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A 600-year tree-ring fire history from Norra Kvills National Park, southern Sweden: implications for conservation strategies in the hemiboreal zone

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Abstract

The fire history of Norra Kvills National Park in southeastern hemiboreal Sweden was reconstructed for the last 600 years by cross-dating of fire scars in trees, stumps and snags of Scots pine (*Pinus sylvestris*). Between 1401 and 1770 forty different fires were recorded; fire frequency at point scale was 20 years, which is 3–4 times more frequent than in northern Sweden. Since 1770, no large fires have been recorded. This has had considerable consequences for the forest structure and fauna in that it has resulted in a shift from a Scots pine-dominated ecosystem to a fire-sensitive Norway spruce (*Picea abies*) system over large parts of the park. For rare late-successional species associated with Norway spruce (e.g. *Fomitopsis rosea,* a polyporous fungus and *Ceruchus chrysomelinus,* a beetle) this has been advantageous, while fire-, light- and thermophilous species like the saproxylic beetle *Tragosoma depsarium* may be increasingly threatened if the process of spruce invasion and suppression of fires is allowed to continue. We discuss the importance and problems of incorporating fire in management plans of reserves and in forestry practices, with the aim of preserving the large number of species that are directly or indirectly dependent on fire in southern Sweden. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Fire history; Dendrochronology; Hemiboreal; Disturbance regimes; Conservation strategies; Conservation management

1. Introduction

Natural disturbance regimes of the Swedish hemiboreal forests have not been extensively studied, largely because there are no large natural forests left (Nilsson, 1997). In southern Sweden, only 0.8% of the forest area is protected in reserves or in national parks (Bernes, 1994). In contrast to northern Swedish forests, human impact has been much more extensive and the transformation into intensively managed forest in southern Sweden was generally initiated earlier (Nilsson, 1997). Single old-growth features such as standing snags and large or very old trees that can offer tree-ring information on past disturbances are extremely rare in the forests in this part of Sweden. In addition, the number of threatened forest species in the hemiboreal (mainly lichens, mosses, fungi, invertebrates) is considerably higher than that in boreal northern forests. At present, ca. 900 species, mainly saproxylic beetles, are considered endangered by forestry activities, compared to 500 for northern Sweden (Berg et al., 1994). Large efforts are urgently needed for conserving and promoting endangered species and natural processes in this region. The standard way to do this is to designate reserves or national parks, which then are protected not only from forestry but also from natural disturbances. In the boreal forests of northern Sweden, this policy has recently been shown to result in invasion of shade-tolerant, late successional species like *Picea abies* where fires earlier maintained an open sparse forest dominated by *Pinus sylvestris* and *Betula pendula* (Linder, 1998; Zackrisson, 1977). At present, large efforts are devoted to the re-introduction of fire in northern Swedish forests, both in reserves and in managed forests in order to sustain and improve biodiversity (Fries et al., 1997). However, this process is hampered in southern Sweden for several

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reasons. The land ownership situation is more complex, the tradition of slash-burning in clearcuts is almost lost, and only scant records of fire history and past fire regimes exist compared to northern Sweden where fire history has been consistently recorded (Kohh, 1975; Zackrisson, 1977; Engelmark, 1984; Linder, 1998; Niklasson and Granström, 2000).

In this study we have reconstructed the fire history of Norra Kvills National Park by using dendrochronology. Norra Kvill is one of the extremely few remaining conifer-dominated natural forests in the hemiboreal zone of Sweden. We discuss the likely effects on fauna and flora brought about by the changes in the disturbance regime that have taken place during the last 600 years. Based on the results we discuss future management alternatives for conifer-dominated reserves and for forestry in the eastern part of the hemiboreal region of Sweden.

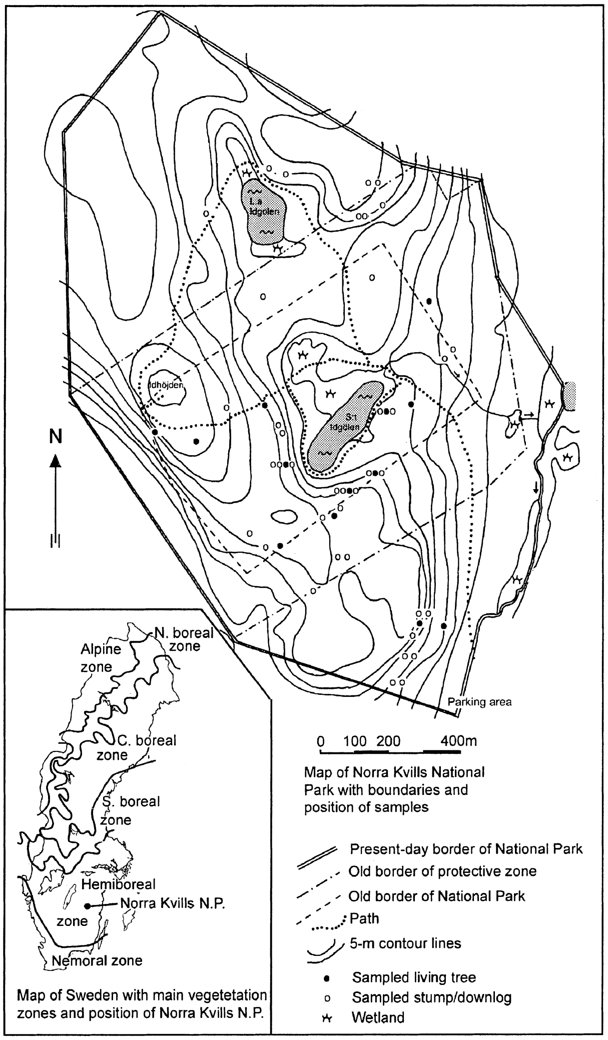

Fig. 1. The location of Norra Kvills National Park and position of wood samples.

2. Methods

2.1. Study area

Norra Kvills National Park is situated in the hemiboreal zone (according to Sjörs, 1965), c. 20 km northwest of the small town of Vimmerby (Fig. 1) in the southern Swedish province of Småland (57° 30′ N, 15° 36′ E). It was established in 1928 on the basis that "the area is covered by a very old forest where no loggings have been conducted during living memory" (Sterner, 1929). At inauguration the park was only 27 ha but later a protective forest of some 30 ha which had similar characteristics was added. In 1995 the park was further enlargened by a purchase of adjacent private and state lands making the total area 110 ha (Fig. 1). The management plan of 1985 states that the forest should be left for "free development" (Anon., 1985). Fires are regarded as a threat and if they occur they are to be suppressed.

The park is situated in a hilly terrain, the lowest point of which is 120 m above sea level, and the highest point is 230 m above sea level. The terrain is rich in boulders with some rocky outcrops and a few very steep slopes. The underlying bedrock is acidic, dominated by granites of the trans-Scandinavian porphyr belt (Lundqvist and Bygghammar, 1994) and covered by moraines. Two small lakes (Stora Idgölen and Lilla Idgölen) inside the park are drained by a little transient creek down to wetlands along the eastern border of the park. The climate is temperate with fairly warm summers and rather cold winters (July mean 16.1°C, January mean −3.3°C in Vimmerby 18 km to the southeast). Precipitation is rather low; annual rainfall is 535 mm with 38 and 66 mm falling in January and July, respectively (Alexandersson et al., 1991). Snow normally covers the ground from January to March. According to Eriksson (1986) the area falls within the slightly summer dry region (Martonnes humidity index 30–34). The period of vegetative growth is 210–220 days (temp exceeding 5°C; Odin et al., 1983). A general description of the forest and its flora is given in Sterner (1929), and is only summarized here.

The forest is dominated by old Scots pine (*Pinus sylvestris*) on dry and very wet and oligotrophic sites while Norway spruce (*Picea abies*) occupies the more fertile mesic or moist sites. All spruce-dominated stands incorporate a number of old pines and/or fire-scarred stumps, indicating that pine formerly was more dominant. Fire-scarred pines, which are very rare in south Sweden, occur over most of the park with high densities on slopes around Lake Stora Idgölen and south of the lake. Two of the oldest and living pines have as many as eight or nine fire scars (Fig. 2), which is rarely encountered in Sweden (Niklasson and Drakenberg personal observation). Stumps and fallen logs with fire-scars are not uncommon and these may have as many as 14 scars.

Fig. 2. A 470-year old Scots pine (*Pinus sylvestris*) with eight fire scars in a stand totally dominated by 220-year old post-fire Norway spruce.

Even in the wettest part of the park evidence of past fires is seen on pines growing among *Ledum palustre* — a highly flammable wetland ericaceous dwarf shrub. Pine recruitment during the last century was almost non-existent inside the old park area but in the areas added in 1995 there are younger stands (c. 60–90 years old) of *Pinus* that regenerated after loggings in the early 20th century and after a small fire in 1917.

During the last 3 years, spruce has been heavily attacked by bark beetles (*Ips typographus*) which has opened the canopy up in many stands. It is still under debate as to whether these gaps are large enough to allow for pine and broadleaf recruitment. In older storm gaps spruce has regenerated successfully but there is no pine recruitment. Under a closed canopy very little spruce regeneration occurs. Deciduous trees are rare but silver birch (*Betula pendula*) with typically thick, coarse bark is present both as old trees and scattered young individuals. Black alder (*Alnus glutinosa*) grows together with white birch (*Betula pubescens*) in the wet forest around lakes. Aspen (*Populus tremula*) and goat willow (*Salix caprea*) are rare, and occur more commonly as well-decayed fallen trees. Occasionally, stunted oaks (*Quercus robur*) grow near rocky outcrops. Along the small creek that drains the area some broadleaf trees typical of the nemoral zone and rich soils in the hemiboreal are found, such as: lime (*Tilia cordata*), ash (*Fraxinus excelsior*), elm (*Ulmus glabra*) and hazel (*Corylus avellana*). Within this area a small number of fire-scarred pine stumps are also present.

Dead trees of different ages and fallen logs occur all over the park. Woodpecker activity is evident everywhere and exit-holes of wood-inhabitating insects are common. An old exit-hole from the very rare saproxylic beetle *Tragosoma depsarium* was recorded on a large and exposed fallen log. This species is dependent on large and exposed dead pines and Norra Kvills National Park is host to one of the few populations of this species in southern Sweden, at least up to the 1980s when the last observation was done (Nilsson, Sven G, personal communication). Some of the pines show fruiting bodies of the fungus *Phellinus pini*, a species only found on old pines. The spruce forest along the creek, part of which used to be a meadow in 1750 (Sterner, 1929), contains large amounts of fallen logs in different stages of decay. The fungal flora on these is diverse. Besides common polyporous fungi such as *Fomitopsis pinicola* and *Trichaptum abietinum*, many of the typical boreal red-listed fungi occur — some of them at their southern distribution limit in Sweden. To date *Phlebia centrifuga*, *Phellinus ferrugineofuscus*, *Fomitopsis rosea*, *Phellinus nigrolimitatus* and *Perennipora subacida* have been recorded. These fungi are considered the best indicators of forest continuity in Sweden (Karström, 1992; Nitare and Norén, 1992), and are used in several different inventory systems as indicators of high biological values (e.g. Karström, 1992).

The ground is covered by dwarf shrubs such as *Vaccinium myrtillus, Vaccinium vitis-idea, Calluna vulgaris* and *Arctostaphylos uva-ursi,* and a few grasses such as *Deschampsia flexuosa* and *Calamagrostis arundinacea.* Mosses are dominated by *Hylocomium splendens, Pleurozium schreberi* and *Dicranum* spp. with occasional *Ptilium crista-castrensis*, while rare species include *Bazzania trilobata* and *Trichocolea tomentosa*. On the driest slopes lichens (*Cladina* spp.) are common. Occasionally, *Goodyera repens, Pyrola chloranta* and *Monotropa hypopitys* are found, all typical of old forests.

2.2. Fieldwork and dendrochronological dating of the fires

Between 1992 and 1998, a total of 46 wood samples (all from *Pinus sylvestris*) were collected with an increment borer or a chain saw (Arno and Sneck, 1977; McBride, 1983) from 18 well-preserved stumps, two standing snags and four fallen logs with fire scars. Twenty-two living trees, some with fire scars, were cored and in four instances wedges were removed in order to determine the tree-ring chronology up to the present day and also to determine the date of the last fire. On average, the distance between sample points was 100–200 m (Fig. 1). The primary aim was to collect wood samples at regular intervals all over the park, but this was to some extent dictated by the actual presence of reasonably uneroded and scarred stumps. The sampled stumps were invariably very old, and dated from loggings done 100–200 years ago. Younger unscarred stumps were very rare except around Lilla Idgölen and along paths where blocking trees had been removed. Scarred snags, fallen logs and especially living trees, which were all rare, were sampled more restrictively simply because of the areas national park status. Two groups of multi-scarred living pines along the path were therefore not sampled. Sampling with a corer was unrestricted and most living trees with scars were cored to find the year of the last fire. Samples from stumps were also collected from four localities a few kilometres south and north of the park.

The samples were brought to the laboratory, sanded with a belt sander and dated under a dissecting microscope according to standard cross-dating techniques (Douglass, 1941; Stokes and Smiley, 1968). Narrow rings coincided with years of severe drought, such as in 1959, 1868 and 1693. For the majority of fire scars it was possible to assess the stage of ring development (fire season) inside the scar lesion (Baisan and Swetnam, 1990; Ortloff et al., 1995). Phenological data from Romell (1925) was used for matching the actual tree-ring stage within a scar lesion to an an approximate season. Inside the scar lesion incompletely developed rings was expressed as the percentage of a fully developed ring (cambial division from end of May/early June to middle of August). Dormant season scars were assigned to be early fires (instead of late fires occurring after tree-ring growth) because lightning fires are rare in late summer after tree-ring growth is completed and because man-made fires were more common in the early summer (Larsson, 1980; Granström, 1993).

3. Results

Forty-three different fires were dated inside the park (Fig. 3). The earliest fire of 1401 was recorded on a pine stump that had 12 fire scars and had originated before 1397 (oldest tree ring; pith and centre eroded). The youngest ring on this pine was from 1703, coinciding with a fire dated to 1704 on another stump. The vast majority of fires were recorded before 1770, while after this, only two fires apparently occurred, all recorded in just one tree in 1889 and 1923, respectively. Both fires should have covered very small areas, much less than 1 ha each since no other scars were found. The known fire in 1917 that covered a few ha was not sampled for scars, nor included in the data set. From 1401 to 1770, fires occurred in the park on average every ninth year, at a remarkably regular rate except for a slightly higher rate during the 1600s (Fig. 3). Fire intervals were skewed towards very short intervals with a mean interval of 20 years (Fig. 4) but intervals shorter than 10 years were not uncommon. Three trees even recorded a 5-year interval; to date this is the shortest interval ever reported for the same tree in Sweden (Niklasson, personal observation). Only 10 fire intervals exceeding 40 years were recorded. The great majority of the sampled trees got their first scars as young trees, often below 30 years of age.

Most of the sampled dead trees and stumps had their youngest rings in the 1700s or 1800s. Very few had died during the 1900s, indicating that the logging history was restricted to the 1800s or earlier. Tree ages at death, from logging or fire (minimum estimates since outer

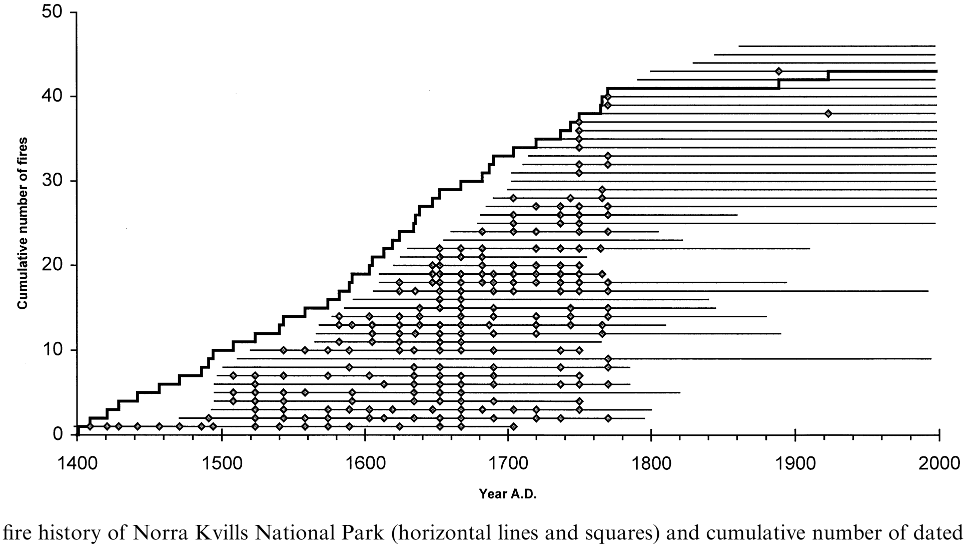

Fig. 3. Cross-dated fire history of Norra Kvills National Park (horizontal lines and squares) and cumulative number of dated fires over time (thick line). One sample (tree/dead tree/snag/stump) is one horizontal line. Fire scars are indicated with squares. Note that *y*-axis refers to the thick line (cumulative number of dated fires over time).

rings were often eroded), were typically around 250 years. The maximum age recorded on living, scarred trees was 470 years, while most of the cored living trees exceeded 300 years of age.

It was possible to assess the seasonal timing of fires with high accuracy for 38 of the 43 fires. Fire seasons varied in timing from when cambial growth was dormant to the latest stages of cambial division late in the growing season. However, most fires occurred during the early period of tree growth, i.e. in early to mid-summer. Before 1690, no clear trends in the seasonal timing of fires were evident (Figs. 5 and 6). From 1690 onwards 9 out of 10 recorded fires occurred outside the growing season (Figs. 5 and 6), which was significantly earlier compared to that in earlier centuries ($P < 0.002$).

Spatial patterns in fires were possible to detect for some fires (data not shown), but very few fires were totally contained within the park. The larger fires may therefore have exceeded 100 ha. Some fires were dated from only one sample but were absent in surrounding sampling points, possibly indicating low-intensity fires that covered just a few ha. On the other hand, some fires like those in 1652 and 1667, scarred nearly all sampled trees, and were the only scars on a stump found standing in the wet section of the creek. These two fires are noteworthy when comparing the proportions of trees scarred by different fires (Fig. 7).

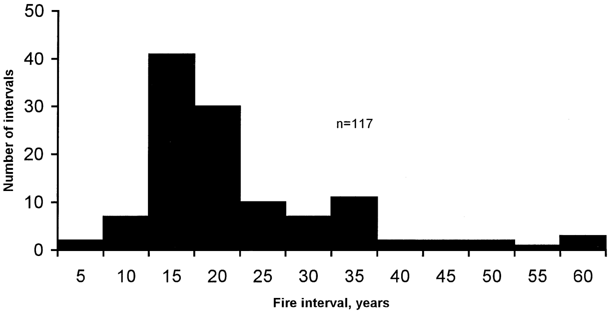

Fig. 4. Fire interval distribution. Mean fire interval 20 years.

4. Discussion

4.1. Effects of fire suppression

The tree-ring dated fire history gives clear evidence of dramatic changes throughout the last 600 years in Norra Kvills National Park. Before 1770, frequent fires affected the forest and must have strongly promoted the dominance of Scots pine as indicated by the large number of pine stumps found. Fires killed or rather excluded spruce (Linder et al., 1998), which would therefore have been restricted to wet and less flammable areas in the park. Dead wood, burnt trees, resin-rich snags and charred wood were continuously created in these forests which thus became prime habitat for many currently threatened invertebrates like the beetle *Tragosoma depsarium* (Wikars, 1997). Today, gap formation by death of single spruce trees or groups of spruce (typically killed by insects like *I. typographus* or storms) constitute the major type of disturbance in the national park. Most of the species directly or indirectly dependent upon fire, have become rare and replaced by mosses and

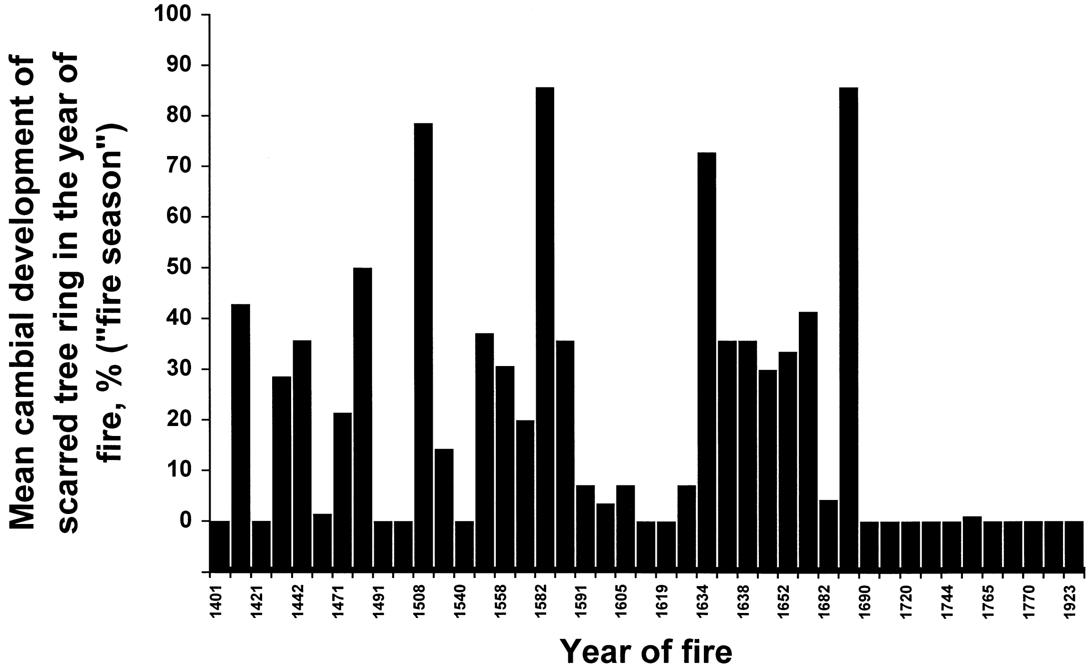

Fig. 5. Fire seasons as recorded by their intra-annual position in the fire scars.

other species that are characteristic of spruce-dominated late succession forests. As mentioned earlier, several rare boreal polyporous spruce-colonizing fungi have their southernmost Swedish occurrences in Norra Kvill (Larsson, 1997). Even more noteable is the finding of the highly endangered saproxylic beetle *Ceruchus chrysomelinus* in fallen spruce logs in Norra Kvill (Nilsson et al., 2000). This species has been extinct over most of southern Sweden, probably due to low dispersal ability and because its specific habitat requirements are not met in production forests (Gärdenfors, 2000). It is almost self-evident that, prior to 1770, these species were not found in their present localities because of the absence of fire-sensitive spruce. Either there must have existed suitable habitats in the past that did not burn in the area, or the species have since colonized from more remote spruce forests.

The succession from pine to spruce dominance in the absence of fires has been described by Linder (1998) from northern Swedish reserves. Although no data exist, it is possible that the natural succession from pine to spruce is more rapid in southern than northern Sweden, due to higher site fertility and the general preference for spruce in managed forests (Nilsson, 1997). It was also probably speeded up by selective cuttings in the 1800s of large dominating Scots pine, of which only a few individuals remain alive today. Change from dominance of fire-adapted tree species, mainly pine, to dominance of late-successional fire-sensitive tree species has been described from other parts of the world where fire suppression has been active, as in North America (e.g. Swetnam, 1993). There, for example, *Abies* spp. and *Calocedrus decurrens* are invading the *Sequoia* forest in the absence of fire (Parsons and DeBenedetti, 1979).

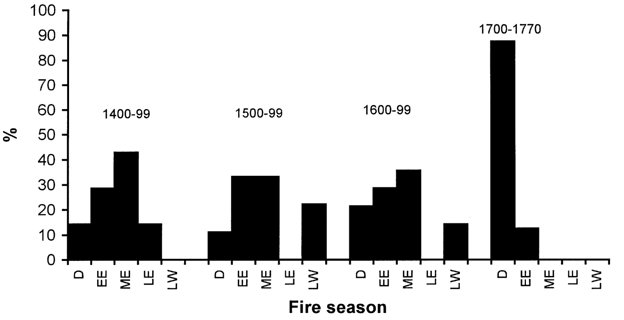

Fig. 6. Fire seasons grouped according to their distribution in each century. A dramatic shift to early fires (Dormant season presumed to be early fires) is evident during the 1700s. D, Dormant season scars, no cambial division recorded. EE, early earlywood, scar occurred in the early earlywood portion of the ring. ME, middle earlywood, scar occurred in the middle of the earlywood portion of the ring. LE, late earlywood, scar occurred in the later part of the earlywood portion of the ring. LW, scar occurred in the latewood part of the ring.

4.2. *Possible reasons for the changes in the fire regime*

The abrupt change from frequent fires to efficient suppression of fires is not unique to Norra Kvill. It is consistent with the general pattern reported from northern and central Sweden (Zackrisson, 1977; Engelmark, 1984; Page et al., 1996; Linder, 1998; Niklasson and Granström, 2000). However, the cessation of fires at Norra Kvill occurred about 100 years earlier than in northern Sweden where fires remained a feature in the landscape up to 1860–1880. The reasons may be different in different regions but we believe one important factor is the earlier start of timber exploitation in southern Sweden that gave the forest a high economic value (Larsson, 1989).

The question of anthropogenic versus climatic influences on the fire regime is, naturally, a major issue in fire history studies and has important implications for conservational issues in many regions (Swetnam, 1993; Lehtonen et al., 1996; Veblen et al., 1999; Niklasson and Granström, 2000). While the influence of man on the fire regime in a restricted area is very difficult to prove, our data set gives other strong support for human interference. First, the number of fires recorded exceeds by far the natural background levels from lightning strikes (Granström, 1993; Niklasson and Granström 2000). In this region, Granström (1993) recorded the equivalent of 20 lightning fires per century in a 10×10 km area. In our study we recorded c. 12 fires per century

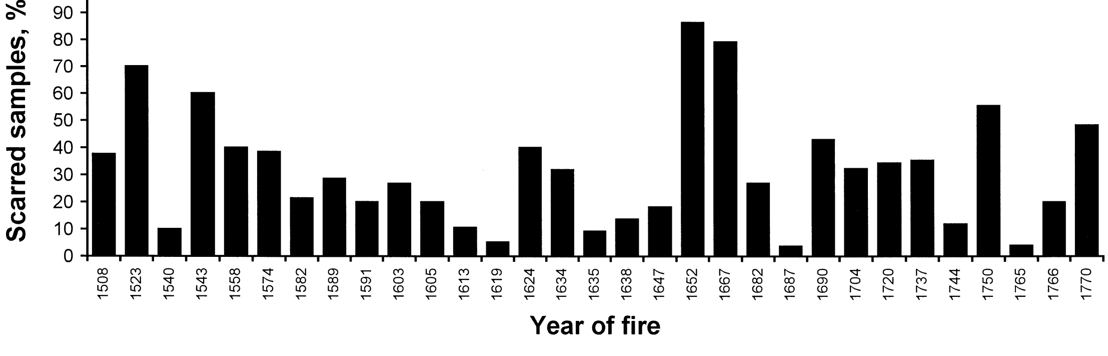

Fig. 7. Fire index for fires from 1508 to 1770. The index is the percentage of scarred trees of the total number of recording trees and gives a rough measure of the size of each fire.

in an area 100 times smaller, so it is highly likely that the number of fires in a 100 km^2 area would have been much higher than background levels.

Secondly, the significant shift to early season fires in the 1700s is supported in the literature concerning human use of fire. A court report from 1732 (Sturesson, 1994) gives clear evidence that deliberate burning has been present in the region. In this report a man was found guilty for intentional burning of *Calluna* "in order to improve the grazing". Such burning would have mainly aimed at regenerating the *Calluna* and increasing the coverage of palatable grasses that survive mild fires, probably *Calamagrostis* in better sites and *D. flexuosa* in poorer sites (Granström, 1993; Schimmel and Granström, 1997). The very short intervals between fires, 20 years on average, and as little as 5 years (Figs. 3 and 5) are probably close to the lower limit that it is possible to burn due to the time required for the build-up of the fuel (Schimmel and Granström, 1996, 1997). Those short intervals are not solely found inside the National Park since we have also compiled floating chronologies with similar intervals within a radius of 5 km.

We believe that the shift to early season fires during the 1700s is due to man (Figs. 6 and 7) rather than to a sudden change in climate. Spring fires may have been easier to control for both fuel and meteorological reasons, as is well known from Indians in boreal Canada (Lewis, 1982). The majority of naturally ignited fires are started during the warmest part of the summer (Kinnman, 1936; Granström, 1993), while the last 10 fires almost exclusively burned in the dormant period of the trees, i.e. late August to late spring or early summer. For earlier fires, however, the data (Fig. 6) make it difficult to rule out lightning as a cause of fires. For example, the two large fires in 1652 and 1667 were reported as large fires in a cross-dated fire history study in Tiveden National Park (Page et al., 1996); the summer of 1652 was documented as a very hot summer with many fires (Kohh, 1975; Larsson, 1989). During such summers, lightning may very well have ignited the majority of fires, as in the summer of 1933 in northern Sweden (Högbom, 1934).

4.3. Implications for management of earlier fire-disturbed reserves and forests in the hemiboreal zone

It is often proposed that ecologically sound management of protected areas as well as production forest should reflect the disturbance regime of the natural forest (Attiwill 1994; Angelstam, 1998; Seymour and Hunter, 1999) and focus at re-creating key structures that were present in the natural landscape (Fries et al., 1997; Nilsson and Ericsson, 1997). To accomplish this, it is necessary to gather background information on past disturbance regimes (Foster et al., 1996). In southern Sweden, however, the presence or absence of fire is normally very difficult to reconstruct because most above-ground traces (fire-scarred trees, stumps and charcoal) are absent due to long-term suppression of fire and subsequent spruce invasion, together with a long period of more or less organized forestry in southern Sweden. In addition, heavy utilization of dead wood for tar-processing and charcoal production in the past has eradicated most of the dead wood (Nilsson, 1997). As a result, it is only in lake or mire sediments, where charcoal is preserved that data are provided on past fires although these give a less precise picture (Bradshaw and Hannon, 1992; Pitkänen, 1999; Lindbladh et al., 2000; Tryterud, 2000).

Disturbance-mimicking models for sustainable forestry (Angelstam et al., 1993) based solely on ground vegetation types, may therefore easily give results other than those expected. In such models, many of the components for the threatened invertebrate fauna (heavily resin-impregnated wood, charred wood, large senescent trees, snags, sun exposed trees and snags) are difficult or impossible to recreate without using fire in forestry or conservation management. A more complex approach is thus needed where particular requirements for threatened species are identified and re-created. For example, the beetle *Tragosoma depsarium* requires dead trees exposed to the sun but in contact with ground moisture.

Many key features may easily be created within the framework of traditional forestry practices (Ahnlund and Lindhe, 1992), but some are more directly linked to effects of fire. For the large number of species dependent on the latter a burning programme may ensure their long-term survival (Wikars, 1997). For most obligate fire-dependent organisms, like the threatened beetle *Melanophila acuminata*, it is still unknown what threshold levels are needed in terms of annually burned forest area (cf. Ahnlund and Lindhe 1992; Wikars, 1997). It is clear, however, that the present fire frequency is far below such a threshold for some species, such as the beetles *Agonum bogemanni* and *Chalcophora mariana*, which have not been recorded in the country during the last century (Ehnström and Waldén, 1986).

Following this line of reasoning, re-introduction of fire in many protected areas might be the only logical solution. However, there are many factors that complicate how this should be implemented in practice, mainly because of structural and vegetational changes caused by the long time since the last fire. The reintroduction of fire in the core area of Norra Kvills National Park would not be an easy task since the invasion of spruce has dramatically changed the canopy composition and fuel conditions compared to the past. The moss carpet that has replaced dwarf-shrubs under the darker crowns of spruce is flammable only after long period of drought (Granström et al., 1995). In such situations, surrounding managed forests face very high fire hazards if a prescribed burn is set inside the reserve, and single, very old, specimen pines may easily be killed by fire that climb nearby spruces or enter their inner parts through the often rotten core (Linder et al., 1998). Those very rare trees represent very high values for pedagogical and aesthetical reasons and should better be left alive. Therefore, a prescribed fire inside the reserve must be conducted when fire hazard is low. Such fires have limited ecological effects on the field and tree layer, and furthermore, the occurrence of rare species associated with late spruce successions (e.g. *Fomitopsis rosea, Ceruchus chrysomelinus*) in formerly burned forest areas (see Section 4.1) poses a difficult conservation problem. With the present knowledge, such habitats should be treated as fire refugia with a long continuity of spruce where fire-sensitive species can survive (Ohlson and Tryterud, 1999).

Because of these practical and conservation problems, we therefore propose that prescribed burns should be carried out in the younger, mixed stands of pine and broadleaves with some larger pines inside the reserve or in stands in the surrounding landscape. Such fires would rather be aiming at starting a new process in a new area rather than trying to revive conditions in the old part of Norra Kvill — which we consider has passed beyond what is manageable by fire with current techniques. This is supported by the fact that most sampled pines experienced their first fire as young trees and thus fires will imitate the natural landscape with a mosaic of successions and burns where the effects of fire was variable. Should such prescribed fires become too intensive, no great values are at risk compared with the situation in the old park. In addition, a biologically valuable broadleaf succession will probably occur.

Today the non-intervention management model is prevailing in southern Swedish coniferous forest national parks and nature reserves. This applies regardless of whether they were intended to represent earlier fire-disturbed pine/pioneer broadleaf forest types or more fire-sensitive, spruce-dominated forest types. We conclude that this is detrimental for Norra Kvills National Park and similar areas primarily because this forest type is highly dynamic and shaped and regenerated by fire, hence the associated flora and fauna also depend on continued disturbances. Spontaneous, lighting-ignited fires within the park are statistically unlikely (i.e. rare) and those occurring in the surrounding, managed landscape are effectively suppressed. As long as the protected area does not exceed the size of the largest disturbance patch size (probably on the scale of thousands of hectares), the development towards spruce domination therefore will continue (Pickett and Thompson, 1978). Consequently any protected area with a history similar to Norra Kvills National Park will become less and less representative (Norton, 1999) and unsuitable for the rare flora and fauna, for which it was once intended, unless fire is restored in some form as suggested above.

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