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The assessment of naturalness and its role for nature conservation and forestry in Europe

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Abstract

Naturalness is one of the most important criteria in nature conservation. This paper examines the fundamental concepts underlying the definition and assessment of naturalness. Its role in nature conservation and forest management under conditions of global change is also discussed.

The degree of naturalness may be defined in ordinal classes. The "static" concept of the potential natural vegetation (pnV), developed in the 1950ies, is mostly used as the reference state. In other cases, its reversed concept, the hemeroby (degree of artificiality) is assessed, based on the intensity and frequency of human impacts.

Since the 1970ies, more attention has been given to natural dynamics than in earlier approaches, e.g. in forest succession models. At the end of the 1980ies, the previous importance was increasingly stressed of natural browsing by large herbivores and the role of predators. These large herbivors are extinct today in most cultural European landscapes. It is assumed, that they open up the canopy, and create park-like forest structures which contain a diversity of habitats for other types of organism (birds, insects).

Changed and permanently changing environments and altering patterns of competition between species continue to modify natural processes today. Some of the more conspicuous effects are the extinction of native species and immigration of species to new regions. Long-lived ecosystems like forests are however not able to adapt quickly to such changes and may be unable to find a new balance with the environment. Today, such changes occur very rapidly, and are reducing the original naturalness of ecosystems. Because of this, the criterion "naturalness" must be downweighted. Conversely, more importance should be attached to other criteria: particularly originality (= original naturalness) and restorability.

Forestry is contributing to this accelerated change of biocoenoses by increasing disturbances and introducing exotic tree species. Naturalisation of some exotic tree species modifies the natural processes and creates a "new allochthonous naturalness". Because of this, forest planning should try to preserve or restore stands with attributes of the "original forest". Exotic species should not be planted, or only in a very restricted way.

Key words: naturalness, hemeroby, originality, human impacts, global change, forestry, nature conservation.

Zusammenfassung

Naturnähe ist eines des wichtigsten Bewertungskritierien im Naturschutz. Die vorliegende Arbeit untersucht die den gängigen Naturnähe-Konzepten zugrundeliegenden Definitionen und Bewertungsmaßstäbe. Auch wird die Rolle von Naturnähe für Naturschutz und Waldbewirtschaftung im „Globalen Landschaftswandel" diskutiert.

Die Einteilung von Naturnähe erfolgt in graduellen Abstufungen. Zumeist wird dazu das "statische" in den 1950 er Jahren entwickelte Konzept der Potenziellen natürlichen Vegetation Vegetation (pnV) verwendet. In anderen Fällen wird die zur Naturähe gegenläufige Hemerobie (Grad des Nutzungseinflusses) herangezogen.

Seit den 1970er Jahren wurden verstärkt Aspekte der natürlichen Dyanmik berücksichtigt, z.B. sogenannte „Phasenmodelle". Ende der 1980er Jahre wurde die ehemalige Bedeutung der Megafauna (große Pflanzenfresser und Prädatoren) hervorgehoben, die heute in den europäischen Kulturlandschaften weitgehend ausgestorben sind. Es wird vermutet, dass Megaherbivoren einst in der Lage waren, den Wald aufzulichten und teilweise parkartige Strukturen mit einer großen Habitatvielfalt für andere Tierartengruppen (Vögel, Insekten) zu schaffen.

Veränderte und sich permanent ändernde Umweltbedingungen und sich wandelnde Konkurrenzmuster zwischen den Arten führen auch heute zu sich laufend ändernden Naturprozessen. Einige der auffälligsten Effekte sind das Aussterben heimischer Arten und die Einwanderung von „fremden" Arten in neue Regionen. Langlebige Ökosysteme wie die Wälder sind nicht in der Lage, rasch ein neues Gleichgewicht mit den Umweltbedingungen zu finden, ihre Umstellung dauert viele Jahrzehnte. Heute finden Veränderungen von Standortsbedingungen sowie die Einwanderung von Tier- und Pflanzenarten sehr rasch statt. Diese Prozesse reduzieren die frühere Naturnähe („Ursprünglichkeit") der Ökosysteme. Deshalb ist bei naturschutzfachlichen Bewertungen das Kriterium „Naturnähe" aus heutiger Sicht tendenziell geringer zu wichten. Umgekehrt sollte anderen Aspekten größere Bedeutung beigemessen werden, insbesondere der Ursprünglichkeit (bzw. angestammten Naturnähe) und der Wiederherstellbarkeit.

Die Forstwirtschaft trägt zu einem beschleunigten Wandel der Lebensgemeinschaften bei durch zunehmende Eingriffe (Häufigkeit, Intensität) und Einbringen von Gastbaumarten. Die Einbürgerung einiger exotischer Baumarten verändert die natürlichen Prozesse und kreiert eine "neue allochthone Naturnähe". Deshalb sollte die Forstplanung versuchen, „angestammt naturnahe" Bestände zu schützen oder wiederherstellen. Exotische Arten sollten nur in einem sehr begrenzten Umfang angepflanzt werden.

Schlüsselbegriffe: Naturnähe, Hemerobie, Ursprünglichkeit, menschliche Einflussnahme, global change, Forstwirtschaft, Naturschutz.

1. Introduction

Naturalness is one of the most important criteria in nature conservation (Plachter 1991; Peterken 1977, 1993, 1996; Usher & Erz 1994; Reif 2000; Knight & Landres 2002). It follows that many attempts have been made to define naturalness and attribute degrees of naturalness to ecosystems and landscapes (Anderson 1991; Siipi 2004).

Under naturalness we understand the actual expression of the natural state, as opposed to the cultural state (= state created by man) and the original state (= previous state in nature, uninfluenced by man) (Scherzinger 1996). Ecosystems which are not influenced by man, or only indirectly, or only very extensively by hunters and gatherers, may also be regarded as natural (Erz 1992; Bergstedt 1997).

Natural forests are extremely rare in Central Europe and restricted to a few regions (Leibundgut 1983; Bücking 2007). Land use history has, more or less, reduced the naturalness of nearly all forests. Most forests of natural origin are replaced today by diverse types of substitute plant communities. As a result, we encounter a mosaic of secondary forests, pastures, meadows, heathlands and fields. Fragmentation and accompanying isolation, as well as soil degradation of forests are important hindrances to recolonisation by organisms after the local extinction of metapopulations (Thomas et al. 1997).

The degree of naturalness is often assessed by the similarity of a biocoenosis to the presumed natural state before it was affected by man. Because in Europe virgin forests which might act as reference areas no longer exist, the naturalness of forests can only be a hypothetical construct (Fischer & Young 2007). Unfortunately, available data for forest dynamics, structures, species assemblages, species migration and the nutrient cycles between soil and vegetation are almost exclusively from studies in secondary forests, which thus refer to a "tamed nature".

To evaluate the degree of naturalness, in practice we distinguish between the concept of naturalness (von Hornstein 1950) and its reversed term, hemeroby (Jalas 1955). Hemeroby expresses the magnitude of cultural influences which work against the natural succession towards a terminal phase in the development of an ecosystem. Natural vegetation is "ahemerob", an artificial environment is "metahemerob" (Kowarik 1988, 1999).

Example 1: The hemeroby of the Austrian forests is expressed in a nine-level scale (Grabherr et al. 1998a, b). It reaches from "natural" to "artificial". This differentiated scale is based on 12 criteria, including e.g. the tree species composition, the ground vegetation, development and structure characteristics, and criteria related to exploitation.

The degrees of naturalness and hemeroby can be attributed to different hierarchical levels - to species, ecosystems, or landscapes. The analysis of naturalness provides the basis for practical applications, e.g. evaluations in nature conservation, in which ordinal values are attributed to different degrees of naturalness.

2. Concepts of naturalness

Three concepts of naturalness can be distinguished. They are all mental constructs (Fischer & Young 2007), representing debates conducted during three main periods after the middle of last century.

Fig. 1: Successional pioneer forest with birch (*Betula pendula*) after clearcut of the previous beech (*Fagus sylvatica*) forest. The naturalness of the tree species composition in both stands can be regarded as similarly high. Differences in value for nature conservation may be attributed to other criteria, e.g., occurrence of rare and endangered species, or differences in the time required to restore these stands. – Bergisches Land, west of Odenthal, 1.1.2008.

2.1. The “Potential Natural Vegetation” - a static approach of naturalness

Tüxen (1956) constructed a model of naturalness in form of the “potential natural vegetation” (pnV). The present pnV was defined as the vegetation that would develop under present site conditions, if human influence were excluded completely, and the resulting succession took place immediately. The result is a mental construction of the potential natural “climax community” as the terminal stage of successions arising from the existing situation. Successional stages were regarded as less natural, because they result from “disturbances”, which were seen as irregularly interrupting the natural balance (Tüxen 1956) (figure 1). The pnV-concept still is widely applied today, e.g., for vegetation mapping (e.g., Bohn et al. 2004; Cross 2006).

In the last years, discussion about naturalness focussed upon the problems induced by the static definition of the pnV. For example, forests are more and more understood as dynamic systems whose present condition may result from a long history. The hypothetical construct of an “immediately” formed climax vegetation excludes the effects of successions. Medium-term changes of soil and humus, or modified competition induced by the recruitment of species new to the area, are ignored by the “static” pnV-concept.

This is illustrated by example 2: When spruce (*Picea abies*) stands growing under climatic conditions favourable for beech (*Fagus sylvatica*) are thrown by storm, spruce forest will re-establish from existing seedlings on the ground and also dominate the next tree generation (Fischer 1998). Because the pnV-concept excludes successional processes, such as the long-term immigration of beech, spruce forest will be defined as potentially natural on that site, even when beech is the most competitive tree species (e.g., in BMVEL 2004 for Sauerland in NW Germany).

Proposals were made to overcome these weaknesses and to formulate the pnV so that it corresponds to the „natural development potential of the actual biotope“ (Schmidt 1997). This entails more consideration of the phasal changes and succession. In Austria too, „long-lived successional stages“ are „taken into account“ as potential vegetation units in the evaluation of the tree layer (Grabherr et al. 1998a, b). The necessity of a dynamic perspective has been recognised, but is not yet fully applied.

2.2. The virgin forest models: dynamics as a fundamental element of the naturalness concept

Forests are dynamic biocoenoses with relatively long-lived, stand-forming species. In the 1970ies, studies on the structure of „virgin forest remnants“ in Central Europe first made it possible to formulate models of the phasal development of forests (Leibundgut 1978, 1993; Pickett & Thompson 1978; Mayer 1986; Korpel 1995; Scherzinger 1999; Wissel 1992; Neuert et al. 2001). According to those models, when overmature trees come to die, the pre-existing underwood then develops through a regeneration and building phase (figure 2). This last grows on through a mature phase, an aging and degradation phase, from where the regeneration phase again sets in. All this takes place in the so-called “small cycle” in the climax forest. Furthermore, the development phases ofbuilding, ageing and regeneration occur in a small-scale mosaic-like texture, e.g. in the virgin forest of Corkova Uvala in Croatia (Mayer & Neumann 1981; figure 3). For a near-natural beech-dominated forest in Denmark, a model of the full forest cycle was developed, equalling some 284 years and including the sequential phases “innovation” (duration 14 years), “aggradation” (56 years), “early biostatic” (96 years), “late biostatic” (108 years) and “degradation” (10 years) (Emborg et al. 2000).

The “large cycle” includes disturbances caused by catastrophes, they lead to a light-demanding, rapidly growing cover of pioneer shrubs and trees. Under the canopy of the pioneer forest, shade tolerant species can establish and re-establish the climax forest. An example is found in the Slovak natural beech forest of Badin, where pioneer forests were initiated by large-scale storm damage (Korpel 1995) (figure 4).

The concept of the pnV sensu Tüxen is basically a static one. It does not take into account the forest dynamics that can be assumed to naturally occur. Its climax vegetation corresponds only to the “optimum phase” of models of natural forest, whereas the virgin forest models regard all dynamic stages and phases as equally natural, e.g. solitary tree gaps, extensive storm damage or femel-like gaps. Virgin forest models also attempt to reflect that many animal species are temporally and spatially niched to highly specific structural requisites. For example, a lot of characteristic, structure-adapted, forest species benefit from standing, decaying wood, e.g., woodpeckers (Scherzinger 1996), arthropods (Kleinevoss et al. 1996; Müller et al. 2005; Winter 2005; Winter et al. 2005), lichens and fungi. All these specific indicators of naturalness are neglected by the pnV-concept.

2.3. Natural forest and large herbivores

In the 1990ies, the models of cyclic development phases in virgin forests were modified to include a broader view of zoological aspects. Most of the biocoenoses on Earth are shaped by a long coevolution between animals and plants (Mitchell & Kirby 1990). Even some of the forest species of Central Europe have to a certain extent adapted themselves to the browsing pressure of herbivores, e.g. by developing defence mechanisms and / or a capacity for vegetative regeneration. It has been postulated that the open phases were once much longer because of the browsing pressure of large herbivores now extinct, such as wisent (*Bison europaeus*), aurochs (*Bos primigenius*) and elk (*Alces alces*) (“mosaic-cycle theory”; Remmert 1991).

When reconstructing the present-natural state and taking into account the large herbivores, reference can be made to the behaviour biology of cattle (Vera 2000). Because of the robustness of those animals it can be expected that, even if there were predators, herds of wild cattle grazed on suitable areas over longer periods. As rather indiscriminate browsers, they temporarily contributed to keeping the clearings open. Depending on the season the animals might have preferred the alluvial areas (during winter) or the mountain ridges exposed to the wind (during summer).

If the grazing stops, the balance of competition shifts, so that long-lived, shade-tolerant tree species without defence mechanisms overgrow and displace photophilous pioneer species, shoot-forming tree species and browsing-tolerant shrubs with defence mechanisms. The latter tend to retreat to forest edges or disappear, and the structural and floristic diversity decreases.

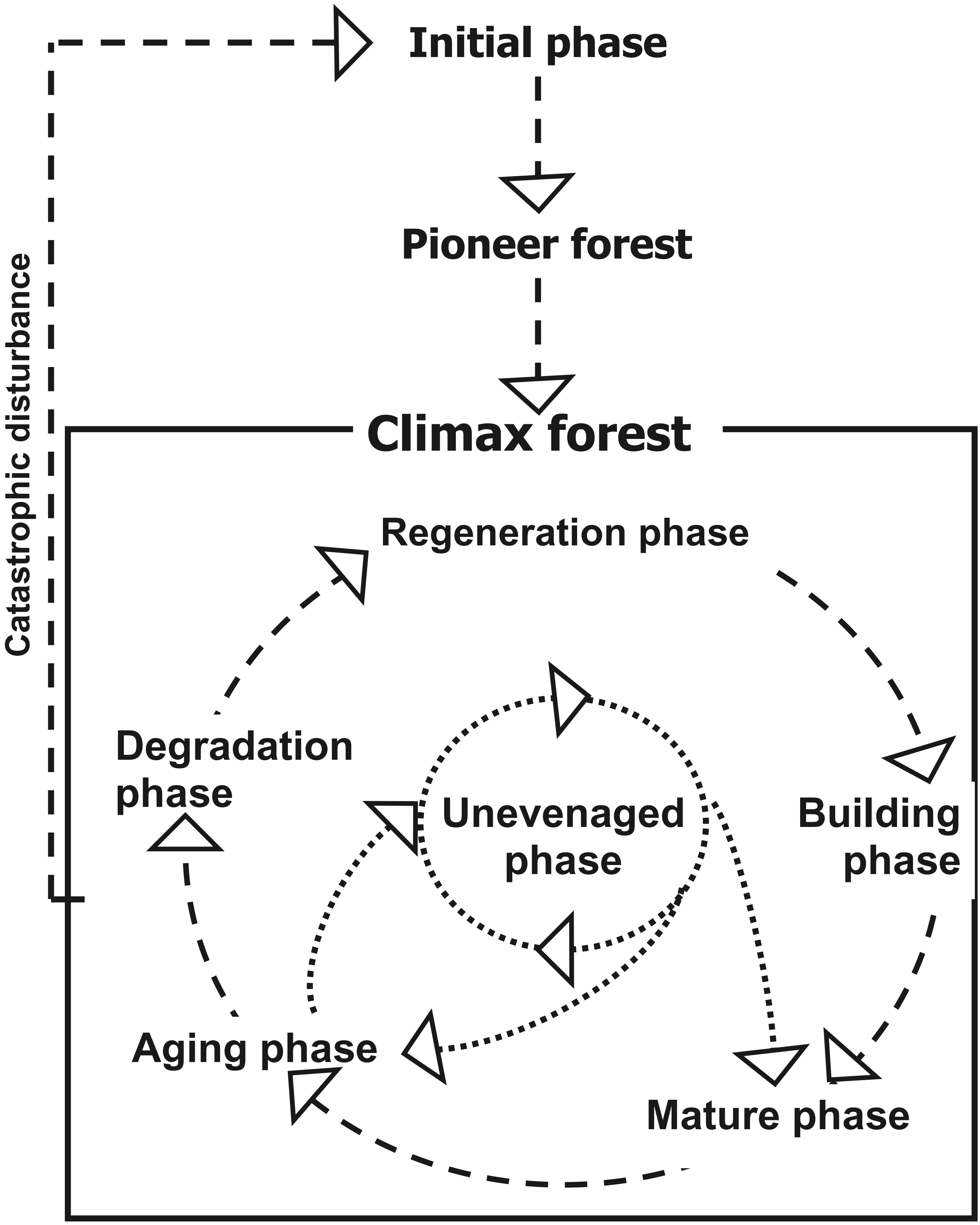

Fig. 2: Dynamic model of a Central European primary forest. Compiled after models from MAYER (1986), LEIBUNDGUT (1993), KORPEL (1995).

The original forests of Central Europe were then frequently pictured as a "half-open, park-like landscape" and this condition was considered to be of high value for nature conservation (GEISER 1992; BUNZEL-DRÜKE et al. 1994, 1995; BUNZEL-DRÜKE 1996; BEUTLER 1996, 1997).

These ideas met with great opposition from some foresters (MÜLLER-KROEHLING & SCHMIDT 1999a, b). Studies on forest pasture with cattle in the Upper Bavarian mountain mixed forest (with ca. 1 large animal/10ha) have shown that there the cattle prefer to browse the young beech trees, but also

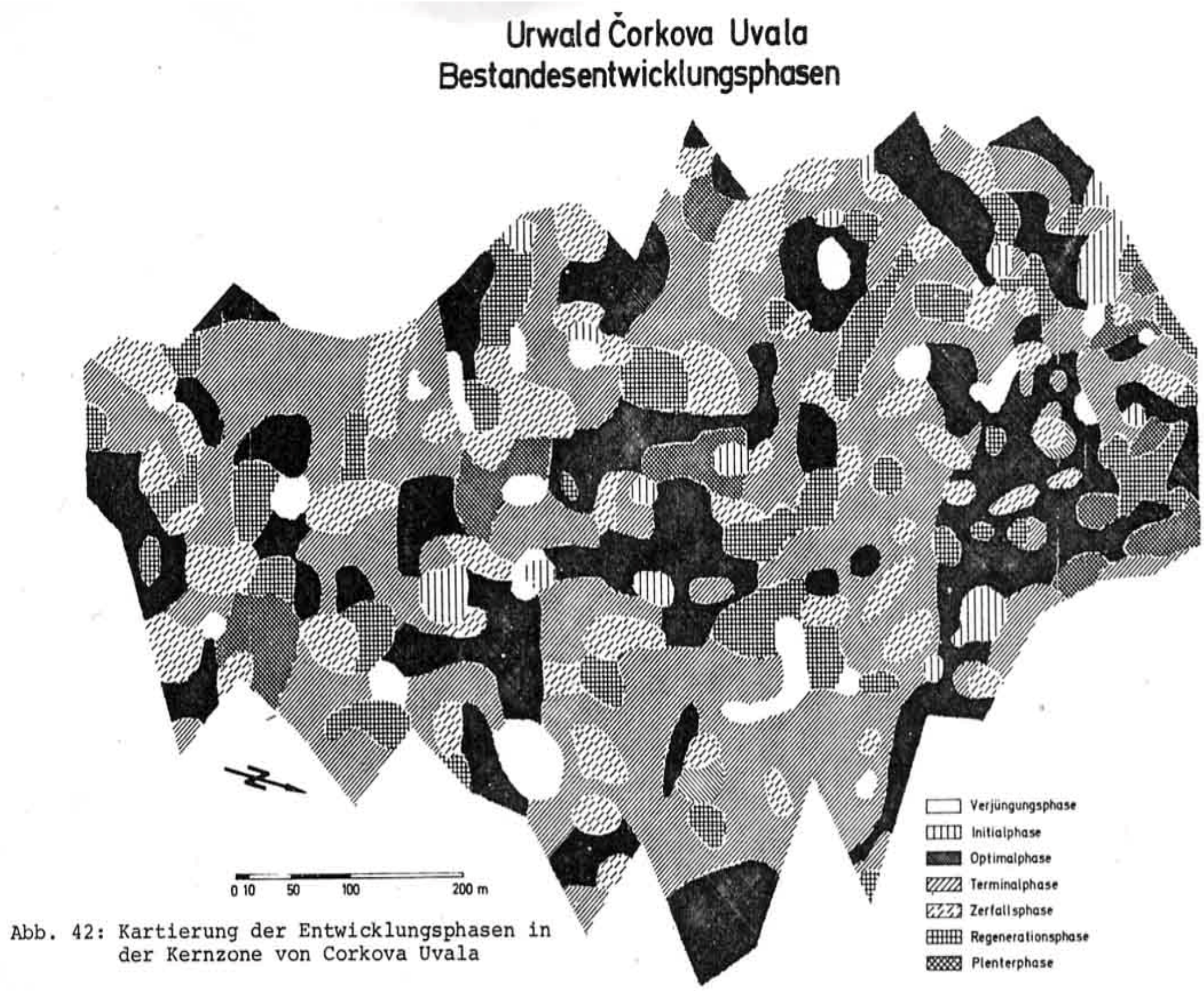

Fig. 3: The texture of the virgin forest "Corkova Uvala" results from a mosaic of different development phases (Neumann 1978;Emborg et al. 2000).

Fig. 4: Successional stage on a large wind-thrown area of several hectares within the primary forest of Badin (Slovakia). Initially, pioneer softwood species formed a successional forest, e.g., the willow *Salix caprea*. After 40 years, succession has resulted in a pole stand dominated by *Fagus sylvatica*. August 1994.

that the browsing pressure is not high enough to prevent a reforestation. The cattle avoid spruce and fir trees (Liss 1988). These results contradict the picture of an "originally park-like, cleared" landscape in the montane belt.

However, at a landscape level, some specialized trees of floodplains such as *Alnus*, *Populus* and *Salix* show physiological characteristics such as a quick germination on raw soil, resistance to browsing and the capability to vegetative regeneration, which may be interpreted as adaptations for the regulation of zoogene stress factors (Walentowski & Karrer 2006). River valleys are the preferred migration routes of herds of megafauna and have the highest population densities because of their warmth, semi-open landscapes, and availability of ample food and water.

2.4. Conclusion

With regard to the present state of knowledge, the reduction of naturalness to the level of floristic composition of an area can not be seen as satisfactory (Walentowski & Winter 2007). A valid evaluation of naturalness must include more than the percentages of tree species in a stand. It has to integrate structural criteria and dynamic forest models at the landscape level. Additionally, it must include consideration of the forest-dwelling animal species, especially those which demand long and continuous habitat traditions (Müller et al. 2005, Roberge & Angelstam 2006; Dorow et al. 2007). Constructs of naturalness should also take into consideration the possibility of the existence of a local and site-determined half-open, park-like forest pasture landscape. Definitions of naturalness have to take into account the influence of wild cattle (*Bos primigenius*), elk (*Alces alces*) and predators such as lynx (*Lynx lynx*) and wolf (*Canis lupus*). Even in the future, it is not going to be possible to resolve the uncertainties about the extent and length of the clearings in a "real natural" forest, because for methodological reasons the reconstruction of the „original forest state“ will always remain hypothetical (Siipi 2004, Fischer & Young 2007).

3. Degrees of naturalness

After Tüxen (1956), a great number of authors have dealt with the question of the potential natural vegetation. Because natural vegetation in Europe can hardly be found any more, they were trying to define degrees of naturalness or of its inverse, the hemeroby (degree of artificiality). Some of the more significant studies are by Ellenberg (1963), Sukopp (1972), Blume & Sukopp (1976), Dierschke (1984), Kowarik (1987, 1988), Kalkhoven & van der Werf (1988), Härdtle (1989), Jahn et al. (1990), Waldenspuhl (1990), Seibert & Conrad-Brauner (1995), Fischer 1995, Koch & Kirchmeir (1997), Leuschner (1997), Schmidt (1997), Stöcker (1997), Zerbe (1997), Grabherr et al. (1998a, 1998b), Michiels (1998), Kowarik (1999), Schirmer (1999), Reif (2000), Machado (2004) and Siipi (2004) (table 1).

In evaluating the degree of naturalness of vegetation, the construct of the present-natural potential vegetation is almost always used as a measure (Dierschke 1984, Kowarik 1999). This reference is needed, because to a varying extent all Central European forest structures and species compositions have been changed by human influences.

Table 1: Grades of hemeroby or naturalness (after Grabherr et al. 1998, modified)

Grabherr et al. 1997, 1998	**Hornstein 1950**	**Dierschke 1984**	**Ellenberg 1963**	**Examples from forests** (following Grabherr et al. 1998, modified)
9 (ahemerob)	Natural forest community	Natural	Virgin	Forests **untouched** by man, inaccessible sites; or previous impact completely historic; e.g., spruce forests and Pinus mugo-"Krummholz" on steep slopes in the Alps
8 (γ-oligohemerob)			Natural	
7 (β-oligohemerob)		Near-natural	Near-natural ("naturnah")	Forests **with irregular, weak, selective use**; near-natural tree species composition; only minor modifcations of ground vegetation and stand strucutres; absence of old stand phases ("decaying stage"); e.g., some spruce forests in the Alps.
6 (α- oligohemerob)	Seminatural managed forest		Relatively near-natural	
5 (β-mesohemerob)		Semi-natural	Relatively unnatural ("naturfern")	**Moderately modified** forests. Dominant and subdominant tree species of the potential natural vegetation occur, but with shifted proportions due to management (harvesting of trees, wood pasture). E.g., beech-fir-forests with >50 % spruce in the Alps
4 (α-mesohemerob)	Relatively unnatural managed forest ("naturferne Waldbautypen")	Relatively unnatural ("Naturfern")		**Strongly modified, intensively used** forests with simple stand structure (evenaged forests); tree species of pnV only minor canopy component. In the ground vegetation, many species from openland (ruderals, weeds) can be found, or even complete absence of ground vegetation due to lack of light. Example: stand with canopy formed by spruce or even exotic species (only few deciduous native species) in beech climate.
3 (β-euhemerob)			Relatively unnatural ("naturfern")	
2 (α-euhemerob)	Not natural managed forest	Artificial („künstlich“)	Not natural	"Artificial" (evenaged) forest of planted tree species not native to that site; in field-layer ruderals and weed species predominate, forest species are rare. Example: Afforestation with conifers (in beech climate)
1 (polyhemerob)	Artificial forest		Artificial ("künstlich")	

The present-natural potential vegetation has to be reconstructed and defined for each site. The degree of human influence is reflected in the deviation from the present-natural potential vegetation. This is normally expressed in a graduated scale. In most cases, the high naturalness of pioneer forests is still ignored (e.g., Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft [BMVEL] 2004), and "naturalness" is here being confused with "restorability" (figure 1).

The definitions of the ordinal classes representing degrees of naturalness, and the names used for these is very much a political issue. Differences in the selection, weighting and balancing of the indicators (parameters), and subsequent subjective terminology of the degrees of naturalness can lead to totally different conclusions about naturalness. In the various methods of forest habitat mapping, the evaluation of the degree of naturalness has very important consequences for management practice. The evaluation of the degree of naturalness can be steered in a certain direction according to the classifications and indicators selected.

Example 3: In forest habitat mapping in Baden-Württemberg, southwest Germany, a stand with a share of 49% of an exotic species, e.g., Douglas Fir (*Pseudotsuga menziesii*), and 51% of a natural, site-adapted species, e.g. beech (*Fagus sylvatica)*, would have been classified as "relatively natural" (Schirmer 1999; table 2), the same stand in Lower Saxony would have been considered "still seminatural" (Weigel 1998).

Example 4: After publication of the second national forest inventory ("Bundeswaldinventur II"; Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft [BMVEL] 2004; table 3), the definition of naturalness of the tree species composition provoked controversial debates between foresters and nature conservationists (Reif et al. 2005). For example, the canopy composition of pure, even-aged spruce (*Picea abies*) forests in Northeast Bavaria led to this being regarded as "moderately near-natural" ("bedingt naturnah"; table 3), because it was argued on the basis of a minor presence of spruce in pollen profiles that this species already played a significant role in the original vegetation of the region.

Conclusion:

(1) The dynamics and successional processes of natural forest ecosystems are unpredictable and subject to random fluctuations, caused by factors such as insect damage, storm and snow-break, amongst others. Successional stages following natural catastrophic disturbances of autochthonous tree species should also be attributed a high degree of naturalness.

(2) Analogous to the conditions in a mosaic-like forest landscape with various stand phases, the degree of naturalness in commercial forests should also be evaluated on a landscape scale, preferably at the level of a regional unit. Several hypothetical conditions of stands should be accepted as near-natural for a particular site type. For instance it should be checked, using the data of the appropriate forestry field office, which required elements of the (mentally constructed) natural forest landscape are already present and in what proportions. A major criterion would then surely be the presence of stands with a near-natural tree species composition. These could be managed as selection forests ("Dauerwald"), where structural conditions might correspond to the optimal phase or to the early "Plenterphase" (selection phase) of natural forest. But equally important are the presence of the degradation phase (overmature timber stand, "Altholz", containing large amounts of dead wood) and early successional stands which would cor-

Table 2: Scale of naturalness used for forest habitat mapping in Baden-Württemberg, Germany (Schirmer 1999)

Degree of naturalness	Characterization
1 (non-native)	Share of the tree species which are native on the site <20 %. Foreign tree species form the stand
2 (native to a certain extent)	Share of the tree species which are native on the site 20-49 %. Foreign tree species determine the stand
3 (relatively near-natural)	Share of the tree species which are native on the site >50 %
4 (near-natural)	Share of the tree species which are native on the site >80 %
5b (very near-natural)	The most important tree species of the pnv of the site are present. The share of accidental tree species <20 %
5a (very near-natural)	The most important tree species of the pnv of the site are present. The share of accidental tree species <10 %

Table 3: Scale of naturalness applied in the national forest inventory (BWI II) and its indicators (BMVEL 2004)

Degree of naturalness		Indicators
I	very near-natural	All dominant tree species which are native on the site occur; stocking of all of them >50% Share of the tree species of the natural forest vegetation >90% Share of exotic tree species <10%
II	near-natural	Share of the sum of all dominant tree species which are native on the site between 10 and 50 % of the stock Share of the tree species which are native on the site >75% Share of exotic tree species <30%
III	relatively near-natural	Share of the tree species which are native on the site between >50 and 75%
IV	strongly cultural („kulturbetont")	Share of the tree species which are native on the site between >25 and 50%
V	cultural	Share of the tree species which are native on the site <25%

respond to the initial and regeneration phases dominated by photophilous species.

(3) Definitions of naturalness have to be transparent and consistent.

4. Naturalness and time

4.1. Changing naturalness with time

In the 1950ies in South-west Germany, the natural state of postglacial forest was interpreted using pollen analysis linked to site assessment and reconstruction. The results were classified as regional forest communities ("Regionalwaldgesellschaften", Hauff 1960, 1961). The potential tree species composition proposed was then used as a reference by forestry management in this area.

Parallel to this development, other reconstructions of the natural vegetation started to differentiate between historical and actual natural vegetation (Firbas 1949). In the 1980ies, the discussions about forest dieback (Ulrich & Meyer 1987; Ulrich 1993; Schulze et al. 1989) and related environmental changes put more emphasis on the distinction between historical and actual naturalness. It became increasingly clear that changes in the environment induce long-term biocoenotic changes (Bürger-Arndt 1988; Ulrich 1993; Linder 1999).

Example 5: In sessile oak and pine forests on acidic soils with low base saturation, the invasive trees Douglas fir (*Pseudotsuga menziesii*) and black cherry (*Prunus serotina*) establish themselves naturally. With time, they may form completely new forest types. The forest site classification in Baden-Württemberg therefore attributes to their presence an increase in the naturalness of a stand (Michiels 1998; Aldinger et al. 1998).

Example 6: In the plain of the Upper Rhine Valley, south to Breisach, the bed of the Rhine has eroded and become much deeper during the last 130 years. As a consequence, the riparian forests of willow and poplar species that formerly grew there have completely collapsed (Reif 1996). Today, small-leaved lime (*Tilia cordata*) and some pedunculate oak (*Quercus robur*) are regenerating amongst the pioneering shrubs which for the moment dominate. In this case, a drought-tolerant oak-lime forest must be regarded as the present-natural potential vegetation.

Today almost all specialists agree that in many cases the present potential natural forest is different from the natural forest of the past, and climatic change is going to produce yet another type of pnV (IPCC 2007). Causes of the changing naturalness (pnV) are irreversible changes of site characteristics and environment as well as the extinction of species, the immigration and naturalisation of new species, and the resultant successional processes. Locally, important anthropogenic changes include, for example, drainage of soils or river regulation. On a regional and global level, changes in the chemical composition of the atmosphere are of overriding importance. Against this background, it is essential that we should distinguish carefully between original-natural, past-natural, present-natural and future-natural potential vegetation.

For methodological reasons, a mental reconstruction of the "original" forest is almost impossible. The biggest problem encountered here is deciding the point of reference in time. This might conceivably be placed in the Atlantic period, ca 6.000 to 8.000 years b.p. (Burga & Perret 1998), with the reasoning that man had not yet directly influenced larger forest regions and that beech had already begun to immigrate. However, even if a single period could be commonly accepted as a point of reference, the reconstruction of an "original natural state" would remain very difficult, either because the postglacial climate was different from that of today or because human influence had already begun to take effect.

Conclusion: Within a few decades anthropogenic site changes have led in many places to a new potential natural vegetation. For nature conservation, the question is if the natural states of the past or the present are to be aimed for, and how these are to be evaluated. In the end, decisions must be taken on where and in what proportion "nature" can be allowed to exist. As a consequence we must address the following problems:

- which species and ecosystems are able to adapt to rapid changes? Which are becoming endangered or extinct?
- do changes affect the significance of the criterion "naturalness"?
- how should the criterion originality = original-naturalness be handled?

4.2. Changing naturalness, changing value of naturalness

Changes in environments and species composition have always occurred and are a natural phenomenon of ecosystems. However, the frequency of changes has recently increased dramatically (Sprugel 1991).

Today's forest ecosystems are not in equilibrium with their environment; they are undergoing insidious biocoenotic changes. During the 19th century the former devastating forest exploitation methods of the agroforestry systems were replaced by a strict separation of agriculture and forestry. The spreading of diaspores, game densities, the extent and intensity of disturbances or silvicultural management as well as the potential to find a niche for new species are changing. Even in forests, exotic animal and plant species can naturalize and are increasingly being encountered (Kowarik 1988; Knoerzer 1998).

Example 7: The naturalization of Douglas fir (*Pseudotsuga menziesii*) on acidic, shallow soils in southwest Germany can eventually with time replace the original-natural sessile oak (*Quercus petraea*) forests and associated species (Knoerzer 1999).

Example 8: Introduced ornamental shrubs can naturalize, spread, endanger the native flora and fauna, and impede land use, e.g. the European shrubs Crataegus monogyna and Rosa rubiginosa in New Zealand (Webb et al. 1988) and Patagonia.

These direct human influences are taking place concurrently with changes in the atmosphere, involving "acid rain" (Schulze et al. 1989), emissions of nitrogen (Obersteiner & Smidt 2007; Umweltbundesamt 2007), or an increase in CO_2–content and temperature (IPCC 2007). In this way natural processes and "naturalness" are both steadily and rapidly changing. Under these conditions, long-lived ecosystems such as forests can hardly be expected to reach an equilibrium.

The consequences are a permanent modification and endangerment of existing biocoenoses, with a loss of their original characteristics. This endangers especially long-lived species, species with a low dispersal ability, as well as the evolutive adaptation of the species composition to the environment (Müller-Starck 1996; Jedicke 1997). In forests, even after many centuries, re-afforested sites have still not been colonised by all typical forest plants (Peterken & Game 1984; Wulf 1997; von Oheimb et al. 2007) and animals (Müller et al. 2005).

Conclusion: For nature conservation, the criteria of endangerment and originality (or original-naturalness) are becoming ever increasingly important in evaluation of a rapidly changing environment. The conservation of ancient woods and of the species native to those sites has to be given great attention (Peterken & Game 1984; Wulf & Kelm 1984). The qualitative and irreversible changes to biocoenoses following the extinction and immigration of species have to be regarded as very important. This underlines the increasing significance of the criterion originality, in spite of the practical problems associated with it, whereas the significance of the criterion naturalness decreases. Great emphasis should also be placed on the criterion restorability, especially in the case of biotopes which are difficult to restore.

5. Significance of naturalness

5.1. Significance to nature conservation

Natural forests are habitats for particular species and biocoenoses (e.g., Müller et al. 2005). They are rich in structures, dynamic, consist of a variety of phases (Leibundgut 1978; Mayer 1984; Korpel 1996) and are relatively stable and resilient. For evaluating the value of forests for nature conservation, the criterion of naturalness therefore has a great importance (Usher & Erz 1994; Scherzinger 1996; Reif 2000; Walentowski & Winter 2007).

Many species depend on structures such as large-sized deadwood. For Northern Bavarian beech forests it was possible to show that threshold values of deadwood between 38 and 60 m³/ha increased significantly the numbers of xylobiontic forest-dwelling beetle species, terrestrial molluscs and fungi. Deadwood quantities of >100 m³/ha appeared to represent another threshold, creating habitat suitable for Coleoptera of virgin forest ("Urwaldreliktarten") (Müller et al. 2007).

Naturalness is only one evaluation criterion among others. It must be seen in the context of criteria like diversity, rarity, restorability, completeness, particularity, originality (Peterken 1993, 1996, Reif et al. 2001). To illustrate this:

Fig. 5: Degraded alder swamp forest. The stilt-rooted alder (*Alnus glutinosa*) trees have established under soil conditions before severe peat decomposition. Today, more and more of the remaining "relict" trees are being harvested, and replaced by regenerating ash (*Fraxinus excelsior*) and maple (*Acer pseudoplatanus*) trees. - Wasenweiler, Südbaden, 7.4.2006.

- Many forest stands of Central European beech exhibit a high degree of naturalness in plant species composition, but a low diversity. They may contain only a few rare or endangered species, or none at all.

- Some of today´s near-natural forests may differ strongly from their original natural state, e.g., on hydromeliorated soil of former swamp forests (the "new" forest on the meliorated site may be near-natural, but the previous alder swamp forest may have been much more valuable, based on the criteria rarity, endangerment and restorability; figure 5).

- The special character ("Eigenart") and cultural value of openland regions would be completely altered if succession or reforestation towards more natural conditions should take place.

Conclusion: The value for nature conservation depends on the combination of all criteria, not only on naturalness.

5.2. Significance to forestry

The Central European forests are part of a cultural and not of a natural landscape. The preservation and the further development of production forests should also be according to the principles and aims of nature conservation (Jenssen & Hoffmann 1997; Lindenmayer et al. 2006). Sustainable forestry has to include the protection of rare, endangered forest species, the preservation of the diversity which is typical for a specific site, and a high degree of naturalness of biocoenoses (Götmark 1992; Schnitzler & Borlea 1998). This is why, as far as forests are concerned, a well thought-out combination of protected areas and production forests with differentiated integration of nature conservation aspects should be striven for, aiming at maintaining and improving ecosystem and landscape integrity (Müller et al. 2000).

Many foresters weight the criterion of naturalness very highly. For the sake of stand stability and soil preservation, it is sensible to strive for a tree species combination and stand structures that are as natural as possible (in a managed forest), with tree species native to the site (Böckenhüser 1992; Weidenbach & Karius 1993). Naturalness in forests means the co-occurrence of structural diversity of different stands offering a variety of niches, with species compositions belonging to all successional stages and cyclical phases. These conditions should exist at least partially and in some parts of a forest. It follows that naturalness can only be defined within a forested landscape, not within a single stand. For example, a "continuous forest stand" may be compared with an early "optimum phase" of forest models. The absence of other phases, including old growth and declining phases, will reduce the naturalness of the forest region.

Today, the relatively rapid changes in environmental conditions and changing balance of competition endanger not only species native to the site, but in the long term even the ability of ecosystems to function.

Example 9: The introduction of the fungus *Ceratocystis ulm*i from North America to Europe endangers the native European elm (*Ulmus sp.*) species. The vitality of the oak (*Quercus*) species is being reduced after the introduction of the oak-mildew fungus (*Microsphaera alphitoides*), which was recorded first in 1907 in Alsace (Jones 1959) (fig. 6).

Example 10: After their naturalisation, robinia (*Robinia pseudacacia*) and black cherry (*Prunus serotina*) are now driving out native woody plants on certain sites, forming completely new forest communities.

Example 11: Climatic change will cause replacement of the present forest vegetation on certain sites (IPCC 2007). Continuous instead of abrupt transitions will help to maintain habitat tradition for as long as possible. Today, strategies are needed to adapt the existing forest vegetation to the site conditions of the future (e.g. Kölling et al. 2007).

The attitudes and responses of foresters and nature conservationists to a permanently changing forest "nature" are different. Forestry tries to adapt the stands to future stress, and tends to welcome naturalized exotic tree species when these are productive. Nature conservation aims at preserving rare, endangered, native species, maintaining habitat continuity, and restoring habitats.

Little attention is paid by foresters to the facts (1) that the naturalisation of exotic species endangers species and biocoenoses which are native to the site and (2) that controlling processes of naturalisation of certain species will be difficult. Naturalisation of exotic species endangers the originality of the forests and their specific species inventory. This is why the following recommendations, on how to handle exotic species, are given:

- Exotic species should not be planted, or only to a very restricted extent, because it is only partly possible to predict the ecological consequences of their presence. Until now, evaluation of the effects of their introduction has been mostly restricted to the economic aspect. Species, biocoenoses and requirements of the forests which are regarded as original should be preserved as far as possible.

- If exotic tree species are planted, those plantings should be integrated in the natural forest scene. Mixed stands should be preferred to single-species stands.

- Unplanned natural regeneration of exotic species should not be given the opportunity to find a niche in neighbouring biotopes. If necessary, buffer zones of sufficient should be planned for.

- If measures have to be taken to remove exotic species that are naturalising in valuable biotopes, these measures should not endanger the species native to the site. Such operations should be controlled by an external agency, but the party responsible for introduction should be liable for the costs of removal.

- The extermination of unwanted, well-naturalised species is often no longer feasible. In such cases their further spread should be halted, as far as possible. The species might still be repressed locally, for instance, in order to conserve particularly valuable protected areas in their actual state. In other areas an integration of exotic species in land use planning should be strived for.

- Example 12: Responses to the spread of the black cherry (*Prunus serotina*) should be planned case by case, with local repression. A further spread should be stopped as far as possible. However, in forests where *Prunus serotina* has become extensively natu-

Fig. 6: Seedlings of oak (*Quercus petraea*), many of them infected by oak-mildew fungus (*Microsphaera alphitoides*), which was first recorded in Europe in 1907 near Colmar, Alsace. The infection reduces the vitality, growth, and survival of the young trees. - Freiburg, 7.7.2007.

ralised, it should be integrated in the exploitation model.

- The planting of exotic species on sites which are not used for the production should be stopped. Introduction and subsequent spread of exotic species increase the risks and reduce the degree of naturalness without bringing any economic benefit. Recommendations for planting northern red oak (*Quercus rubra*) or robinia (*Robinia pseudacacia*) on forest edges are neither economically justified nor compatible with the objectives of nature conservation.

Conclusion: Forest management which wants to embrace the aims of nature conservation must place greater emphasis on the criteria of originality, endangerment and restorability, somewhat at the cost of other criteria such as naturalness and diversity. In face of the dramatic drift of ecosystems and loss of species, forest planning should try to preserve requisites of the "original forest". Species and biocoenoses (ecosystems) native on a specific site may then be able to survive, as is postulated in the European Parliament Resolution, Objective 5 of 22 May 2007, on halting the loss of biodiversity by 2010. A forest industry can only be considered sustainable, in the sense of sustaining ecosystem services for human well–being, if it can fulfil these conditions.

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