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The Natural Northern European Boreal Forests: Unifying the Concepts, Terminologies, and Their Application

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Recent emphasis on conserving the biodiversity has stressed the value of natural ecosystems in saving the species from extinction. In the Fennoscandian region the conifer-dominated boreal forests form the largest single ecosystem. The forests have been under varying intensity of human influence for decades or centuries. Recent attempts have tried to seek the last remaining natural forests to be included in the protection programmes. However, due to long and widespread human influence, finding and defining the natural forests has proven to be extremely difficult, not only because they are so rare but also because the concept of natural forest is vague. These difficulties are partly seen through the diverse terminology used.

We first review the varying terminology as seen in recent studies. Secondly, we propose the basis for defining the natural forest and show some intriguing and challenging difficulties are involved in the concept. These difficulties are at least partly related to inherent strong and long-term dynamic component in boreal forest ecosystems that is manifested over several temporal and spatial scales. Finally, we outline a more general terminology with associated indicators and measurements that might be used in the classification and terminology.

Conceptual clarification is necessary, for example, to compile ecologically justified and representative global, national and regional forest statistics. Many currently applied definitions of "forest" and "natural" that are applied in the context of forest statistics overlook ecologically important components of natural forests, and thus provide quite misleading or inadequate data of existing diversity patterns in these ecosystems.

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1 Introduction

Natural is one of the most ambiguous terms in English language, yet persists in usage because it signifies something of great aesthetic and spiritual importance to many people (White 1967, Christensen et al. 1996, Peterken 1996, Hull et al. 2001). What people consider natural seems to be a function of social, economic, cultural, historical, temporal, and normative – as well as ecological – criteria (Shrader-Frechette and McCoy 1995).

When defining "natural environment", like natural forest, a question immediately arises: are people part of nature (Peterken 1996)? The answer is determined by everyone´s personal perception and consciousness. The most common usage of "natural" in the ecological literature is understood to mean a process, situation or system free of human influence (e.g. Wright 1990, Hunter 1996), although definitions are tending towards the view that natural ecosystems are likely to have been modified slightly by man just as they might also be modified by other species (e.g. Maser 1990, Andrews 1996, Comer 1997, Haila 1997).

In theory, the concept of a natural forest is usually defined as a forest that has never been affected by human activity of any kind (e.g. Anderson 1991, Hunter 1996, Peterken 1996, Kuuluvainen 2002). In practise, however, the definition remains elusive. This is due to the great natural variability and constant change in characteristics of forest ecosystems and to the long-lasting intimate relationship and interaction between forests and humans (Sprugel 1991, Shrader-Frechette and McCoy 1995, Landres et al. 1999). Even the largest and most remote wilderness areas are not immune to current worldwide effects of industrial civilization such as global warming, stratospheric ozone depletion, and long-distance transport of pollutants.

The concept behind phrase *natural* is central to strategy being developed to sustain natural variability. Unfortunately, the phrase is widely used by the media, citizens, policy makers, and also naturalists and sylviculturists without adequate attention to the concept they embody. The ability to communicate effectively depends on a common understanding of terms and definitions. This is especially important when dealing with emotionally sensitive topics, such as state and management of forest resources (Lund 2002a). There has been ample discussion about definitions of "biodiversity" (e.g. Angermeier 1994, Angermeier et al. 1994, Haila and Kouki 1994) and "forest" (Helms 2002, Lund 2002a, b), such as what is actually forest and does biodiversity include artificial diversity. In addition, the definition of the term "old-growth forest" has received a lot of attention (Hunter 1989, Duchesne 1994, Frelich and Reich 2003, Mosseler et al. 2003, Helms 2004, Spies 2004). Thus, discussion about "natural forest" can be seen as a continuum in the clarification process of definitions.

Recent attempts have tried to seek the last remaining natural boreal forests to be included in the protection programmes (Parviainen 1999, Angelstam and Kuuluvainen 2004). Studies of the dynamic processes within natural forest can also serve as guidelines and a source of inspiration for the development of "close-to-nature" silvicultural systems and restoration of degraded forests (Colak et al. 2003, Angelstam and Kuuluvainen 2004, Stanturf 2005). However, due to long and widespread human influence, finding and defining the natural boreal forests has proven to be extremely difficult, not only because they are so rare (Hannah et al. 1995, Yaroshenko et al. 2001, Bradshaw 2005) but also because the concept of natural forest is vague. These difficulties are partly seen through the diverse terminology used. Our objective is to clarify the concept and the terminology used in relation to natural Fennoscandian boreal forests.

2 The Applied Terminology

There is considerable variation nationally and globally in the definition and use of the natural forest -related terms (see Schuck et al. 1994, Buchwald 2002, Lund 2002a, 2005). According to Lund (2002a) the definitions of *natural forest* vary from meaning a forest that has been free of human influence to one that is merely composed of indigenous species.

Several definitions of the natural forest can be found from the technical reports that compile and compare forest inventories from different

countries. Such definitions are available from, for example, FAO (2000, 2001, 2003, 2006, Carle and Holmgren 2003, the European-wide COST-Action E4 programme (Parviainen 1999), or from the European Commission's (2003) manuals (Council of… 1992). However, it seems that the worldwide (FAO) and European wide (EU-COST-Action E4) definitions of natural forest and related terms are used only in the reviews of global and regional forest resources, so that forest statistics from different countries are managed to get comparable with each other. Reports and definitions do not necessarily present scientific background for the specific terminology applied. In the smaller-scale, local studies the applied terminology is much more diverse but often based on specific ecological factors and considerations.

There are ample definitions for the term *natural forest*. The idea in most of the definitions is that *natural forest* is a forest that has evolved and reproduced itself naturally from organisms previously established, and that has not been significantly altered by human activity, i.e. it is forest whose structure and dynamics have not significantly been affected by humans. The difficulty is in defining what is meant by "significantly altered/affected": this conceptual approach is not free from debate, affecting both the role of humans in the ecosystem, as well as the time span of its influence (see Anderson 1991). On the most strict sense, it is defined as "without any direct interference by man" (e.g. Volkov et al. 1997). Term is applied in forests virtually unaltered by direct human activity (Söderström 1988, Ohlson and Tryterud 1999), but in the greater part of the studies direct human activity in the past is allowed (e.g. Andersson and Hytteborn 1991, Rouvinen and Kuuluvainen 1997, Kuuluvainen et al. 1998a, Lindblad 1998, Sippola et al. 1998, Karjalainen and Kuuluvainen 2002, Stokland and Kauserud 2004, Junninen et al. 2006). If human influence is accepted, there is not common consensus on criteria what kind it could be, and the precise characteristics and attributes of the term are not identified. However, Rouvinen et al. (2002b) used in old forests criteria: 1) natural forest stands have < 10 old cut stumps per ha and 2) the stand structure is uneven-sized, which is characteristic of old unmanaged boreal forests; if the number of cut stumps was higher, but the overall stand structure was similar to that in natural forest, the term used was "selectively logged". Quite correspondingly, Uotila et al. (2002) suggested that 5 cut stumps per ha is the amount that won't influence on forest structural characters. Okland et al. (2003) used more strict criteria compared to Rouvinen et al (2002b) and Uotila et al. (2002): forest stands classified as natural did not contain any cut stumps.

Term *old-growth forest,* widely used in North America, is commonly used also in Finland (e.g. Punttila et al. 1994, Martikainen et al. 1999, Sippola and Renvall 1999, Siitonen et al. 2000, 2001, Rouvinen and Kouki 2002, Kuuluvainen and Kalmari 2003), in Sweden (e.g. Steijlen et al. 1995, Hörnberg et al. 1997, Drobyshev 1999, 2001, Jonsson 2000, Berglund and Jonsson 2001, Edman and Jonsson 2001) and Norway (e.g. Okland 1996, Rydgren et al. 1998, Storaunet and Rolstad 2002, 2004, Sverdrup-Thygeson 2002). Wallenius (2004) defines old-growth forest as forest that is essentially unmanaged and in forestry terms over-aged, often including abundantly large living and dead trees. The term is used more or less as synonym to natural old forest, but it refers more to the age (and other structural characteristics?) of forest than to the naturalness of a forest. Usually human influence is not specified, but Siitonen et al. (2000) defines old-growth forest as a forest of over 129 years old, where are no or few cut stumps. Occasionally the term has a specifier, like genuine (Rolstad et al. 2004) or undisturbed (Svensson and Jeglum 2001).

In principle, *virgin forest* is a forest not being disturbed by humans. In practice, however, the forests called as virgin forests have quite high variation in human impact: seemingly not disturbed (Hofgaard 1993) to slightly/moderately disturbed (Lähde et al. 1991, Linder 1998, Atlegrim and Sjöberg 2004) by humans. Term *virgin forest* has often used in Russian silvicultural literature and there it denotes to climax, but there are also opinions that these are forests untouched by men at different stages of natural succession (Volkov et al. 1997).

Pristine and *primeval forests* are also traditional terms used. Those terms are applied primarily by Russian (Gromtsev 1998, 2002, Yakovlev et al. 2000, Shorohova and Soloviev 2002) and Finnish scientists (Kuuluvainen et al. 1996, 1998b, 2001,

Sippola et al. 2001), and in lesser extent elsewhere (Hytteborn et al. 1987, Liu and Hytteborn 1991, Wirth et al. 1999). According to Volkov et al. (1997), the term primeval is often used in Russian sylvicultural literature to denote climax, but there are also opinions that these are forests untouched by men at different stages of natural succession. Kuuluvainen et al. (1996) applied the term primeval because the studied forest had developed largely without human influence for a long time, i.e. there were no distinctive signs of human disturbance.

Terms *unmanaged*, *unlogged, semi-natural* and *near-natural forests* are applied in recent boreal Fennoscandian forest studies (Okland 1994, 1996, Uotila et al. 2001, 2002, Similä et al. 2002, 2003, Uotila 2004, Wallenius 2004, Lilja and Kuuluvainen 2005, Wallenius et al. 2005, Lilja 2006, Lilja et al. 2006). Wallenius (2004) defines the term unmanaged forest as a forest that is unaffected by modern forestry. Okland (1996) refers with the term unlogged to old-growth forest that has no cut stumps. Uotila (2004) apply the term semi-natural for forests that lie outside the scope of regular management and timber harvesting, if they have early human impacts characterized by the removal of single trees in light selection fellings. Lilja's (2006) definition for near-natural forest is: "unmanaged stand that may show traces of past human impact, i.e. < 5 cut stumps per hectare". Terms *near-virgin* and *intact* are applied in some articles emphasizing human presence or absence in a forest ecosystem, respectively (Nilsson et al. 2001, Angelstam and Kuuluvainen 2004). Term *naturally dynamic forest* is also used occasionally, usually referring to landscape scale natural forest dynamics (Kuuluvainen 2002, Rouvinen 2002, Rouvinen et al. 2002a, Angelstam and Kuuluvainen 2004). It refers to forest/forest landscape where the natural successional dynamics have been predominant for a period of time lasting for several decades at least.

Volkov et al. (1997) mentioned that in Russia seral forest vegetation when not affected by economic activities and forest vegetation in the climax stage are often called *spontaneous*. We did not find that the term was applied more widely. The term *undisturbed forest* was used in one article done by Russian scientists (Volkov et al. 1997), but also in two articles done by Swedish scientists (Svensson 1998, Svensson and Jeglum 2001), where the term was specified as "undisturbed by forestry". Numerous other terms, like primary, ancient and native, referring natural state of a forest are used in western world (see Lund 2005): however, the usage of those terms in Fennoscandian scientific literature seems to be rare as we did not find any articles containing those terms. In addition, the concept frontier forest, referring large, ecologically intact, and relatively undisturbed natural forests (Bryant et al. 1997), has been avoided in Fennoscandia, as it is also done in the rest of the world (Innes and Er 2002).

3 Spatio-Temporal Scale and Naturalness

Ecosystem processes operate over a wide range of spatial and temporal scales, and their behavior at any given location is very much affected by status and behavior of the systems or landscape that surrounds them (e.g. Levin 1992). Thus, the concepts and terminologies are dependent both on spatial and temporal scale. For example, a forest stand may be completely natural in its characteristics yet it may be located in the midst of totally unnatural (managed) landscape. Thus, the naturalness cannot be defined without addressing the spatial scale. The same applies also for temporal scale effects on the conceptual clarifications. Temporal aspects seem to be exceptionally important in boreal forests that are characterized by long-term natural disturbance-succession complexity.

Boreal forests with a history of human disturbance may develop structural, compositional, and functional characteristics that are similar to those of relatively undisturbed forests. Studies in Finland and in northwestern Russia have shown that pine (*Pinus sylvestris* L.) -dominated forests selectively cut in the past, typically in the early 20th century, and not treated since, resemble natural forests in the structural stand characteristics of living (Lilja and Kuuluvainen 2005) and dead (Rouvinen et al. 2002b) trees. In Norway, Storaunet et al. (2000) concluded that old-growth stand characteristics, such as reversed J-shaped age distributions and dead wood in advanced

decay classes, can be obtained 100–150 years after intensive selective logging in spruce (*Picea abies* (L.) Karst.) -dominated forests. In addition, Storaunet et al. (2005) found in coniferous forests that several of the forest stand characteristics were only slightly influenced by the intensity of the selective logging the last 50–100 years: however, the study also suggested how earlier logging activity may have influenced forest structures and characteristics long after obvious signs of such (i.e., logging stumps) were no longer visible in field inventories. Understory vegetation in human disturbed forests similarly resemble those in natural forests as time goes on (Uotila and Kouki 2005, Uotila et al. 2005).

Given the spatial and temporal variation in natural disturbances, it is difficult to determine what size of forest is required to include all the essential natural processes. Although fires, important natural disturbance factors in the boreal zone, have probably been considerably smaller in Fennoscandia compared to boreal North America, fires larger than 1000 ha have been relatively common and the largest fires have been tens of thousands of hectares (Niklasson and Granström 2000). As the forest landscape is largely fragmented in Fennoscandia during the last century (Östlund et al. 1997, Axelsson and Östlund 2001, Kouki et al. 2001, Löfman and Kouki 2001), it may not be feasible to find a natural forest area of such and larger size. It means that many forest areas, also the protected ones, are not large enough to allow for natural disturbances to occur within their boundaries. In addition, modified lands adjoining natural forest areas can exert influences on the natural area itself (Väisänen et al. 1986, Laurance 2000). Within forest stand and especially landscape, there can be found marks indicating different degrees of human impact from virtually untouched to quite heavily managed patches. For example, Rouvinen et al. (2005) found that the protected, 32 ha old-growth forest in eastern Finland had a wide variety on its naturalness, as determined on occurrence of visible cut stumps. On the other hand, there were several old cut stumps in certain parts of the area in a naturally dynamic forest landscape in northwestern Russia, although it was remote located (Karjalainen and Kuuluvainen 2002).

4 Towards Coherent Terminology and Indicators

In Europe there is no convenient and generally accepted condition corresponding to some major change in land use which could serve as a baseline from which change could be measured and naturalness thus defined (Margules and Usher 1981). In contrast, for example, in Australia the influence of aborigines in the forest ecosystems is being accepted as natural (Machado 2004) and in North America stands which have not been directly altered by Europeans are called "pre-settlement" forests, most of which are "old-growth", relatively unaffected by people (Peterken 1996, Bradshaw 2005). In Fennoscandia this has led to applying the term natural forest and related terms in a wide range of situations: however, typically they are forests where no silviculture has been practiced during the past few decades, but which bear signs of human impact (e.g. old cut stumps) dating back to earlier days.

The number of manmade stumps may be a relatively quick and easy method of assessing the naturalness of woody biomass structure in the Fennoscandian boreal forests. CWD (coarse woody debris) profile (*sensu* Stokland 2001), based on the quantitative and qualitative composition of dead lying wood at the stand level, can also be applied (Stokland and Kauserud 2004). However, neither presence of significant amounts of dead wood nor the lack of logging stumps does necessarily imply that the forest has not been influenced by logging activity (e.g. Rouvinen and Kouki 2002, Okland et al. 2003, Rouvinen et al. 2005, Storaunet et al. 2005). For example, on the basis of the stumps found, it is possible to determine only fairly recent loggings, but due to the decaying process, the older loggings, done e.g. > 100 years ago, are much more difficult to detect (Nyyssönen 1956, Storaunet et al. 2000, Groven et a. 2002). Pommerening (2002) presents several structure indices, quantifying spatial stand structure, to analyze observed and expected structures, and uses randomness as a substitute for naturalness in the comparisons: although randomness is widely used in statistics, it is easy to establish and there is some evidence to randomness of tree locations, especially in old natural forests (Stoyan

and Penttinen 2000), randomness as a reference is not substitute for naturalness. In addition, it must be remembered when the natural features of a forest is described that separate and explicit evaluations of the kind and degree of naturalness of trees, shrubs, ground vegetation, soils and other features are needed (Peterken 1996).

For many areas in Fennoscandia, sufficient data exist for a general understanding of quite recent history of human induced disturbances, such as slash-and-burn cultivation (Heikinheimo 1915), tar production (Kaila 1931), or the modern intensive management (Lihtonen 1949). Site-specific data, however, are lacking for most areas, and there is insufficient temporal depth for many of the areas that have been studied, requiring inference and extrapolation in forest history. The effect of these inferences on our understanding of past conditions and variation is poorly known, especially in topographically complex landscapes and when extrapolating the effects of disturbances across a landscape (Landres et al. 1999). Furthermore, the spatial arrangement of patches and severity of disturbances are not usually identified with confidence in historical data, resulting in a general lack of information about the spatial variation of past conditions. Although limitations, historical ecology approach (Swetnam et al. 1999) with "natural", i.e. those "recorded" by earth-system processes (like pollen, charcoal and tree rings), and "documentary" archives, i.e. written, tabulated, mapped, or photographic records (like chronicles, diaries, land surveys and maps) should be used. For example, in state-owned forests in Finland the detailed documented period goes back to the end of the 19th century (Sippola et al. 2001, Uotila et al. 2002). Also in Sweden, the best and most extensive forest historical records are those of the state forests (Axelsson 2001).

In conclusion, we recommend that spatial and temporal bounds must always be explicit parts of the definition and use of natural forest concept. In practice, it means that assessments of naturalness should be backed by evidence of human influence – such as the presence and the number of manmade stumps – on the studied forest area. The choice of the term applied is based on those facts. The specific names for the terms are not important as long as they are clearly defined: consistent use of the terms and possible specifiers (adjectives) may, however, clarify the terms.

We suggest, however, that the term "natural forest" is still to be preferred, although there are marked differences in applying the terms "natural" and "old-growth", in particular between the European tradition and the North American tradition. The "natural forest" could be defines as "a forest that has evolved and reproduced itself naturally from organisms previously established, and that has not been significantly altered by human activity, i.e. it is forest whose structure and dynamics have not significantly been affected by humans." In particular, we argue that several definitions available in technical forest assessments (e.g. Parviainen 1999, FAO 2006) should be applied with great care due to their obvious insensitivity to the variation in ecologically important properties of truly natural forests.

5 Concluding Remarks

It is quite likely indeed that there will never be a generally applicable and precise definition of natural forest because the definition is context-, scale-, and value-dependent. However, the criteria chosen to delimit natural forest should minimize arbitrary thresholds that are scaled to human size and time scales, and human values. We emphasize that spatial and temporal bounds must always be explicit parts of the definition and use of natural forest concept, regardless of the term used.

The general concepts like "forest" and "natural" and their exact definitions have considerable influence on forest and conservation policy, too. Global and regional statistic on coverage, distributions and temporal trends always have to apply a specifically defined concept. A definition may be justified in relation to a particular purpose – such as assessing the timber and biomass volume – but may be highly biased in relation to diversity patterns or to the occurrence of natural forests. Both global statistics (e.g. FAO 2006) and more detailed analyses (e.g. Kauppi et al. 2006) are likely to reveal ecological diversity patterns and trends more accurately if the concept of natural forest is developed further and applied more rigorously in these contexts. Obviously, there is an urgent need to incorporate better ecological

sensitivity and resolution to these measures and base the definitions on the current understanding of forest ecosystem dynamics and patterns.

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