Experiences in other reserves

A total of 60 forest reserves are included in the Dutch forest reserve program. The size of these reserves ranges from 5 to 450 ha. So far 50 reserves have been recorded for the first time and already 10 of these reserves have been recorded for the second time. Based on our experiences in these reserves “Vijlnerbos” is an ordinary reserve for its size in terms of time needed for the fieldwork. Time-consuming reserves are either difficult to access (low thorny shrubby growth in the dune area, large number of small streams and ditches, large amounts of blown over trees) or have a low transparency (young stands, dense shrub layers). Under these circumstances especially the time needed for the establishment of the grid system might easily double.

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6 Summaries of Data Collected in Different Countries

An overview of existing methodologies for the monitoring of stand dynamics in Strict Forest Reserves

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Introduction

Strict Forest Reserves are important research areas, both for fundamental and applied scientific research. They allow us to study the principles and mechanisms of forest dynamics and are the basic reference tools for nature based silviculture. They provide information on how to manage our forests in a close-to-nature context and act as controls for the evaluation of management impacts on the ecosystem and its faunal and floral components.

Ideally, truly virgin forests best perform these functions; however near-natural or managed forests that have been left unmanaged for long periods provide a modest ‘ersatz’, i.e. the next best alternative (Leibundgut, 1966).

Historical development

The first Strict Forest Reserves were established during the 19th century for ‘aesthetic’ reasons. Very little research was carried out in them. However, the first studies of forest structure and

dynamics in Strict Forest Reserves date back to the end of the 19th century. At that time the first full inventories were made of the last remnants of virgin forests in Central Europe, some of which had, by that time, received protection status.

Shortly after the Second World War, ideas on nature-based silviculture, which dated back to the beginning of the 20th century, received considerable interest, especially amongst the forestry universities in Central-Europe. This generated interest in strict reserves and more elaborate research programmes were established, using full inventories and line transects to study distribution and structure of different developmental stages (Leibundgut, 1959, 1981; Mayer, 1966, 1967, Mayer et al., 1988;Mlinsek, 1970; Korpel, 1995; Prusa, 1985)

From the 1970s onward, more attention was paid to the analysis of soil and ground vegetation; until then, measurements focused almost exclusively on trees, stand structure and tree mortality.

During the 1970s, interest in developing forest reserves increased in Germany, not only within forest science disciplines, but also for nature conservation purposes. In the absence of true virgin forests, well-structured managed forests were selected to become 'natural' forest reserves. Monitoring programmes applied here were initiated using a different approach, based on circular sampling plots within a grid system and detailed research in core areas (Albrecht, 1990; Bücking, 1990; Althoff et al., 1993). Within the Dutch forest reserves programme this methodology was further developed (Koop, 1989; Broekmeyer, 1995).

Even more recently, Strict Forest Reserves have become more important than ever, not only for their research potential, but also for nature conservation objectives. This is also reflected in modern research programmes. Not only do these programmes receive more attention, but also the scope of research has broadened to include important topics, which affect nature conservation. Inventories and monitoring of populations of fungi, birds, bats, saproxylic invertebrates and red-data book species are increasingly being integrated into monitoring programmes (Bücking, 1996; Rauh, 1993; Köhler, 1996).

In Scandinavian countries and in the British Isles, strict reserves have been established primarily for nature conservation, with nature-based silviculture being only of secondary interest. It is only very recently that there has been sufficient interest in developing forestry-related research in these areas. Nevertheless, there are important long-term studies of natural stand change and dynamics, with some transects in nature reserves dating back to the 1940s-50s (Peterken and Backmeroff 1988; Mountford et al., 1999).

Principal Results

The actual status and methodologies of monitoring programmes in the different member countries of COST-E4 are elaborated in Table 1 below. This information was largely derived from a questionnaire prepared by COST-E4 Working Group 2 and filled by the country representatives in this working group, combined with information derived from the country reports published in Parviainen et al., (eds.) (1999) and Diaci (ed.) (1999).

The principal findings confirm what might be expected as a result of historical developments in this field, i.e. although most of the countries have initiated monitoring programmes to study forest dynamics in Strict Forest Reserves, there are a wide variety of methodologies and parameters monitored in the different countries.

Methodologies can be split into two main groups :

- Many programmes, especially in Central European countries and a number in the UK have utilised long line transects, occasionally combined with mapping of the developmental stages for the whole reserve, based on full inventories or aerial photographs.
- Austria, the Netherlands Belgium and most German States have adopted grids of circular sampling plots,
- sometimes combined with detailed studies in a core area. Plot designs using clusters of circular plots are applied in Finland.

Moreover, there is considerable variation in plot sizes, plot densities, and parameters measured across Europe. Even for parameters that seem very obvious and clearcut, different recording methods exist :

- Dead wood degradation stages are given in most countries, however the number of identifiable stages varies; most countries use four stages, some have five and others only three stages of degradation.
- DBH is measured in all countries. However, the minimum threshold varies between 1 to 10 cm DBH.

Discussion

In many countries, monitoring programmes have existed for many decades. One of the basic rules in monitoring programmes that incorporate permanent plot systems is to adhere to the chosen system, design and methodology. Only then can comparable data sets be compiled and subsequently, reliable conclusions elucidated. The more repetitions of parameter measurements that are made, the more interesting and reliable are the results and conclusions. Thus, it would be most unlikely and inadvisable that countries change their existing sampling programmes and methodologies.

The original goal of Working Group 2, namely the development of a common sampling plot technique for all European countries, is almost certainly over ambitious. The Working Group can however, produce a number of suggestions and recommendations for countries where new programmes have yet to be established.

If different countries wish to co-operate and combine their data for analyses - which is strongly advisable - recommendations can be made on how to rationalise national monitoring programmes so that data comparisons can be made.

Conclusions

1. It is possible that general conclusions can be drawn where different methodologies are used. Existing methodologies can certainly be expanded; it is better to have a broad as opposed to a narrow focus, to keep records simple and archive details of the methodology used.
2. A standard approach is unlikely to prove suitable because the aims of forest dynamic studies differ between countries across Europe (dynamics of canopy trees, factors controlling regeneration, influence of soil, etc.). In addition, conditions vary between sites within countries and in different parts of Europe. Recorders may need to introduce new methods or temporarily abandon existing methods as new methods arise superseding existing practices.
3. Advice on the minimum threshold for measuring different parameters (e.g. minimum stem size) is desirable as this enables comparison.

4. Long-term studies are by their nature somewhat open-ended as we cannot foresee what may arise in the future and the influence new factors may have on individual sites.

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Table 1. Overview of research methodology systems for monitoring forest stand dynamics in the participating countries of COST E4.

Country	Methodology for monitoring stand dynamics	**Additional information and research / specification/differentiation**
Austria Standard monitoring programme started in 1995	Guidelines for the establishment of monitoring plots, including a mandatory, detailed field manual under the new **National Forest Reserve Programme**. **Sampling method** : Circular plots (150-100 m²) in grids (50*50 or 100*100) and/or transects (10(20)*30(50)m or full inventory (small reserves). Regeneration in small sub-plots (1-4 m²) Ground-vegetation : 100-500 m² (Braun-Blanquet) resulting in forest communities – maps (based on relevés), Mapping scale : 1/1000 to 1/10.000 Mapping of developmental stages The new **National Forest Reserves Programme** includes a standard monitoring programme based on a permanent grid system, i.e. BITTERLICH sampling plot techniques. All trees <1.3 m are recorded using polar co-ordinates for periodical measurement: species. DBH in mm using girth band, tree height, stem quality and occasionally age. Monitoring frequency: dependant on forest community type.	**Global information :** Name, area, size, short description (height, slope, climate factors, geological substrate, soil type) **Specific description** : forest history (pollen analysis), stand structure Under the **National Forest Reserve Programme**, which was initiated in 1995,a minimal programme was developed for standard reserves and an 'enlarged programme' for key reserves. The minimal programme includes key parameters that should be monitored at the very least while the 'enlarged programme' contains extra parameters. Vegetation relevés measured using the Braun Blanquet method, where possible, within the grid system. Detailed soil mapping and description, and mapping of forest communities are obligatory. Specific monitoring programmes carried out in key reserves, i.e. burned areas or virgin forest remnants. Remote sensing using aerial photography in key reserves and additional faunistic research at selected sites.
Belgium (Flanders) Standard monitoring programme to commence in 2000	**Sampling method** : Standard : circular plots in grid (50*50-100*100) + core area (1ha). <u>Nested circular plots</u> : 1000 m² : position, species and DBH of trees (DBH>40cm) 500 m² : position, species and DBH of trees (DBH> 8 cm) 100 m² : regeneration / 16*16m square : vegetation relevés Light measurements and soil sampling <u>Core area</u> : full inventory with crown projections.	Standard programme for 30 reserves Minimum programme for all others: transects 10*100 m (1 transect every 3-4 ha) Additional faunistic research in selected reserves : - xylobiontic organisms - bird inventories - mosses, lichens and fungi.

Denmark No standard monitoring programme to date	**Sampling method :** A basic research programme for natural forests was developed in 1995 (Nielsen *et al*., 1995) but has yet to be implemented. It is planned that permanent plots will be established where tree positioning, DBH and tree height will be measured. Biogeochemical and climatic measurements, as well as inventories of flora, fungi and selected groups of insects are envisaged. Approximately 6 to 8 strict reserves are presently monitored at regular intervals by a number of institutions in Denmark. However, this is not done using a standardised methodology.	Minor strict reserves were established by the Geological Survey in 1948 in stands dominated by native species. The purpose was to use long term monitoring of forest dynamics for in order to obtaining better tools for interpreting pollen diagrams. (Pollen analysis is a major topic of research). Some specific research on structure, dynamics and light-conditions is carried out at some reserves In Draved skov, 2 stands of 4-6 hectares each, have been monitored intensively since1948, while the geological Survey of Denmark have been monitoring in Eldrup Skov 1 stand of 9 hectares since 1968. Monitoring includes canopy trees (position (mapping), diameter, crown health, etc., for all trees with dbh > 10 cm) on single tree level and understory at grid level (25 m^2). Soil and herb vegetation are assessed on a 10*10 meter grid. Pollen deposition is monitored using traps (Møller 1987, 1988).
Finland Monitoring programme started in 1993	**Sampling method :** 400-500 permanent sample plots established in strictly protected areas spread across all forest types in Finland (some plots in Russia) Typically a plot consists of 1 central circle (circle size : 900-2500 m² depending on stem number) and 8 satellite circles (circle size: 180-500 m² depending on stem number). All trees (living and dead, DBH>5cm) are recorded in the central plot and 4 of the 8 satellite plots (species location, DBH, understorey, health, shape; (Height and bole length for designated individuals). Small trees (DBH<5cm are recorded in all 9 plots (circle size: 100m²). Monitoring frequency : 10 years	Vegetation relevés, vegetation mapping, fauna, humus soil and nutrient cycling are optional depending on the availability of experts, i.e. optional -not included in the standard programme.
France No systematic monitoring programme to date	Monitoring and research carried out in Fontainebleau. In 1999, a monitoring programme of Strict Forest Reserves was launched in public forests, based on the COST - guidelines (e.g. the strict forest reserve of Guebwiller in the "Vosges" mountains, ca. 110 ha).	

Germany Every 'State' has its own system. Some programmes initiated as early as 1975, but most were initiated between 1985 and 1990.	**Sampling method : (*based on Balcar (s.d.)*** In 13 Länder, monitoring programmes are performed. In 4 cases, a grid of circular sample plots is used, in 1 State, a core area is used, while in 7 States, a combination of both is used. Full inventories are only used in the monitoring programme of one State. Sample plots vary in size between 0.05 and 0.5 ha (mostly 0.1 ha), while core areas vary between 0.21 to 2 ha (generally 1 ha). Measurements : Living trees (DBH >4 –7 cm (in most cases > 7 cm): species, DBH, height (all), x,y co-ordinates (11 out of 13), crown-parameters (5), bole-length (5), IUFRO-classification (8) Regeneration : in small subplots, including shrubs < 7 cm DBH Dead wood : considerable variation on minimum diameter for lying dead wood ; DBH, length, degradation stage (4 classes), species (where possible)	In almost all States, ground flora is studied using vegetation relevés in the sample plots. A great deal of additional research is done on fungi, xylobiontic beetles, birds, and other ecosystem components. Also reserve areas are often compared with managed areas located nearby. This research however is, as a rule, limited to case studies, and is not systematically included in the monitoring programme.
Greece No systematic monitoring programme to date	Only a few experimental plots designed according to COST guidelines. **Sampling method :** Single circular plots of 500-1000 m². Tree species, position, DBH. Minimum size DBH = 5 cm	Vegetation relevés optional
Hungary First monitoring/ research initiated in 1986; systematic monitoring/ research started in 1997	An official programme, focussing on ten so-called 'sample and demonstration reserves' was initiated in 1997, however the monitoring programme is still being developed. After mapping of developmental stages and forest-types, permanent plots are installed in each of the ten reserves. Until recently, vegetation and soil surveys were generally the norm. **Sampling method :** Mainly transects (20*20 m) (also sample plots on a 50*50 m grid; variable size using relascope Measurements : Tree species, position, DBH, height and crown dimensions	Other data is now being collected in the ten study areas including : Geological description, historical data, detailed soil-mapping (1/5000) and soil-profile analysis, meteorological observations, microclimatic studies, tree ring analyses on dead wood, vegetation mapping, mosses, fungi, data processing of aerial photographs and faunal inventories

Ireland No systematic monitoring programme to date	Isolated monitoring projects with permanent plots since 1975; no standard methodology **Sampling method :** sample plots of 25-15000 m² Major emphasis on vegetation description and assessment of regeneration – published data on stand structure is scarce	The sites with longest data sets include those at Killarney and Glendalough. Roughly ten years of data collected at Brackloon Wood, i.e. forest health, radioisotopes, soil fauna, flora (ground and arboreal), bats, birds – all using approved methodology, i.e. UN-ECE and ECN protocols. Soil research, pollen analyses and site history combined in order to interpret future monitoring data more accurately
Italy No systematic monitoring programme to date	**Sampling method :** 24 permanent plots, 1-6 ha each (84 ha in total) are left unmanaged and have been studied since 1952. Dendrometric and floristic analysis	Dendrochronology
Netherlands Systematic monitoring started in 1988.	**Sampling method :** Combination of circular plots and core areas 50-70 circular plots (500m²) stratified randomly selected on a 50*50 m grid. Living trees : DBH (>5cm), co-ordinates, species; Small trees (DBH>5cm) counted and height >0.5 m; dead wood (DBH>10 cm) : species, DBH, degradation phase vegetation relevés (18*18 m, 36 subplots), 1 core-area (70*140 m = 1 ha) : vegetation mapping, living trees (DBH>5cm) : species, DBH, co-ordinates, crown-parameters; dead wood : cfr. Circular plots; vegetation and regeneration studies in central strip (10*140 m) Monitoring frequency : 10 years	Additional research in all monitoring sites : Soil profiles (every circular plot), geological mapping, aerial photography Mapping of indicator species denoting old-growth forests Additional research on fungi, birds and beetles at some sites
Norway No systematic monitoring programme to date	Some studies and inventories are carried out when reserves are being established. The Norwegian Monitoring Programme for Terrestrial Ecosystems, established in 1990, includes research on stand structure, ground vegetation and epiphytic lichens in some protected forest areas. The ground vegetation is monitored in permanent plots at different scales, using 0.25*0.25m, 1*1m and 5*10m sample plots in selected core areas.	An inventory of red data book species is carried out. Mapping of indicator species. Integrated studies of chemical and biological monitoring, including precipitation, soil, vegetation and faunal parameters.
Portugal No systematic monitoring programme to date	No monitoring programme on protected areas; only plant inventories, vegetation mapping and phytosociological studies	Additional faunistic inventories are performed in places

Slovakia **Very long tradition of monitoring in strict reserves**	Long-term research : main results published in Korpel (1993) **Sampling method :** Permanent experimental plots of variable size (occasionally whole reserves) : living trees DBH>8 cm : species, DBH, height, sociological (age) class, stem and crown quality, degree of sucker formation, damage; necromass (3 degradation phases) Transects : living trees DBH >1cm : species, DBH, height, position, crown parameters, regeneration (using 4 height classes) Monitoring frequency : 5-10 years	Biogeochemistry
Slovenia Very long tradition in monitoring of strict reserves	**Sampling method :** 1882-1950 : full inventory of stand structure in the old-growth forest reserves (up to 100 ha) 1951-1980 : in 25-30 reserves : additional new network of permanent plots in all typical identifiable developmental phases of the woodland : transects mainly of 1-2 ha measurements : living trees (>5cm DBH) : species, species co-ordinates, DBH, height, sociological (age) class, stem and crown quality, damage, health condition; necromass : species, level of degradation, co-ordinates; shrub, ground-vegetation and mosses; subplots for regeneration patterns Monitoring frequency : 5-10 years	Some reserves have very valuable data sets, i.e. repeated measurements at regular intervals over 100 years. Additional research : Phytocoenology, zoology, birds, fungi Recent developments : emphasis on inter-disciplinary and comparative research in reserves and managed areas
Spain No systematic monitoring programme	Structural, dynamic and functional studies on natural forests are very scarce, permanent plots almost non-existent. A detailed monitoring programme occurs at only one location, i.e.: in Garajonay N.P. (Started in 1995) **Sampling method :** Global vegetation level : information on structure, growth, regeneration, mortality in all forest communities : circular plots of 250-900 m² in a 500*500 grid (62 plots) Living trees DBH>7 cm : species, DBH, height, vitality, regeneration : in subplots; vegetation relevee in 10*10m subplot Gaps and necromass (DBH>10 cm) measured and positioned; Monitoring frequency : 10 years Additional necromass studies in transects (DBH>40 cm) : measured annually Intensive vegetation monitoring : 6 circular plots out of 900-2500 m² Monitoring frequency : 5 years	Inventories made for the EU Habitats Directive and for the inventory of National and Natural Parks of Spain. Additional research in Garajonay : hydrology, climatology, inventories of autochthonous and introduced fauna, endangered species, qualitative erosion, fuel accumulation and aerial photography

Sweden No systematic monitoring programme	Strict reserves are especially selected for protection purposes, not for research An 'Integrated environmental monitoring' programme is performed at 18 locations : measurements of a wide range of ecosystem variables in small catchment areas	Many independent research activities in National parks and reserves, which mainly focus on conservation biology : - inventory of fauna and flora in remnant biotopes - biodiversity indicators in the forest landscape - bird and xylobiont beetle inventories
United Kingdom **No systematic monitoring programme**	No nationally co-ordinated research programme on forest dynamics, but the statutory nature conservation body in England (English Nature) is initiating a programme in a representative series of semi-natural reserves managed under a minimum intervention policy. Part of the Environmental Change Network (ECN) monitors forest dynamics and there are several existing baselines and some important long-term studies in unmanaged woodland reserves (Peterken and Backmeroff 1988) **Sampling method** : 20 m wide transects (some are up to 1 km long), small plots based on a 50-100m grid system or individual plots: all living trees over 1.3 m height and all stems over 1-5cm DBH: position, species, DBH, crown position (5 classes), crown parameters (in rough classes), crown dieback, trunk damage, description of stem form Necromass and canopy gap estimation : line transect method or measurement and plotting of large dead wood pieces DBH >10 cm; length > 1m), plotting of gaps onto transect/plot diagrams Ground vegetation : established coverage of each species per block Monitoring frequency : approximately every 10 years	Some UK environmental change network sites include forest reserves: integrated monitoring of a wide range of variables, including climate, hydrology, air pollution, vegetation, soils and animal populations Forest vegetation and tree measurements: Up to 50 square permanent plots, 10 m*10 m, randomly selected from a grid. In each plot up to 10 trees are marked and recorded for DBH every three years and for height, every nine years. Ground vegetation is recorded every nine years in these plots; other plots are used to record ground vegetation every three years (Sykes & Lane, 1996). There are also grid systems elsewhere, e.g. at Wytham Woods (established in 1976 – Kirby *et al*., 1996)

Table 2. Differences in criteria measured and monitoring methodologies used in Strict Forest Reserves in fifteen European countries

Country	grid based	line transects	core area (ha)	circular plot size (m2)	ground vegetation	mapping scale	min. Tree height (cm)	min. DBH (cm)	dead wood classes	Monitoring frequency (yr)
Austria	50(100) * 50(100)	10(20) * 30(100)		1-4	BB 100-500 m2	1:1000 / 1:10000	130	-		
Belgium	50(100) * 50(100)		1	1000 (500) {100}				40 (8) {-}		
Finland				1*[900-2500] + 8*[180-500]				<5 / >5		10
Germany	50(100) * 50(100)		0,2-2,0	500-5000	100-500			4-7	yes / 4	10
Greece				500-1000				5		
Hungary										
Ireland				25-15000						
Italy										
Netherlands	50*50		1 (70*140 m)	500			50	5	yes / 4	10
Norway										
Slovakia								8 (1)		5-10
Slovenia			1-2					5		
Spain	500*500			250-900 (900-2500)				7		10 (5)
Sweden										
UK										