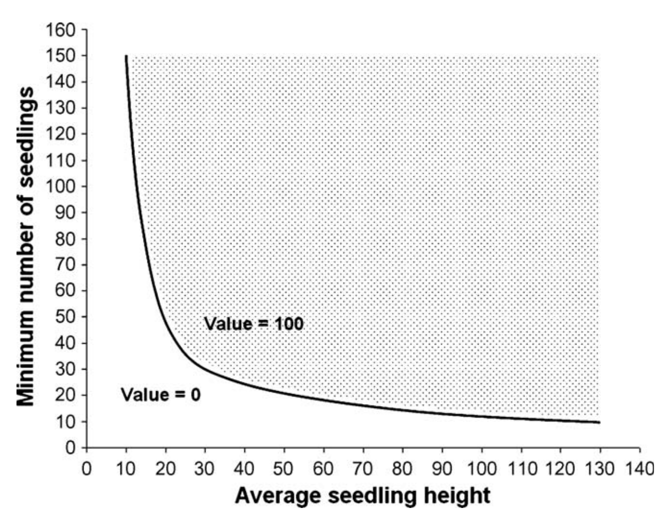

Fig. 2. Defined relationship between average seedling height and minimum number of seedlings in the AFI plots. The dotted area right/above the curve represents the value 100, in the white area left/below the curve the value is zero.

Indicator weight: 2.
Monitoring period: every AFI (i.e., every 5–7 years).

4.8. Regeneration—indigenous seed sources

Basics: Genetic diversity of forest stands is strongly influenced by the choice of reproductive forest material. Its inappropriate use has probably the most significant impact on the genetic diversity of forest trees in Europe (Geburek and Konrad, 2008). Generally, genetic variability of introduced material tends to be considerably lower compared to local populations (Laikre and Ryman, 1996). Reproductive material with deficient adaptedness or adaptability not only increases the susceptibility to stress factors, but also negatively affects species communities associated with respective tree species. Detrimental effects on biodiversity may additionally result from "genetic pollution", i.e., gene flow (pollen, seed) from unwanted genetic sources into adjacent native populations.

For Norway spruce, the most important Austrian forest tree species, a geographic-genetic map exists that predicts the most likely autochthonous molecular haplotype (Fig. 3). So far this map is based on a maternal inherited minisatellite in the mitochondrial NAD1 intron 2 (Tollefsrud et al., 2008). In the long run with improved molecular tools a genetic monitoring would allow an assessment of the genetic diversity of different age classes and of the future adaptability of this and other species. However, for the time being we limit this indicator to Norway spruce and the mitochondrial haplotype.

Target: All Norway spruce trees in Austria are indigenous.

Measure: Genetic analysis using mitochondrial DNA of Norway spruce trees in the AFI plots and comparison with local DNA profile using the national Norway spruce database.

Assigned values: Probability (in percent) that the observed haplotype found in an AFI plot is indigenous/autochthonous. This calculation is possible for all haplotypes based on respective kriging maps. The final value averaged over all plots ranges from 0 to 100.

Indicator weight: 1.
Monitoring period: Every third AFI (i.e., every 15–21 years).

4.9. Forest landscape pattern

Basics: Forest fragmentation is an ecological process in the course of which formerly large and continuous forests split into a set of separated smaller pieces of forest habitat (for a review see Fahrig, 2003). Particularly, at the landscape scale, habitat loss and the associated habitat fragmentation of forested areas is a major threat to biodiversity (Kupfer, 2006).

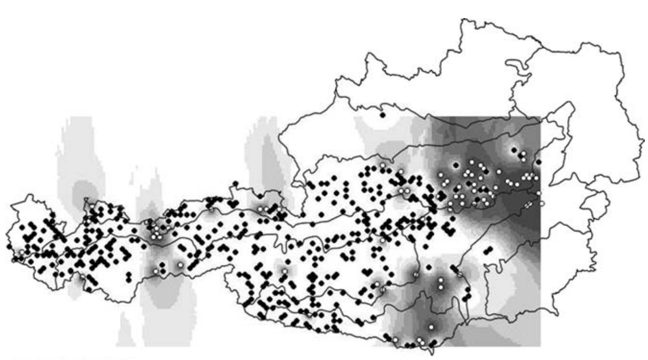

Fig. 3. Predicted probabilities to find the haplotype 815 as the natural (likely autochthonous) baseline in Norway spruce as one example of different available haplotypic structures. White colour within the rectangle represents an area where haplotype 815 is to be expected with a probability of 100%; with increasing shading this probability eventually decreases to 0. Spruce samples derived from a countrywide sampling within the Austrian forest inventory will be used for a genetic comparison in order to identify the non-indigenous populations. Scale is 100 km.

Target: Forests are not fragmented.

Measure: This indicator is based on the forest map of Austria (Bauernhansl and Schadauer, unpubl.). The map is superimposed with a grid of 1 km × 1 km pixels. Forested pixels are defined by a forest cover of at least 20%. Analysis of forest fragmentation is based on a 9 × 9 grid of these pixels (later in the text called "window") by using the fragmentation model of Riitters et al. (2000). The calculation for this model is as follows: within each window, two measures are calculated: first, the proportion of single pixels that are forested (Pf = pixels forested), i.e., actual number of forest pixels divided by 81 (the maximum number of pixels), and second, the proportion of pixel pairs of which both are forested divided by the maximum number of pixel pairs of which at least one is forested (Pff = pixels forested fragmented). Finally, the ratio of both numbers (Pf as numerator, Pff as denominator) is calculated. Subsequently, Riitters et al. (2000) distinguish between six fragmentation categories: (1) patch ($Pf < 0.4$), (2) transitional ($0.4 < Pf < 0.6$), (3) edge ($Pf > 0.6$ and $Pf - Pff < 0$), (4) perforated ($Pf > 0.6$ and $Pf - Pff > 0$), (5) undetermined ($Pf > 0.6$ and $Pf = Pff$), and (6) interior ($Pf = 1.0$, $Pff = 1.0$). In the model, there are two critical values of Pf, i.e., 0.4 and 0.6; below 0.4 the "pixels non-forested" form a continuous path across the window, above 0.6 the "pixels forested" form such a continuous path. Areas naturally not covered by forests such as water or mountain peaks are treated as missing values. For the proposed grid the maximum number of pixels is 81, and the maximum number of adjacent pixel pairs is 144. In case of missing values, Riitters et al. (2000) recommend at least 50 pixels.

Assigned values: Referring to the model of Riitters et al. (2000) we assigned the following values: interior, undetermined or perforated (100); edge (75); transitional (50); patch (25); non-forest (0). The indicator value is calculated as the average of all window category values across Austria.

Indicator weight: 2.
Monitoring period: Every second AFI (i.e., every 10–14 years).

4.10. Natural forest reserves

Basics: The establishment of a comprehensive, adequate and representative forest reserve system is a key mean to conserve the natural dynamics of Austrian forest communities (Frank and Müller, 2003). This response indicator describes distinctive forest areas fully protected against direct human interventions, such as tree harvest, logging of deadwood or artificial regeneration. Hunting is permitted in natural forest reserves in order to adjust the game stock. It is the goal that these forests can freely develop towards their climax conditions (Parviainen and Frank, 2003).

Target: Presence of at least one reserve forest per forest community in each of the 22 forest growth areas or 9 ecozones, respectively (Table 2) that are classified according to climatic, geological and vegetation criteria (Kilian et al., 1994).

Measure: Comparison between already existing nature forest reserves and respective target number (541 reserves, Table 2) according to the Austrian Natural Forest Reserve Programme, identification and declaration of the respective reserves and placing contracts with the forest owner.

Assigned values: Percentage of adequate representation ranging from 0 to 100.

Indicator weight: 4.
Monitoring period: Every 5 years.

4.11. Genetic reserve forests

Basics: The overall objective of genetic reserve forests is the maintenance of the evolutionary potential of specific (endemic)

Table 2
Targets for groups of forest types and number of included forest associations as defined by the Austrian Natural Forest Reserves Programme.

Group of forest types	Number of included forest associations	Target
Sycamore and sycamore—ash forest	10	56
Swiss mountain pine forest	3	9
(acidophilous) Scots pine—oak forest	5	19
Beech forest	13	59
Oak—hornbeam forest	8	19
Black alder willow—forest marsh	1	2
Spruce – fir – beech forest	14	53
Spruce—fir forest	7	46
Thermophilous oak forest	4	11
Grey alder forest	1	10
Riparian mixed forest with ash, oak and elm	4	10
Montane sycamore maple—beech forest	4	9
(Alpine) larch—Swiss stone pine forest	2	15
Manna ash—hop hornbeam forest	1	3
Calcarous pine forest	5	23
Larch forest	2	7
Mixed lime forest	5	18
Montane spruce forest	6	23
Black alder—poplar forest marsh	2	12
Black alder—ash forest	4	23
Austrian black pine forest	3	5
Acidophilous pine forest	6	15
(Subcontinental) oak—mixed forest	3	6
Subalpine spruce forest	4	37
Riparian softwood forest with poplar and willow	4	28
Scots pine marsh	4	23
Total	125	541

tree species (MCPFE, 2002) in sufficiently large natural populations (Skrøppa, 2005). This is facilitated by a continuous flow of genetic information from one generation to the other by natural reproduction and selection from the gene pool of new genotypes best adapted to the changing environment. This natural process may be enhanced through active forest management to promote natural regeneration and/or to favour specific tree and shrub species of interest (Rotach, 2005).

Target: Estimated necessary number of genetic reserve forests is based on expertise. For each of the 22 forest growth areas (encompassed by 9 ecozones) and altitudinal bands at least one genetic reserve forest (minimum size 30 ha for stand forming species and 2 ha for rare species with scattered distribution per major forest community) is to be declared. Genetic reserve forests must have a natural regeneration and negligible game impact. The use of forest reproductive material originating from these genetic reserve forests should be promoted and/or subsidised by the public.

Measures: Comparison between already existing genetic reserve forests and respective target number, identification and declaration of the respective reserves.

Assigned values: Percentage of adequate representation ranging from 0 to 100.

Indicator weight: 3.

Monitoring period: Every 5 years.

4.12. Seed stands

Basics: Afforestation using reproductive material from ill-adapted sources can alter or even replace local populations and can cause serious disasters (e.g., Münch, 1936). Hence, forest reproductive material should originate from suitable seed sources. While the area of seed stands for each tree species was proposed as one indicator for biological diversity in European forest ecosystems (MCPFE, 2002), such an approach could mask the actual lopsided use of reproductive material from much fewer sources. Instead we try to optimize this indicator by taking into account the actual annual seed demand and evenly harvested seed quantities as well as by considering relevant seed imports.

Target: Sufficient number of evenly harvested seed stands and no seed imports, when appropriate Austrian seed sources are available.

Measures: Assessment of evenly harvested seed sources and of quantity of seed and plant imports.

Assigned values: This indicator value is based on the distribution of seed quantities over all seed stands and a series of subsequent weighting steps considering seven tree species and differences in seed quantity between different years within the monitoring period, seed stand numbers and imported seed material.

(1) For each year of the proposed monitoring period, the evenness (E) of seed quantities (harvests) is measured. This is done by comparing the actual proportion of seed harvests of individual seed stands p_a [actual seed quantity (weight) of an individual seed stand related to the total annual harvest] with the expected value (p_e) assuming that all existing seed stands were harvested evenly according to Gregorius (1984) as follows:

$$E = 1 - \frac{1}{2}\sum |p_e - p_a|$$

(2) Each of these annual evenness values (varying between 0 and 1) are weighted (multiplied) with the proportion of the annual seed quantity in relation the total seed quantity of the whole monitoring period of 10 years. (3) The resulting value is then weighted (multiplied) with the proportion of the actual number of seed stands in relation to the desirable number of seed stands which is defined by expertise (for spruce, pine, fir, larch, beech, oak and sycamore varying expectedly from species to species and among altitudinal bands). (4) The resulting species specific values are weighted (multiplied) with the annual seed imports and eventually will be averaged for the whole monitoring period. Data on seed imports are annually recorded by the Austrian Federal Forest Office. (5) The final value is averaged over all seven forest tree species that are, moreover, weighted with the tree specific area (i.e., the actual occurrence of each of the seven tree species in Austria).

If the actual number of seed stands equals the target number, and if in every year of the monitoring period all seed stands are harvested equally, and no seed was imported, then the value will be 100.

Indicator weight: 1.

Monitoring period: Every 10 years.

4.13. Seed orchards

Basics: Seeds from rare and/or endangered forest tree species are seldom harvested in the wild because of high costs and/or small population size. For these species ex situ seed orchards (consisting of artificial populations derived from regional collections) can provide reproductive material of sufficiently high genetic diversity (Skrøppa, 2005). Ideally for certain tree species a sufficient number of seed orchards are productive and their seeds are made available to commercial nurseries.

Target: Sufficient number of seed producing orchards based on scientific expertise taking both tree species vulnerability and their respective commercial seed harvest feasibility into consideration (Table 3). For each of these tree species, at least one seed producing orchard should be present per forest growth area. To be considered as a seed producing orchard, in at least 1 year of the 10 year monitoring period seeds must have been harvested.

Measure: Comparison of actual versus target number of productive seed orchards.

Table 3
Forest tree species to be preserved by means of seed orchards. Following categories of biological importance are proposed (ranging from highest to lowest): category 4—tree species vulnerable, commercial seed harvest not feasible; category 3—tree species vulnerable, commercial seed harvest feasible; category 2—tree species generally vulnerable, populations locally endangered, commercial seed harvest not feasible; category 1—tree species generally not vulnerable, populations locally endangered, commercial seed harvest feasible.

Forest tree species	Category
Abies alba	3
Acer campestre	1
Acer platanoides	2
Acer pseudoplatanus	2
Alnus glutinosa	2
Alnus incana	1
Betula pubescens	3
Fraxinus angustifolia	3
Fraxinus excelsior	2
Fraxinus ornus	4
Larix decidua	1
Malus sylvestris	4
Picea abies	1[a]
Pinus mugo spp. uncinata	3
Prunus avium	1
Pyrus communis	4
Sorbus aria	2
Sorbus domestica	4
Sorbus torminalis	4
Taxus baccata	2
Tilia cordata	2
Tilia platyphyllos	2
Ulmus glabra	2
Ulmus minor	2
Ulmus laevis	2

[a]Only Norway spruce from high altitude.

Assigned values: Proportion of actual number of conservation seed orchards versus target numbers weighted with the biological importance (see Table 3).

Indicator weight: 1.

Monitoring period: Every 10 years.

5. Discussion

The survey of "life in all its forms" is seemingly an impossible task (Hagan and Whitman, 2006). Although the monitoring of populations and habitats is a valuable and relevant way of assessing human impacts on nature (Balmford et al., 2003) due to limitations in time and money the measurement of species diversity per se might only be possible in few taxonomic groups. For example, in South Africa, Scholes and Biggs (2005) proposed a biodiversity intactness index which addresses changes in biodiversity at the population level of different plants, mammals, birds, reptiles and amphibians, ecosystems and land-use management practices in a given geographical area. This index is based on species richness data as well as on expert judgements about changes in population abundance caused by land-use activities with regard to reference population data derived from large protected areas that represent an unaltered pre-industrial population status quo. From a conservation perspective this approach is appealing, although it has been lately criticized (Rouget et al., 2006). Due to a lack of data and resources in the forest sector, such an intactness index had to be excluded beforehand while in Austrian agricultural ecosystems it may be more applicable to focus on single species or taxa (e.g., Sauberer et al., 2004). However, direct measuring of species richness may be not necessary if effective indicators are available which can be recorded cost-effectively. Consequently, the best practical approach is to assess a number of indicators that are – or at least considered to be – highly correlated with biodiversity components.

The AFBI has been developed as a composite index. The primary goal is to incorporate the most relevant target values of key factors of forest biodiversity and to provide good, cost-effective indicator data for a monitoring period. We have tried to avoid mistakes commonly made in the design of biodiversity indicators by following closely the proposals of Failing and Gregory (2003). Firstly, the AFBI focuses on targets defined by scientific experts in accordance with policy makers, stakeholders and forest managers (cf. Nichols and Williams, 2006). Secondly, we have attempted not to mix means, i.e., policies and management strategies, with objectives. Thirdly, the management context was established, for instance, red-listed species have been used to set priorities in the conservation seed orchards. Fourthly, we have intentionally weighed individual indicators, fully realising that objections to indicator selection and weights given to calculate the AFBI are unavoidable, as subjective judgement is always part of a decision process. The outcome of such a process might be best described by the phrase "to the best of the experts' knowledge". But emphasis has been put on the balance among different facets of biodiversity in order to avoid overrepresentation of certain parts. There tends to be resistance to weighing individual indicators, probably resulting from the belief that everything is important. However, if decision makers face long indicator lists they probably focus either on a more salient indicator, make their own selection, or will dismiss the whole set, overwhelmed by the complexity. Fifthly, and this is probably the most important point, we have designed a composite index. Such an index inevitably may mask some important attributes of the actual forest biodiversity and, of course, regional discrepancies. But we are convinced that a composite index is suitable and will reflect the status of forest biodiversity in a country like the gross national product does in economy or the Dow Jones Industrial for the US stock market.

Our approach allows the presentation of a simple composite index scaled from zero to the maximum value of 100 and thus can be used easily for communication of major trends. Target values of the AFBI consider relevant arguments from the scientific community as well as from forest policy and management kindly provided during several workshops, presentations and discussions. Inspired by the existing forest indicator gross lists (e.g., Europe: Larsson et al., 2001; United Kingdom: Ferris and Humphrey, 1999) and measures (e.g., McElhinny et al., 2005) there was consensus to keep the list of indicators as short as possible and to design them target oriented. We are fully convinced that a single measure balanced for simplicity and stringency of indicators with target values is much more attractive to policy makers and other users than long indicator lists.

The AFBI is a composite index consisting of 13 indicator measures. While individual indicator measures are soundly quantified, target values are assessed mostly on a nominal or ordinal scale. This holds true in particular for state indicators most of which are based on the AFI. While the state indicators measure the current state of biodiversity per se, the response indicators primarily describe the relative extinction security of different forest types by establishment of conservation areas (natural forest reserves), the degree of maintenance of genetic diversity by establishment of genetic reserve forests, the degree of use of adequate reproductive material to maintain genetic diversity and the degree of extinction security for rare tree species by establishment of seed orchards like a gene-bank. It is obvious that a final AFBI value of zero is the worst and a value of 100 is the optimal case as far as the achievements of political implementation are concerned. In fact, the maximum value is a threshold that likely describes an optimal state of forest biodiversity in Austria (Fig. 4). Conceptually the AFBI suggests that biodiversity loss is only significant below this threshold.

Several indicator measures are based on data that are measured in a 5–7-year interval following the periodicity of the AFI. Since the

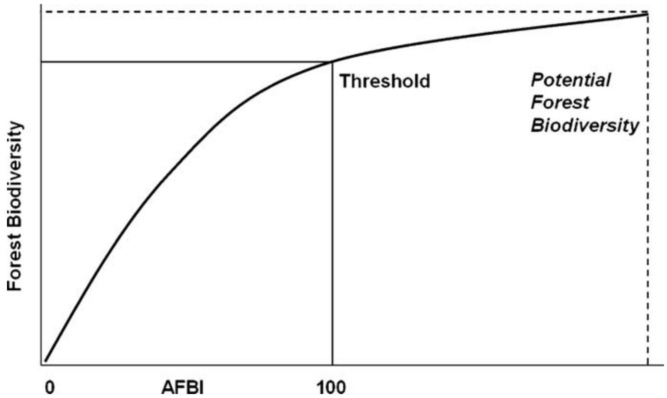

Fig. 4. Simplification of the relationship between the Austrian Forest Biodiversity Index (AFBI) and the forest biodiversity in Austria. An AFBI of 100 is the threshold that describes an optimal state of forest biodiversity.

AFBI can only detect major trends, it may be necessary to prolong this periodicity. This probably contrasts with the agricultural sector because its biodiversity changes are much faster (e.g., Abensperg-Traun et al., 2004). The AFBI is a new tool in documenting and communicating forest biodiversity in Europe, while a similar index is already accepted in Canada (Grosshans et al., 2006). Compared to the Canadian index, that intends to cover all parts of the country, the proposed AFBI is, in fact, limited to the forested landscape. The same goal, i.e., finding a Forest Biodiversity Index, is intended by Petriccione et al. (2007) who aimed at the implementation of a new composite indicator on the status of European forest biodiversity (Forest Status Indicator, FSI), as an elaboration and synthesis of current metadata and methodologies at the European level (EU Forest Focus and UN/ECE CLRTAP ICPs, National Forest Inventories, Natura 2000, LTER-Europe) for four European countries (Germany, Italy, Slovakia and Spain). Similar to our approach different data were normalised in one scale of value ranging from minimum 0 to maximum 100 points.

In our approach we have tried to overcome shortcomings of indicator-based biodiversity monitoring. For instance, we have included several indicators which are specifically addressed at conserving genetic diversity of forest tree species, which are the basic components of the whole ecosystem. This is reflected by the special attention we give to the actual possibility for tree species to reproduce naturally and the evaluation of how practical regeneration is done in managed forests (source of seeds, use of local seed stands, use of local seed orchards for rare tree species). In this way we tried to overcome the simple data reporting (e.g., MCPFE) and comforting description of how many hectares of seed sources have been declared, while in practice huge areas of managed forests could in fact be replanted with reproductive material from very few sources (see Geburek and Konrad, 2008).

In short, the AFBI

- combines separate components of biodiversity into one composite index,
- defines clear targets for each indicator, which are each expressed with values ranging from 0 to a maximum of 100, so that comparisons across indicators are possible,
- is mainly based on quantifiable data provided by a nation-wide, close-meshed forest inventory,
- is a useful tool to inform a wide audience, particularly forest policy makers and other stakeholders.

However, there are still uncertainties which concern (i) the empirical evaluation of subcriteria, (ii) the aims and potential conflicts with other criteria and (iii) the strategy of how the index is supposed to evolve over time. Clearly, no index can scientifically be evaluated in a meaningful way without empirical backup. In fact, the AFBI has not been put to the test yet, i.e., its empirical feasibility is still untested. The AFBI is meant to stimulate discussion, its actual aim, however, is to conclusively test its success under real/natural conditions. Such a test is needed, e.g., to disentangle the correlation pattern between individual indicators of which the AFBI is composed of. Only after such an analysis intercorrelation or conflicts between individual indicators can be detected. The same holds true for the evaluation of criteria or subcriteria. Only after an empirical test run, they can be adequately adjusted before the AFBI is eventually implemented. So far each proposed criterion and measure must be considered as an expert's opinion and not as undisputed scientific knowledge. Concerning its aims, the AFBI is primarily expected to address changes in forest biodiversity and to provide comparable results between the sampling events. As a composite index it can also provide information across different aspects of forest biodiversity and reveals which indicator is changing significantly. The calculation of the AFBI is based on sound data which are collected by well established sampling systems, like the Austrian Forest Inventory (AFI), which is based on permanent sampling plots. Basically, information provided by the AFBI is only possible when it is guaranteed that the data survey is repeatable over time. Unfortunately, such a guarantee cannot be promised as it depends on policy and not on science. Within Austria, the AFBI can also be calculated for smaller scales, such as political or geographical units, and can give an indication of the overall condition of a region relative to the maximum value 100. This state is defined by a threshold that is assumed to work as a safeguard for most forest dependent species. Beyond the value 100 the improvement in forest biodiversity towards a "pre-industrial" condition might theoretically be possible but lies beyond the present conservation, genetic and forest management practice.

Our views are in line with those of Mace (2005) who stated "Even in relatively well-studied areas of the world, the number of biodiversity measures for which long-term trends can be assessed is remarkably limited. Clearly, new approaches are required if we are to make progress". Accordingly, our approach should be a fruitful contribution to attain this goal. We are convinced that the proposed target monitoring approach is meaningful since it is based on a comparably large data set and includes not only forest stand but also genetic parameters. Therefore, we are confident that we can significantly contribute to the ongoing process of finding suitable indicators and an easily applicable biodiversity monitoring concept for Europe.

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