UNEP

CBD

Distr.
GENERAL

CONVENTION ON BIOLOGICAL DIVERSITY

UNEP/CBD/SBSTTA/3/Inf.29
25 August 1997

ORIGINAL: ENGLISH

SUBSIDIARY BODY ON SCIENTIFIC, TECHNICAL AND TECHNOLOGICAL ADVICE
Third Meeting
Montreal, Canada
1 to 5 September 1997

BIODIVERSITY IN MANAGED FORESTS-Concepts and solutions

Submitted by the Government of Sweden

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Biodiversity in managed forests - concepts and solutions

Background

Forests cover 60% of Sweden, and forestry as well as forest biodiversity are central elements in Swedish economy and culture. Forestry has been conducted for centuries in large parts of the country, and this has created a managed forest landscape, like in many other European countries. For countries like Sweden with large forest-cover, and a cultural heritage closely connected to forests, protected areas can never be the only way of conserving forest biodiversity. To maintain biodiversity in the managed forests, and in the landscape, is a goal of equal importance as the production goal in Swedish forestry. To increase knowledge of forest biodiversity and its implications for forest management, an international conference, "Biodiversity in managed forests - concepts and solutions", was arranged in Uppsala, Sweden May 29-31 1997. 400 scientist from all over the world participated in the conference. An excursion with 150 participants followed the conference, with the aim to give visitors a view of Swedish forestry, and promote discussions on options and solutions.

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The Swedish Scientific Council on Biological Diversity

was established by the Swedish government in 1994, as one of many steps to implement the Convention on Biological Diversity (CBD). The Council is an advisory body to the government in issues concerning biodiversity, particularly the implementation of the Convention. The Council also prepares the Swedish participation in the meetings of the Subsidiary Body on Scientific, Technical and Technological Advise (SBSTTA) of the Convention. For this purpose, the Council has prepared this report from the conference "Biodiversity in managed forests". It gives the Council's view on the present knowledge of biodiversity in managed forests as presented at the conference. The conclusions and recommendations in the report were presented at the conference, but the present summary has been prepared by the Council. It does not necessarily reflect the views of all individual scientists.

The following report is based on information given at spoken presentations and discussions. A compilation of abstracts was presented at the start of the Conference and can be ordered from the organizers. A selection of papers will be printed in a special volume of Forest Ecology and

Management. It is important to stress that most of the studies presented at the Conference were conducted in boreal forests. Aspects from other regions are thus less well covered. Genetics were not included in the scope of the Conference.

General conclusions

The positive experience from the conference is that it seems possible to conserve most biodiversity within managed forests, provided that the biodiversity aspect is fully considered in the management. However, if only traditional economic aspects are applied in forest production, management to conserve biodiversity implies extra costs (or less profit) for the forestry. But to apraise the costs or benefits from biodiversity conservation, other values have to be included.

Ecosystem management is the most commonly used term for sustainable forestry, incl. biodiversity conservation. Ecosystem management focuses on processes rather than on individual species, acknowledges humans as a normal part of the ecosystems, and proposes that forests should be managed for multiple use. Thus, several goals for ecosystem management have to be considered, and non of them can be more important than the other. However, ecosystem management is not in itself sufficient to conserve species within the ecosystem, since all species are not needed for ecosystem functioning. We need a frank commitment to maintain biodiversity as an end, not as a means.

Forest history and natural disturbance regimes are by far the most important factors to guide management for biodiversity. In many forest landscapes, the natural disturbance regimes have been altered by man. Here, forest management might be a tool to mimic the effect of such disturbances. Reforested areas should be managed to resemble disturbance regimes in comparable, natural forests.

Variation in management practices provides conditions for conserving biodiversity. This should be acknowledged for example in areas with many small forest owners. It is vital to adjust the management to local conditions and to stand and landscape properties. All scales, in space and time, are equally important and must be considered: landscape level, stand level, and individual trees or structures. We need to keep the pieces, patterns and processes.

However, most knowledge about forest biodiversity relates to the species level. Ecosystem functions and processes are poorly understood. It is important to increase knowledge at the ecosystem level, but in the meantime, knowledge about species and species requirements have to be the guide for management.

Biodiversity conservation in managed forests needs to be supplemented with protection of unmanaged forest areas. These two components - the managed forests and the protected ones - should be viewed as integrated parts in the forest landscapes. Conservation strategies which solely rely on reserves will almost certainly fail. Retention systems and provision of critical habitat features within the managed landscape is essential both for maintenance of regional forest diversity, and to assure long-term sustainability of the intensively managed land. But reserves are also important, even if ecosystem management is applied. We do not know whether we can restore the species composition of virgin forests, hence a certain amount of such forests must always be preserved intact.

Communication and awareness are perhaps the most important tools to reach our goals. What are our conservation objectives, and how do we go about them? We need to fit in the biodiversity goals with the overall goals for a certain area. It is vital that knowledge on conservation biology is transferred from the scientific community to forest managers, land-owners, NGO's and the public.

More research is needed to improve our knowledge on management and biodiversity per see. But more important than increasing knowledge is to act now, and use our tools for short-term steering to reach our long-term goals.

1. Sustainable forestry with an ecosystem approach

1A Criteria for sustainable forestry

Sustainable forestry includes the maintenance of biological diversity. The following criteria have been proposed to qualify for sustainable forest management:

* All species can persist within a landscape over one rotation period.
* Critical habitats across the full range of spatial scales from individual structures to large areas of natural forest (reserves) exist within the landscape.
* Retention-harvest systems are used, retaining individual structures in the new stand (old decadent trees, snags, fallen logs).
* There is significant difference in the degree of resilience and resistance shown by populations and communities when exposed to natural disturbance or human-caused disturbance.

1B. Effect of management on biodiversity

Forest management creates younger, more simplified stands in smaller and more isolated patches, in a landscape with more roads and fewer fires, as compared to virgin forests. Usually, managed forests contain lower amounts of dead wood, offer a much more homogeneous habitat with few structures such as snags and fallen logs, and standing trees are evenly aged. Wetlands are also scarce in managed forests, as they often have been drained. A managed forest may, however, retain all the above qualities, if managed for biodiversity conservation. Managed and unmanaged forests may be rather similar in their biodiversity contents, provided conservation-oriented harvesting systems are used.

There will, however, always be species affected by forest management practices, and such species need specific conservation work to survive in managed landscapes. For example, bird censuses in mature forests in clear-felled areas versus selectively logged ones may show a similar diversity index and abundances of most species, but a small number of species are always negatively affected by clear-felling. Another example is provided by studies from different areas which show that old growth forests have 30-60% more species of saproxylic beetles than managed mature or over-aged forests, due to a much larger amount of dead wood. 40% of the Swedish red-listed species cannot survive clear-felling, but green tree retention does improve the situation.

In Australia, introduced *Pinus radiata* plantations with remnants of indigenous *Eucapyptus* forest have been studied, and compared to control patches in contiguous *Eucalyptus* forest. The results indicate that arboreal marsupials are absent from *Pinus* forest, and cannot survive in remnants smaller than 2 ha. Larger remnants support native marsupial species, with natural species diversity and abundance. The conclusion is that remnants within a forested landscape with introduced trees are important for keeping biodiversity.

Soil biodiversity, which is important both for biodiversity conservation and for production, is also affected by forestry. The effects of air pollution on forests, forest biodiversity and forest soils also has to be considered when discussing biodiversity conservation.

Forestry practices also affect biodiversity outside the forests. For example, fresh water ecosystems in connection to forests are often negatively affected by forestry, if measures to prevent these effects are not taken. Large-scale vegetation changes have been observed in some areas. However, there are no firm conclusions on what the causes are. Forestry practices, as well as major changes in grazing or browsing pressure, air pollution, and impact from drainage have been suggested. In Sweden, major changes in biodiversity in forests not affected by forestry, e.g. national parks, have been observed during the last 50 years. The proposed explanations are climatic variability, decreased fire frequency and changes in grazing/ browsing patterns.

1C. Management methods for the conservation of biodiversity

Timber harvesting should mimic natural disturbance regimes. The most important natural disturbance in boreal forests is fire, in temperate forests gaps and browsing are important, and in riverine forests flooding. Species are adapted to/dependent on such natural disturbances, and may tolerate harvesting better if forestry practices resemble natural disturbances. There are, however, problems in applying such a strategy. Often, we do not know the disturbance history of a forest type, and we do not know how to mimic nature, while still extracting timber from the forest. But there are methods to analyse forest history, for example pollen analysis. The present clear-felling strategy in Finland may seem relatively successful in mimicking natural disturbances, but stands lack in dead wood, the landscape is too homogeneous, and rotation times are too short.

In boreal forests, biodiversity may be preserved in a shifting mosaic of old and young forest stands, mimicking natural dynamics. In temperate broad-leaf forests smaller disturbances, allowing for long term on site continuity, is much more appropriate. When considering disturbance regimes, rare events can be important, e.g. for species with long-distance dispersal.

Reforested areas should, as far as possible, mimic forests natural to that region. Usually it takes a long time for plantations on land, formerly used for other purposes, to approach a natural species composition. With appropriate measures, even reforested areas can achieve high values. Relict forests within the area are extremly important for migration of species. Studies indicate a species number decline gradient with distance to old-growth forests.

Corridors may be useful, but they do not suite all kinds of organisms, and they will probably not create enough possibilities for migration. Studies indicate that dispersal in many organisms is slow. More studies are needed to establish the effects of corridors. So far, we must try to retain the possibilities for species to disperse within managed forests.

Silvicultural approaches that provide for variable levels of structural retention (live and dead trees) is an important element. The traditional harvest cutting system may be obsolescent. Retention can, and should, be used at different levels; stands, individual trees and other structures. Retention systems in boreal forests should as a minimum leave 1-10 green trees, mainly decidiuous, per ha, in groups rather than single trees.

The use of locally native tree species for timber production is perhaps among the most important single measures to conserve biodiversity. Trees also provide habitats for a variety of other species, and these habitats are likely to change if alien species are introduced. Thus, alien species can eradict native species connected with that habitat, like examples from Australia show.

We need to plan forestry at the landscape level, designed and managed for biodiversity conservation, visual harmony and economical benefits. Proportions, open spaces, edges, age classes, and special provisions for key species and habitats, etc. have to be considered. Forest stands should fit the local environment, and form a link with the wider landscape. Many studies indicate the value of manageing edges and gaps for biodiversity - much biodiversity conservation is then achieved at a low cost.

In Australian forestry, a three level landscape strategy has been implied, with large forest reserves (100-1000 ha) covering 15% of each forest type, small reserves (10-100 ha) within forestry areas, and on site management in stands (1-50 ha). A three-level pyramid has been used in Swedish forestry. The base of the pyramid is the managed forests, managed primarily for timber production. The middle are forests managed primarily for other purposes than timber production, such as biodiversity conservation, recreation or water protection, although timber is still extracted. The top are the protected areas, mainly old-growth forests.

There is no single optimal strategy for forestry, not even within one forest landscape. If we manage each stand for the same qualities and structural diversity at that scale, the effect at a larger scale, the landscape, will be homogeneity. Diversity in management practices is also needed.

2. Indicators and monitoring in managed forests

2A. Criteria for indicators

We need good indicators to measure our efficiency in management for biodiversity conservation. When defining indicators we need to carefully consider what they indicate, and establish statistical and causal relationships of associations. A good indicator should be applicable over large geographic areas, give early warning, react to a wide range of stress levels, be easy to measure without dependence on sample size, and natural cycles should be separable from human-caused trends. Indicators must be explanatory, definable and findable. Landscape parameters and structures, as well as species, are possible indicators.

The concept of indicator species as management tools for the assessment of the maintenance of biodiversity has barely been tested. Such species must be validated by intensive field study, and may exist for some forest systems but not for others. Maybe individual species are not that good indicators, but may be used to validate indicators at landscape level. A good indicator species should react critically to environmental changes. A good indicator species should also be area-limited, dispersal-limited, resource-limited, or process-limited, or perhaps a keystone species or a narrow endemic. Even if we may be able to define good indicator species, we need attributes of that species that are measurable. Abundance has too low statistical power, absence/presence may be less than perfect, and demographic traits need much work.

In some countries, there seems to be enough knowledge available to start monitoring with indicators, but we must continue to study them and validate our systems, to refine our techniques, and adapt our monitoring as knowledge gets better. The spacial scales for indicators are also important. We can not define indicators for a geografical unit, we must let the indicator be the guide to in which area or scale it can be used.

2B. Examples of indicators

Large trees, vascular plants, lichens, woodpeckers and wood-living beetles have been employed as indicators. Owl species and marsupial gliders are associated with many other forest species. They could be used as umbrella or indicator species. The term umbrella species is often used for species with specific requirements, for example large areas of a certain habitat. It can be assumed that if we are able to conserve the umbrella species, a lot of other species will also be maintained.

To use taxonomic groups instead of single species is one suggestion to improve the situation. Several studies show good quantitative relationship between number of species of saproxylic beetles and the amount of dead wood. The saproxylics are thus an indicator group that reacts sensitively to changes in amount of dead wood. A managed forest with many saproxylic species is probably also rich in other species adapted to old-growth forest. The amount of dead wood in a forest may therefore be used as an indicator of saproxylic diversity.

Polypores (fungi) are good indicators of old growth in Finland and Norway, as they depend on dead wood, and several species are endangered. Species numbers are directly related to the

(GIS), and use the resulting relationships to simulate the effect on species when altering habitat parameters.

New forestry techniques in multiple use forestry (e.g. uneven-aged stand management, prescribed burning) are usually not scientifically validated procedures. We need reserach on how such techniques affect biodiversity per se.

Very little is still known about the components of forest biodiversity. In Australia, it is estimated that only 12-15% of existing invertebrates have been described so far. The problem is even bigger in developing countries. There is a world-wide lack of taxonomists, that have to be addressed to solve this problem.

Diversity is needed also in research activities.

4 B. Future challenges

In the future, there will be a greater demand for resources, due to an increasing human population. The debate on intensified production in certain areas versus protection of complexity in other areas will continue. To acheive our goals, working links must be established between reseach and management (at all levels), and we need to look a changes as a challenge, not as a threat.

Annex 1.

Reed F. Noss, Forest assessment, monitoring, and planning, Submitted to special Volume of Forest Ecology and Management. Proceedings from the conference "Biodiversity in managed forests", Sweden 1997

Indicators that might be used to monitor degenerative trends in forest conditions (or their reversal through sustainable and restorative forestry). These are only examples of many potential indicators for monitoring and assessing the biodiversity and integrity of forests.

Trend	Indicators	Scale and Type of Measurement
Shift from older to younger age classes of trees; loss of old growth stands and old individual trees	Rotation period of stand-replacing disturbances (natural and human-caused); diameter and age class distributions of surviving trees in stand and trees removed from stand; mean and range of tree ages within defined seral stages across landscape; diversity of tree ages or diameters in stand; area of landscape occupied by old growth and other seral stages; amount of late-successional forest habitat in all patches and per patch	Landscape (remote sensing) and stand (direct measurements)
Shift from structurally complex, all-aged natural forests to simplified secondary forests and plantations	Abundance and density of key structural features (e.g., snags and down logs in various size and decay classes); spatial dispersion of structural elements within stand; physiognomy, including foliage density and layering (profiles), canopy openness, and horizontal patchiness of profile types; percentage of stand in gaps of various sizes and ages since formation; diameter and age class distributions of surviving trees in stand and trees removed from stand; diversity of tree ages or diameters in stand; abundance of species dependent on particular structural features	Direct stand-level measurements for most indicators; remote sensing for some (e.g., gaps)

amount of such wood, which in turn relates to stand age. Old growth has 37-53 species, and mature managed forests 20-33 species.

Structures and landscape features are also used as indicators. However, the use of such indicators must often be validated with species occurence.

A table with examples of indicators is given in Annex 1.

2C. Monitoring

We need monitoring in order to know whether we actually do conserve biodiversity, and whether it is efficiently done. Monitoring is needed at many scales, and at all levels of biodiversity. For example, genetics and population demography are also important. Adaptive management demands assessment and monitoring, which must be linked to research, with similar scientific standards. Partnership between land managers and research scientists is critical for success.

Monitoring often gets too low priority and insufficient funding, probably because a long-term commitment is needed. It is important to make governments etc commit themselves to long-term monitoring, in order to reach the long-term goals of conserving biodiversity.

Three levels of monitoring can be identified:
Implementation monitoring - did we do what we planned to do? Were the recommendations followed?
Effectiveness monitoring - did we do it right? Were the recommendations relevant and purposeful?
Validation monitoring - were our assumptions correct?

Protected areas are important as controls for monitoring.

3. Incorporating traditional systems & participation of local communities

A participatory approach, where all parties concerned, including forest workers and local communities, are participating in planning and management is a prerequisite for biodiversity conservation. Management must be planned from ecological, technical, environmental, socio-economic and cultural aspects. It is important that the people actually living or working in the forests are involved in decision-making and implementation. A full understanding of the rationales for the objectives is needed, for people to feel responsible and collaborate in ecosystem management. Local participation is also needed for adaptive management. In Sweden and Finland, a large reseach project has been started to analyse possibilities for local participation of interested non-owner parties in decision-making for sustainable forest management at the landscape level.

Ownership of forests often correlates with management practices, and thus with biodiversity. Forests owned collectively, or by big companies, create more homogenous and stable management, which may be positive if it is management for biodiversity. Small owners, however, often (but not necessarily) have diverse patterns for management, that generate more biodiversity, even if that is not the purpose. It is important that legislation etc acknowledges the use of different, local or indigenous forest practices, which may allow for innovations in managment practices.

Education and awareness about forest biodiversity issues are important, also for consumers. We need to increase knowledge and capacity for its dissimination. Access to available data is important, and can be acheived through databases and capacity building in developing countries.

4. Research and cooperation

There is little scientific evidence of biodiversity as a prerequisite for ecosystem function. Reserach in this field is clearly important, but much more important is to acknowledge our obligations for future generations to conserve biodiversity, regardless of its known monetary or non-monetary values. Research with the aim to increase knowledge on how to fulfil this goal is of vital importance.

It is also important that scientists communicate their results in an easily assessible way, and at an early stage. There is no time to wait until perfect validation of experiments are ready, as this may take many years. However, it is important to note that such results are simplifications, that might turn out differently when more research has been conducted in that particular field. There is a tendency to assume that the patterns measured are universal, while they often turn out to be site specific.

Science needs to challenge traditions, and to use wider perspectives to improve knowledge of forest biodiversity. We need a positive approach when testing new inventions, since if you do not believe in what you are doing, it will almost certainly fail.

4A. Priority research areas

We need tools to visualize the effects of management, and to evaluate the differences between forestry practices and natural disturbance regimes in their effect on biodiversity. We must study patterns/processes at the scale where they matter to forestry and biodiversity, and not just magnify small-scale studies, i.e., we need large areas and long time scopes in our studies. Empirical results can be used to refine management techniques continuously, and let the management supply the empirical results: adaptive management.

It is possible to use logging activities to set up "quasi-experiments". Unlogged controls and management with replicates is needed, so that the effects of logging techniques can be evaluated. This means close cooperation between the forest industry and academic researchers.

We need simulation models to evaluate the effect of different management techniques/strategies on biodiversity. This can be done e.g. through logistic regression of species distribution data (from monitoring) on geographically surveyable habitat parameters

Large blocks of continuous forest replaced by more, but smaller blocks	Forest patch size frequency distribution for each seral stage and community type and across all stages and types; size frequency distribution of late-successional forest interior patches (minus defined edge zone, e.g., 100-200 m); fractal dimension (a measure of boundary length and complexity); patch shape indices (e.g., deviation from roundness); patch density; fragmentation indices (e.g., from FRAGSTATS software); relative abundance and demographic characteristics of species requiring large patches of forest	Landscape-scale measurements using remote sensing (with ground-truthing); surveys of area-dependent species
Continuous or connected forest blocks replaced by separate, isolated blocks	patch density; fragmentation and connectivity indices; interpatch distance (mean, median, range) for various patch types; juxtaposition measures (percentage of area within a defined distance from patch occupied by different habitat types, length of patch border adjacent to different habitat types); structural contrast (magnitude of difference between adjacent habitats, measured for various structural attributes); presence of habitat corridors or other movement routes for fragmentation-sensitive species; relative abundance and demographic characteristics of species with poor dispersal abilities or otherwise isolation-sensitive	Landscape-scale measurements using remote sensing (with ground-truthing); surveys of isolation-sensitive species

Suppression of natural fires and other alteration of natural disturbance regimes	Frequency, return interval, intensity, timing (seasonality or periodicity), patch size (areal extent), predictability, variability, and other characteristics of fires and disturbances; patch size frequency distribution for each seral stage and community type; abundance and density of key structural features (e.g., snags and down logs in various size and decay classes); physiognomy, including foliage density and layering (profiles), canopy openness, and horizontal patchiness of profile types; percentage of stand in gaps of various sizes and ages since formation; relative abundance and demographic characteristics of species sensitive (either positively or negatively) to fire and other kinds of disturbance	Landscape (remote sensing) and stand-level measurements; surveys of disturbance-sensitive species

Construction of a vast network of roads to access timber	Road density (mi/ mi^2 or km/km^2) for different classes of road and all road classes combined; percentage of landscape in roadless area (for different size thresholds, e.g., 1000 ha and above, 5000 ha and above); miles or kilometers of roads constructed, reconstructed, and closed (seasonally and permanently) each decade; amount of roadless area restored through permanent road closures and revegetation each decade	Landscape-scale measurements using remote sensing (with ground-truthing); engineering data
Invasion of exotic species following road construction, site disturbance, and dispersal by vehicles, other equipment, and humans	Ratio of exotic species to native species in community (species richness, cover, and biomass); invasion rates and pattern of spread of exotic species; demographic characteristics of particular exotic species and native species sensitive to predation or competition from exotics	Stand-level measurements; landscape-level measurements for exotic species that can be sensed remotely
Increased air pollution, including low-level ozone, acid fog, acid precipitation, and particulates	Direct measures of air and precipitation contents; biomass increment and other measures of tree productivity; input/output budgets of ions (as indicators of change in soil pH and nutrient status and of tree nutrition); level of direct damage to leaves and other tissues; status of pollution-sensitive and pollution tolerant species	Stand-level measurements; remote sensing of patterns of mortality and morbidity

Global warming	Changes in biomass, distribution, productivity, and other characteristics of temperature- and moisture-sensitive species; changes in relative abundances of species with C3, C4, and CAM metabolic pathways	Stand and landscape measurements
Increasing recreational use of forests (hiking, hunting, fishing, camping, off-road vehicle use, etc.)	Access indicators (see roads indicators above; also density of airstrips, boat landings, other access points); size and proportion of area closed to human use; measures of erosion, ground-level vegetation density and condition; measures of exotic species invasion (see above); visitor-days for various types of recreation; abundance and demographic characteristics of species sensitive to human harassment or simply human presence; visitor attitudes	Stand and landscape measurements; surveys of sensitive species and visitor attitudes