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Characteristics of a natural forest

In Europe, the tradition is to preserve tree cover with the main purpose of maintaining wood production potential. During the last 15 years or so, there has been a general movement towards more emphasis on managing forests for the purposes of generating richer wildlife and greater biodiversity.

This shift in forest priorities implies a need for evaluating the forest concept and considering what aspects of forests are important for wildlife and biological richness. This paper attempts to do both, based mainly on observations in Denmark and Northern Central Europe.

In the following, some major general characteristics of the multitude of types of tree-dominated land we may call natural forest are described. The purpose is to portray some of the many factors - food productivity, vegetation composition and structure - that makes woody vegetation a framework and basis for very rich and diverse life, yet it is far from being an exhaustive list. For example, hydrology and many specialized animal species are also keystones in shaping the natural forest but these aspects will not be covered here.

WHAT IS A FOREST?

In the nemoral zone (the temperate broadleaf forest zone) of Europe, "forest" is the term commonly used for areas designated for specialized agricultural production - wood and Christmas trees and greenery. In contrast, the forest viewed as a biological system may be very different from plantations and other production forests and may even be found outside those areas we call forest in administrative and productive sense. Gardens, orchards, parks and tree avenues are not considered as forests yet they may have bird, insect and mushroom species characteristic of tree-dominated natural communities.

Woodlands that are used for wood production purposes and forests that are not, will most often turn out very different in structure and biological content. In order to distinguish between them, the term "untouched forest" will be applied to signify forests untouched by wood production measures. The term has become common usage in Denmark in recent years.

"The nearness principle" of the natural forest : many species specialized to live on dead wood rely on high density of large dimensional dead wood for their dispersal and longterm survival. (Photograph: Nepenthes/ Carsten Brandt).

PRODUCTIVITY

Forests untouched by wood cutting are normally perceived as quite unproductive. Yet this is far from true. On the contrary, untouched old-growth forest is the biological system which has the greatest primary production in the nemoral zone. A fully grown forest has more foliage and hence greater photosynthesis than any other kind of vegetation. We must therefore expect forests to be the most productive of all ecosystems in terms of biomass produced per unit area and energy fixed in plant material. When no wood is removed, this large quantity of organically fixed energy (calories) remains as food in the ecosystem.

At the same time, most organisms that consume and convert wood and other plant material, are highly specialized. Untouched or non-intervention forest is therefore an ecosystem which has a strong basis for both a great quantity of animals of all sizes and for a great diversity of species. "Dead wood" is not dead, but the food and habitat for myriads of lifeforms.

TREE SPECIES DIVERSITY

It is a widespread myth in forestry that our natural forests - particularly in northwestern Europe - are poor in tree species (e.g., Whitmore 1978). This is not the case. A small country like Denmark has 61 native woody species. Southern Europe to the Alps has some 253, Europe north of the Alps 140, and Europe north of Denmark some 72. In total, Europe to the Ural Mountains has 386 species of woody plants reaching a height of two meters or more (Thomsen 2000).

Comparing equal-sized parts of temperate North America and Europe, species numbers are much the same (**Table 1**). When apomicts are included, i. e., most of the numerous species of *Sorbus*, Europe is richer in woody species than North America. Hence the natural species richness in European forests is typical for the temperate zone, rather than being poor.

TABLE I.
Number of species of trees and major shrubs in comparable regions of Europe and North America. The account shows that the natural forests of Europe are as species-rich as those of North America (Source: Huntley 1993).

Region	No of species	Area in mill.sqkm	
		total	under 1000 m
Western North America	324	12.7	8.5
Eastern North America excl. Florida	318	7.6	7.5
Europe (West. of 30° E)	286	10.0	9.2
Europe (incl.apomictic species)	359		

*Note: A plant species being apomictic means that its flowers produce seed without pollination, i.e., reproduction is asexual. For example, dandelions (*Taraxacum spp.*) constitute a large group of mutually closely related apomictic species. The same is true for brambles (*Rubus spp.*).*

INDICATIONS BY RED DATA BOOKS

Red Data Books comprise species that are extinct, threatened or in need of protection in a given area. In Denmark, the distribution of redlisted species in different types of habitat shows clearly that forest ranks highest, with more than half of the Danish total (**figure 1**).

Before 1990, Danish redlists comprised mainly of species of mammals, birds, reptiles and flowering plants. As many of these are not found inside the forest for biological and historical reasons, the importance of forests for biodiversity was not evident. Since then, surveys have begun including the really species-rich groups like fungi, lichens and numerous insect taxa. They comprise thousands of species of which many are forest species.

Even though the distribution of species over different habitats is not absolute, the account gives an idea of which parts of the Danish forests that are most important for the threatened parts of biodiversity: Untouched forests, old-growth forests, and broadleaf forests (see **Figure 2**). Probably this distribution of redlisted species points to the importance of a natural complex forest structure and the predominance of native tree species in forming forest habitats.

FIG. I

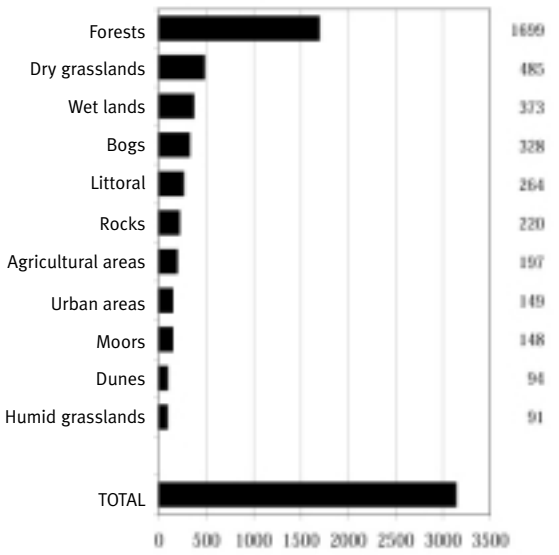

Figure I.
The number of redlisted species in different habitat types in Denmark. Forests are home for most, 54 per cent of the total. Dry meadow ranks clearly second. (Source: Stoltze & Pihl 1998).

NATIVE TREE SPECIES

Native tree species attract much interest in a conservation context because they are considered to be a habitat for a disproportionally large number of insect species, compared to introduced tree species (note that regardless of tree species, the age of a given tree is always an important factor for the occurrence of insects). **Figure 3** shows that the tree taxa that have a local prehistory of 10,000 years - oak, birch, willow, hawthorn, and Scots pine - are home for considerably more species than trees with a prehistory

FIG. 2

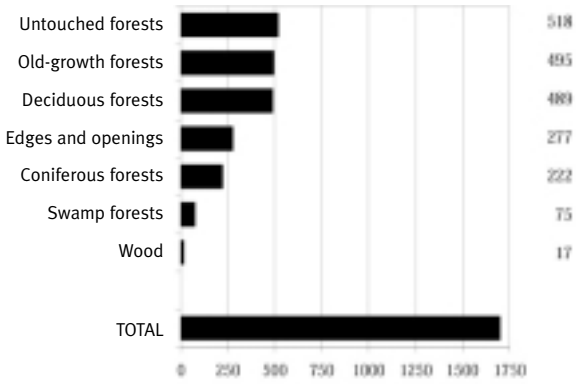

Figure 2. *The number of redlisted species in Denmark's forests, as distributed on various habitat types. Note that although two-thirds of the forests consist of conifers, broadleaf forest contains more than twice as many redlist species. (Source: Stoltze & Pihl 1998).*

of a few hundred to a few thousand years - in Great Britain red beech, and Norway spruce. In Sweden, Norway spruce has a much longer prehistory and accordingly more associated insect species.

Regrettably, surprisingly few studies have been made of this aspect which is important in preserving biodiversity. In most countries nothing has been done. The best entomologists are employed to study insects as pests in the forest, not as indicators of the richness of nature. The figures in Figure 3 represent the best study so far, at least in northern Europe, even though it is from as long ago as 1961.

FOREST STRUCTURE

Figure 4 illustrates the different structure and composition one may encounter in a forest. The prevalent system of silviculture in temperate Europe is age class forestry. In this system, the forest is subdivided into parcels.

Every parcel will be clear-cut and replanted, typically with only one tree species (even-aged monoculture). In "close-to-nature" silviculture, the stands are mixed with regard to the both the species and sizes of the trees, and the spontaneous seeding (regeneration) of the trees is employed to a much larger extent than in normal silviculture where much is invested in replanting.

As the name indicates, forest under close-to-nature (or nature-based) silviculture has some resemblance with a natural forest. However, there are important differences, too. A natural forest without timber extraction has much more dead wood and a far greater structural variation of both living trees and dead wood than an extraction forest.

If knowledge of insect life on the various tree species is limited, there is even less concerning the entire forest structures. Still, there are good reasons to assume that close-to-nature silviculture provides a basis for more species and greater biodiversity than does ordinary silviculture. These are presented below:

The very mix of tree species provides opportunities for species which in their habit are dependent on combinations of different tree species. For example, it is known that some bird species are favoured by co-occurrence of broadleaves and conifers, in Denmark for example the green woodpecker, (*Picus viridis*), black woodpecker (*Dendrocopus martius*), and hobby (*Falco subbuteo*). Likewise, mixes of young and old trees provide opportunities for meeting various requirements to niche types.

In an even-aged monoculture, the whole stand will constantly grow out of a given age class class and into another. One may expect that small species with poor dispersal capacities and specific habitat

*Light-demanding species such as wild apple (*Malus sylvestris*) may have been widely distributed in Europe's original woodlands. The role of large herbivores in maintaining a more open forest landscape is becoming increasingly recognized. (Photograph: Nepenthes/ Karsten Thomsen).*

requirements (and this is true of a large number of native species) will become locally extinct. In the very heterogeneous stand, there is greater chance that a given niche will occur within reach. This I have called the "nearness principle" of the forest (Thomsen 1996). Numerical evidence for the presumed differences in species richness between homogeneous and heterogeneous stands is still scarce.

The favourable conditions for biodiversity outlined above are even more pronounced for old, untouched forest. And where figures are lacking for higher biodiversity in close-to-nature forestry than in ordered forestry, clear evidence is available for higher biodiversity in untouched (non-intervention) forest compared to production forest.

For example, Møller (1997) found consistently more bird species per area in untouched forest than in production forest in seven pairs of forest stands on Zealand (Denmark) where approximately the same tree species occurred in each pair, but where only one was subject to silvicultural production. Moreover there were two to three times more bird individuals per unit area in untouched forest. Also for other groups of organisms the untouched forest was found to be richer.

This is doubtless an effect of the greater amount of food provided by the untouched forest, and its more varied structure.

GRAZING BY LARGE HERBIVORES

The untouched forest is not in itself the full expression for forest nature in its richest display. Animals are lacking. The story of the natural richness of forests goes beyond mere differences in vegetational characteristics. Herbivores play a great role, which is perhaps shown by the present-day importance of dry meadows as habitats in Denmark.

Dry meadows rank clearly second as a habitat for endangered species in Denmark (see **Figure 1**). This may seem surprising since dry meadows are a cultural management category and not immediately perceived as a natural type of landscape. For example, bogs and coastal zones are very natural landscape elements in Denmark, but these have far fewer redlisted species than meadows. True enough, a redlist is not a direct measure of the total number of occurring species, but only the number of threatened species. However, it is reasonable to assume that the differences in the figures do, to some extent, reflect how much biodiversity may be found in the various natural habitats. Why do the man-made meadows support such an amazing concentration of redlisted species compared to purely natural habitat types?

Agriculture has had a notable influence on the landscapes of Europe from at least 8,000 years ago in the south to some 6,000 years ago in the north (Diamond 1992). It has been a widely accepted assumption that numerous light-dependent plants and animals became widespread only after the opening up by humans of a formerly massive cover of primeval forest and that at least approximately a half of Europe's present flora and fauna depends on the presence of man-made open landscape elements (Wallis de Vries 1999, Vera 2000). Still, one should be surprised by the great species-richness of dry meadows. Species

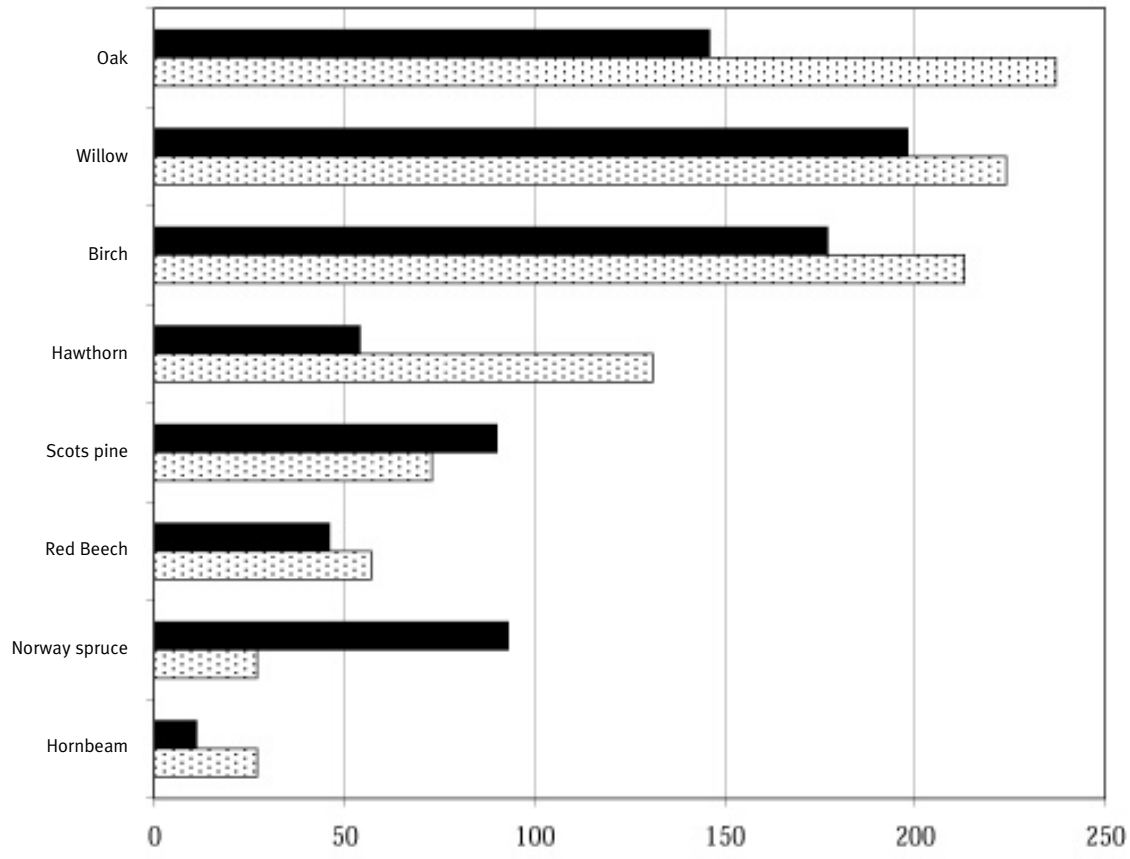

FIG.3

Figure 3. *The number of insect species from selected groups of butterflies and beetles associated with different tree taxa. The tree species with a long prehistory have most insect species. Data from Great Britain (dotted bars) and Sweden (black bars). (Source: Southwood 1961).*

do not evolve within a few thousand years, but rather during millions of years, and cultivated fields accordingly do not contain many wild species even though they have been around as long as human-made dry meadows.

Natural grazing is likely to have a much greater impact in the forest landscapes that existed prior to the time of agriculture than formerly assumed; see below. This is presumably the major part of the explanation for the many species in dry meadows today.

Figure 4 also illustrates, how the most recent ecological studies describe structure and dynamics in a primeval European forest ecosystem (an "urskovssystem") that includes the natural large herbivores (especially cattle and deer, but also horses): In the dense-crowned shadowy stands, the forest understorey will be open, and herbivores may easily find and bite down tree seedlings and thereby prevent sufficient regeneration for maintaining the dominance of the trees. Sooner or later the stand will break down. It will transform into a well-lit structure where nutrient-rich vegetation sprout and attract herbivores. The grazing will keep the vegetation low, until thorny bushes get established and create a defence for larger woody plants that in time will dominate anew. Hence the forest is naturally a mosaic of grazed vegetation, thorny scrub, young and old trees (Vera 2000). Since we have no established term for this vegetation structure, I have suggested the term "forest nature" for such a mosaic forest (Thomsen 2000).

FIG 4

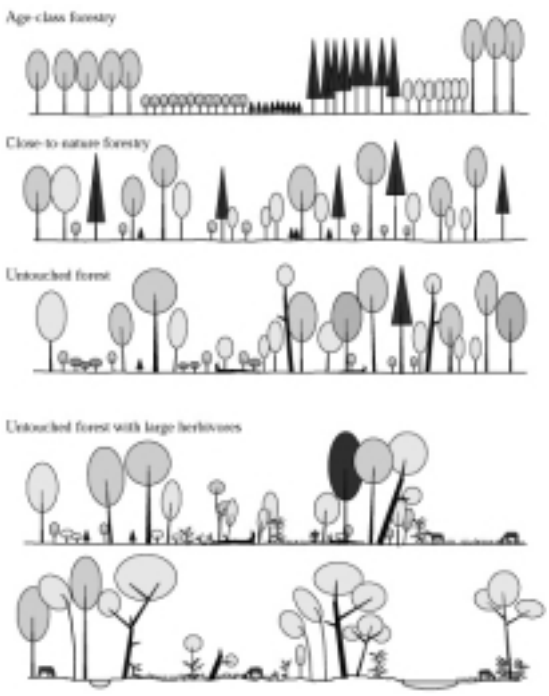

Figure 4. *Schematic comparison of forest structure in forest (from top):* **1)** *under age class,* **2)** *close-to-nature, and* **3-5)** *no silviculture (non-intervention, untouchedness). The untouched forest may be expected to contain most living and dead wood, and greatest biodiversity. The lower two transects,* **4-5)**, *illustrate vegetation structure in untouched forest nature with natural densities of large herbivores. Large tree stands alternate over time with more or less open thorny scrubs and grass/herb cover. A large part of the forest regeneration takes place in thorny scrub sheltered from herbivores. In this state of nature, no sharp distinction can be made between forest and open, grazed land. Based on Vera (2000).*

A perhaps surprising fact about large mammal herbivores is that they have been important elements in European forest ecosystems all through the Quaternary era (roughly the last two million years) (e.g., Andersson & Appelqvist 1990, Bunzel-Drüke *et al.* 1994, Beutler 1996). Although during the Post-glacial era, the Holocene, large wild herbivores became increasingly scarce, the domestic forms of some of the species (cattle, horse, sheep, pig) have substituted the role of the wild relatives in the landscapes until the most recent centuries (Thomsen 1996, Bunzel-Drüke in press, Thomsen in press). Today, the ecological importance of large herbivorous mammals in the landscapes can hardly be overestimated (Vera 2000). This view is indirectly supported by well-argued theories that prehistoric and historic large wild herbivore species did not disappear primarily because of changes in vegetation and climate, but rather because of human hunting and - in the agricultural era - competition from domestic animals (e.g., Alroy, Martin & Steadman, and Stuart in MacPhee 1999, Schuster & Schüle 2000). Indeed, had it not been for the advent of modern humans some 50,000 years ago, the European fauna would most probably still have included straight-tusked elephant, Merck's rhinoceros, hippopotamus, European water buffalo, giant deer, wild ass, tarpan, and aurochs (Bunzel-Drüke *et al.* 1994, Klein 2000, Schuster & Schüle 2000, Thomsen 2000).

THE SUCCESS AND FAILURE OF DANISH FOREST DEVELOPMENT

The development of Denmark's forest area during recent history is usually portrayed as a success story where forests were salvaged from overexploitation and destruction through a new Forestry Act in 1805. The need for success was underscored by dramatic events at that time. First, the British marine defeated the second-strongest war fleet in Europe, the Danish, in the Battle at Reden in 1801. Then, Lord Nelson in 1807 bombarded Copenhagen and there was a subsequent ferocious burn-down of countless wooden buildings and war ships. This made the resource crisis concerning wood in Denmark apparent. By biological measures, however, the success is limited. The re-established forest area consists of plantations. The increase in area is equalled by the increase in area of trees of introduced (exotic) species, whereas the area with native woody species has not increased significantly. The area with natural forest has continued decreasing to what appears to be an historical minimum (**Figure 5**). The composition and structure of today's Danish forests are thus radically different from those of earlier forests.

We do not have any clear picture of the development regarding wildlife values in Danish forests. Forest wildlife is so incompletely mapped that it is not documented how much is covered with forest with a natural structure and how much with native trees. In

contrast, forestry parameters such as time of planting, hardwood/softwood, and timber volume are for obvious reasons well-documented. However, the area with broadleaf forest is presumably roughly equivalent to the area with native tree species, although it is not physically the same. Most deciduous trees belong to native species whereas coniferous forests in Denmark consist of exotic species, except for Scots pine (*Pinus sylvestris*) which is native •

FIG 5

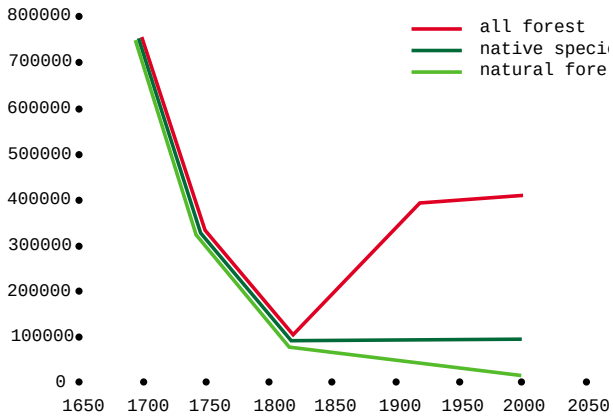

Figure 5.
Estimate of Denmark's forest area (in hectares) during the last centuries. The total tree covered area has increased ever since the passing of a new forestry act in 1805, but the area of native tree species has probably not increased notably, and the area with natural forest has decreased, now totalling perhaps 12,000 ha

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(Photograph: Nepenthes/ Carsten Brandt).

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