# Anthropogenic impact on past and present fire regimes in a boreal forest landscape of southeastern Norway

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**Abstract:** Fire-scarred wood samples from 50 stumps, snags, and living trees of Scots pine (*Pinus sylvestris* L.) were dendrochronologically cross-dated to describe an 800 year long fire history of Eldferdalen Nature Reserve (~6 ha) and its surroundings (~4000 ha) in southeastern Norway. In the western part of the study area, we recorded 55 different fires within a 200 ha area around the reserve between 1511 and 1759 and a mean fire interval in single samples of 24.6 years. The composite mean fire interval for the nature reserve was 10.5 years. Fire intervals were longer in the eastern part of the study area, with a single sample mean fire interval of 49.1 years. Only three fires were detected after 1759, the last one in 1822. Based on historical accounts, we assume that the high number of fires and short fire intervals were influenced by deliberate ignition for agricultural purposes, most likely burning to improve the conditions for cattle grazing and slash-and-burn cultivation. We suggest that the cessation of fires was influenced by the increased value of timber and mining activity, thereby leading to increased interest in conservation of the timber resources.

**Résumé :** Des échantillons de bois portant des cicatrices de feu et provenant de 50 souches, chicots et tiges vivantes de pin sylvestre (*Pinus sylvestris* L.) ont été datés par recoupement à l'aide de la dendrochronologie pour reconstituer l'historique des incendies sur une période de 800 ans dans la réserve naturelle Eldferdalen (~6 ha) et aux alentours (~4000 ha) dans le sud-est de la Norvège. Dans la partie ouest de l'aire d'étude, les auteurs ont identifié 55 incendies différents à l'intérieur d'une zone de 200 ha autour de la réserve entre 1511 et 1759 et un intervalle moyen entre les incendies dans les échantillons uniques de 24,6 années. L'intervalle moyen composé entre les incendies pour la réserve naturelle était de 10,5 années. Les intervalles entre les incendies étaient plus longs dans la partie est de l'aire d'étude avec un intervalle moyen entre les incendies dans les échantillons uniques de 49,1 ans. Seulement trois incendies ont été détectés après 1759, le dernier étant survenu en 1822. Sur la base de comptes rendus historiques, ils assument que le nombre et la fréquence élevés des incendies ont été influencés par des allumages délibérés à des fins agricoles, fort probablement le brûlage pour améliorer les conditions de pâturage pour le bétail et la culture itinérante sur brûlis. Les auteurs croient que les incendies ont cessé à cause de la valeur accrue du bois et de l'activité minière et, par conséquent, de l'intérêt croissant pour la conservation des ressources ligneuses.

[Traduit par la Rédaction]

## Introduction

Forest fire is recognized as the principal disturbance agent in boreal coniferous forests in the past (Zackrisson 1977; Heinselman 1981) and of great importance for plant succession, ecosystem processes, landscape structure, and biological diversity. Hence, forest fire history is an important component in describing the historical range of variability in forest ecosystems, which may serve as a guideline for forest management and nature reserve management (Landres et al. 1999; Swetnam et al. 1999). However, natural forest fire regimes were highly variable depending on climate, topography, and vegetation (Engelmark 1987; Swetnam 1993; Hellberg et al. 2004; Wallenius et al. 2004). Moreover, humans used forest fires for numerous purposes, for example, clearing land, improving grazing conditions, and slash-and-burn cultivation (Pyne 1997). Hence, forest fire history will vary between study areas and different time periods.

Several studies of forest fire history in Fennoscandia (Zackrisson 1977; Haapanen and Siitonen 1978; Engelmark 1984; Lehtonen and Kolström 2000; Niklasson and Granström 2000) were undertaken in areas that were first settled by farmers from the late 1600s. Results from such areas have partly been used in developing forest management models to mimic natural disturbance regimes in Fennoscandia (Angelstam 1998). Anthropogenic influence on past forest fire regimes through slash-and-burn cultivation and burning to improve grazing conditions has been documented from different parts of Fennoscandia (Lehtonen et al. 1996; Lehtonen and Huttunen 1997; Lehtonen 1998; Niklasson and Granström 2000; Niklasson and Drakenberg 2001), but still little is known about the extent of human influence on forest fire history in the southern part of Fennoscandia. The purpose of this study

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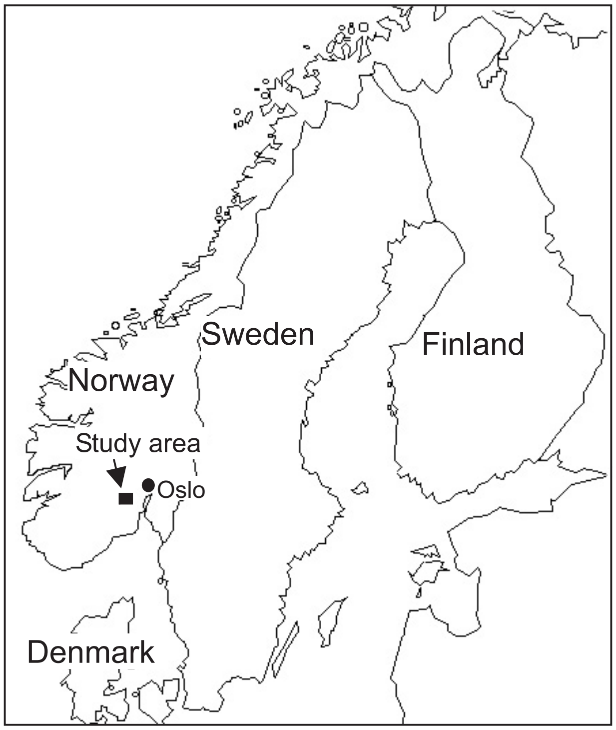
**Fig. 1.** Location of the study area.




was to document the fire history of a southern Fennoscandian location in Norway, a region with hitherto unknown fire history.

## Materials and methods

### Study area

The study was initiated in Elferdalen Nature Reserve (59°39′N, 9°19′E) (Fig. 1), a small forest reserve (~6 ha) with a postfire succession of Norway spruce (*Picea abies* (L.) Karst) established under a canopy of Scots pine (*Pinus sylvestris* L.) (Huse 1964). To explore the spatial variation in fire history around the reserve, samples were collected within a total area of ~4000 ha between 300 and 700 m above sea level (Fig. 2). The study area is situated in the transition between the southern and middle boreal vegetation zones (Moen et al. 1999). The mean annual temperature is 4.5 °C, and mean annual precipitation is 800 mm (Kongsberg, 171 m above sea level). The growing period (number of days with an average temperature ≥5 °C) lasts 170–190 days (Moen et al. 1999), and ~40% of the annual precipitation falls in the summer months of May, June, July, and August. Soils consist of relatively thin and discontinuous layers of podsolized morainic material and the bedrock is dominated by gneisses with zones of amphibolites.

The study area has ~90% forest cover. The remaining part is constituted by water bodies (~2%), mires (~2%), and nonproductive areas (~4%). Scots pine and Norway spruce are the dominant tree species at the landscape scale, at present comprising >95% of the timber volume, with Scots pine as the dominant conifer (80%). The landscape is dominated by dryish to mesic vegetation types, and ericaceous dwarf scrubs (*Calluna vulgaris*, *Vaccinium myrtillus*, and *Vaccinium vitis-idaea*) dominate the ground vegetation. The forest floor is covered with pleurocarp mosses (*Pleurozium schreberi* and *Hylocomium splendens*) and *Dicranum* spp. in mesic sites, while lichens of mainly *Cladonia* spp. dominate on the driest sites.

### History of the study area

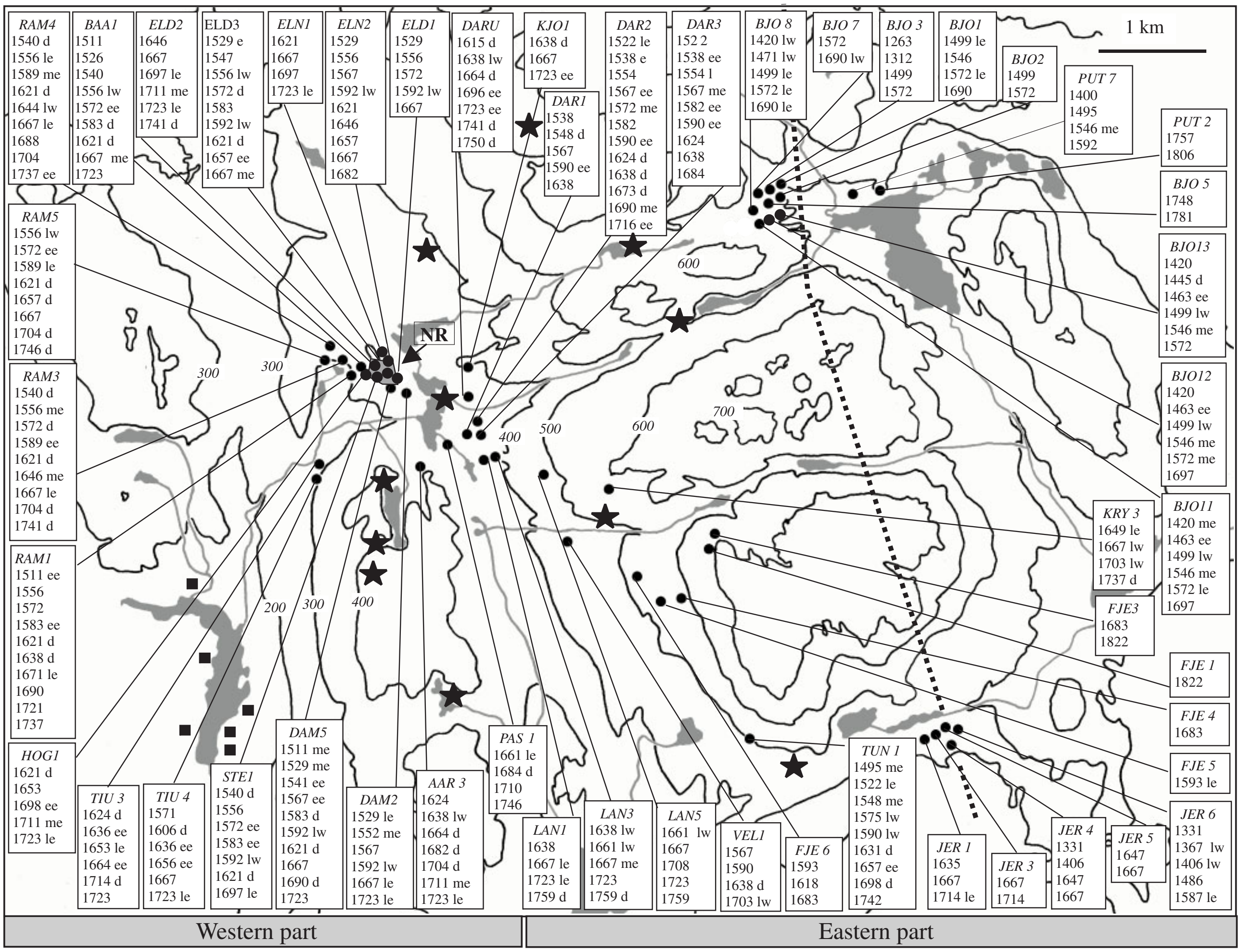
Several farms in the nearby settlement Lisleherad are documented in historical sources since the late 1300s (Fig. 2), but their origin is before the historical sources (Holta 1927). According to tradition and ethnological evidence, the farmers utilized the forested areas for logging of building materials and firewood, summer dairy farms, fodder collection, and grazing. Logging for sale and export to Europe started already in the late 1500s (Østvedt 1963), but we have no accounts of the magnitude of this early logging activity in the study area. From 1721, the area east of the present county border (Fig. 2) was administered by Kongsberg silver mines to ensure the supply of firewood and timber to the mines. The silver mines, operating from 1623 to 1958, were Norway's largest industrial enterprise in the 1700s (Helleberg 2000).

### Methods of data collection and data analysis

We searched the area for fire-scarred stumps, snags, and living trees of Scots pine and used a chainsaw to sample complete or partial stem discs with fire scars (Arno and Sneck 1977). Living trees with fire scars were rare, with only seven samples coming from living or recently dead trees. Stumps and snags with multiple scars were preferred over single scarred material when there were alternatives within a short distance, and not all detected fire-scarred material was sampled at sites with several alternatives. Samples were first collected within Eldferdalen Nature Reserve and preliminary dating revealed very short fire intervals compared with previous studies in Fennoscandia. Therefore, we enlarged the study area to check whether the pattern of frequent fires was upheld at a larger spatial scale. First, we tried to obtain an even distribution of samples within a radius of 1.5 km of the reserve. Second, we searched for fire-scarred material in four directions (northeast, southeast, northwest, and southwest) up to 9 km from the nature reserve. Sampling was partly governed by accessibility by road. The distribution of fire-scarred material was very variable throughout the study area owing to previous logging activity and extraction of stumps for tar production. Together with many undated samples, the resulting spatial distribution of dated samples is relatively scattered (Fig. 2).

Stem discs were sanded with a belt sander before cross-dating under a binocular microscope (6–40× magnification). Cross-dating followed the pointer year method (Douglass 1941; Stokes and Smiley 1968; Niklasson et al. 1994). Fire scars, and in some cases fire-induced ring disturbances, were used as positive fire indicators (Brown and Swetnam 1994; Niklasson and Granström 2000). After a fire, a fully open scar is not always formed and a similar case can be found when the sample is taken above a scar that is overgrown. Tree-ring features like large concentrations of traumatic resin canals, a sudden local negative growth reaction, and unusually pale or "double" latewood may be present in the tree rings as a result of fire (Niklasson and Granström 2000). Such features were only used as positive fire indicators when

**Fig. 2.** Map of the study area with the location of cross-dated fire-scarred samples (circles). Fire year and seasonal dating are listed in a text box for each sample. Fire scars were classified as dormant season (D) scars, early earlywood (EE) scars, middle earlywood (ME) scars, late earlywood (LE) scars, and latewood (LW) scars; no letter(s) denotes fire years with unknown season. Delineation between the western and eastern parts of the study area is marked at the bottom of the map. Solid lines, contour lines (contour interval 100 m); grey areas and lines, lakes and streams; broken line, county border; squares, farms; stars, summer dairy farms; NR, Eldferdalen Nature Reserve.




they were confirmed by open scars in neighboring samples. We collected more than 90 samples from snags, stumps, and living trees with fire scars. The pointer years were very site specific, probably owing to differences in water stress among sites, so pointer year chronologies had to be established at a local scale. In all, 50 samples were successfully cross-dated.

We recorded the position of the fire scars within the tree ring to assess the season of the fires. Fire scars were classified as dormant season (D) scars, early earlywood (EE) scars, middle earlywood (ME) scars, late earlywood (LE) scars, latewood (LW) scars, or unknown season (Baisan and Swetnam 1990). D scars were assigned to either the earlier or later year, depending on the presence of early- or late-season scars in neighboring samples, respectively. In cases without neighboring samples with seasonal dating, D scars were assumed to be early-season fires.

Mean fire interval (MFI) was calculated on the basis of fire intervals in single samples. Composite mean fire interval (CMFI) (Dieterich 1980) for clusters of samples was calculated for Eldferdalen Nature Reserve, including samples within 50 m from the reserve border. In the western part of the study area with the highest fire frequency, we also calculated CMFI by clustering neighboring samples <200 m apart (nine clusters, average number of samples 2.4), and no samples were used in more than one cluster. Comparisons of fire interval distributions between the two portions of the study area were only performed for the period 1487–1822, since no samples in the western part dated earlier than 1487.

A rough assessment of the spatial extent of single fires was obtained by measuring the distance between the two samples that were situated farthest apart for each fire year. The FHX2 computer program was used to analyze the fire history data (Grissino-Mayer 1995).

## Results

The cross-dated tree-ring chronology for the study area covered 800 years (AD 1196–1996), with the first fire dated to 1263 and the most recent fire to 1822 (Fig. 3). We recorded a total of 86 fire years (from 263 scars) with 82% of

**Fig. 3.** Forest fires in the study area around Eldferdalen Nature Reserve. Horizontal lines represent individual trees and the fire years are marked with vertical bars. Each fire year is projected to the time axis and the composite fire chronology for all samples is shown as long vertical bars above the time axis.

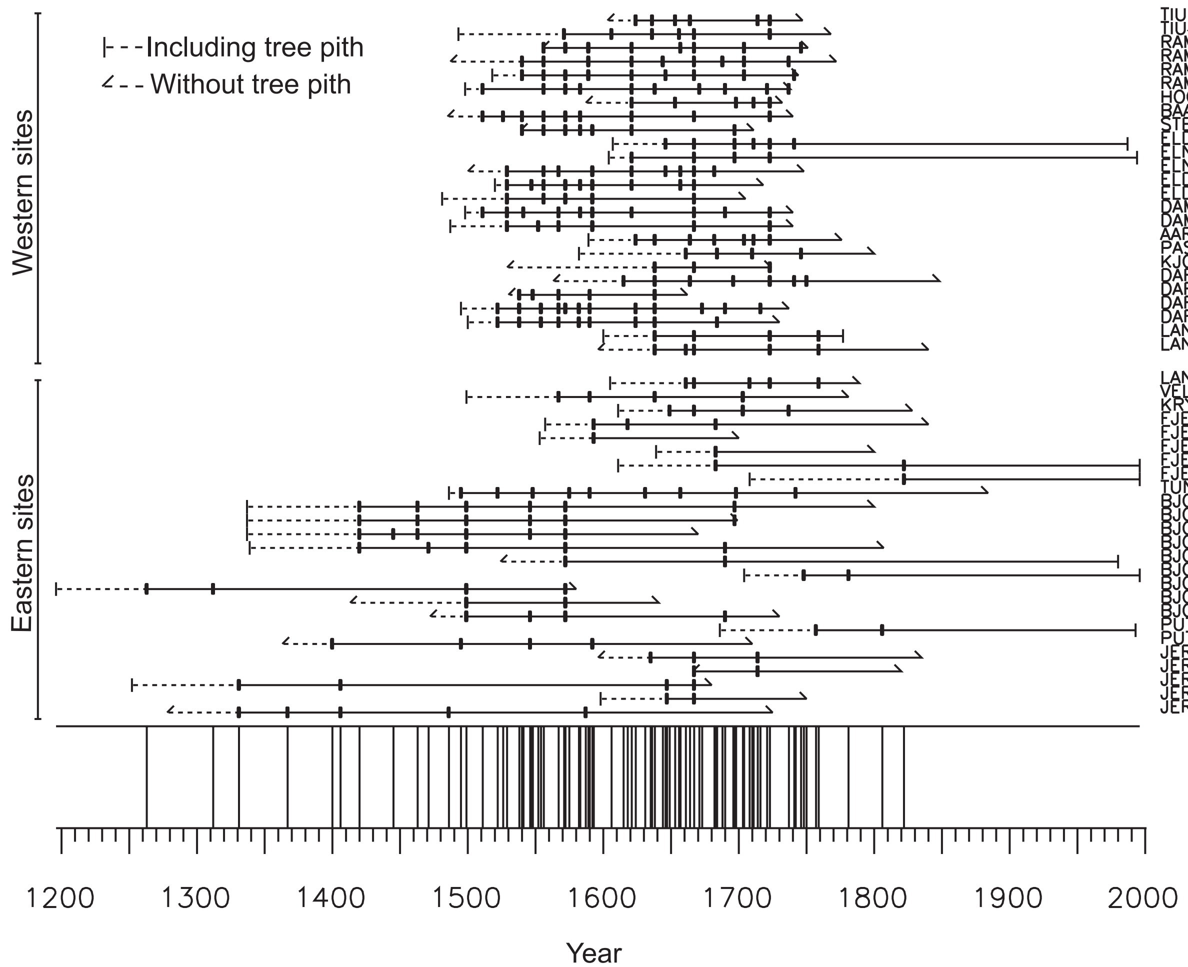
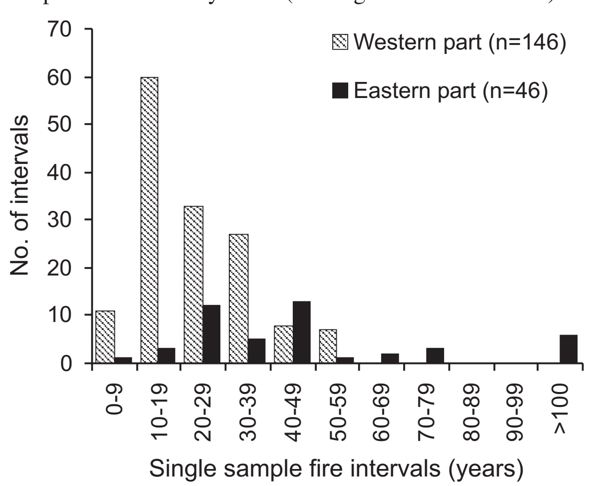



**Fig. 4.** Fire intervals in single samples split into the western and eastern parts of the study area. (see Fig. 2 for delineation).

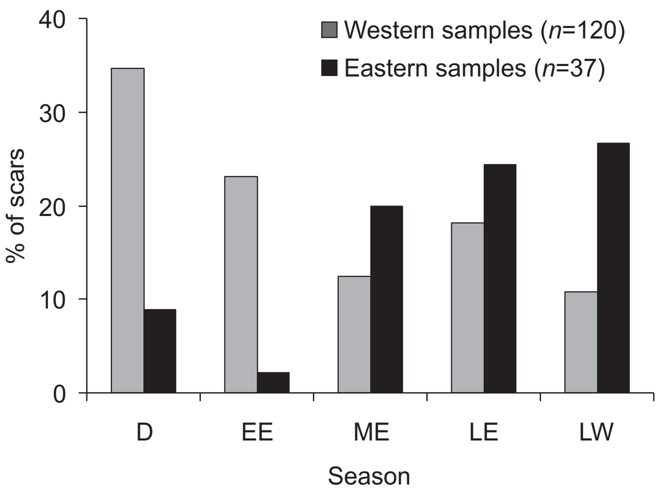



the fire years dating to the period between 1490 and 1769. This corresponds to a fire event every 6.5 years for the whole study area between 1263 and 1822. Samples extending prior to 1487 were only found in the eastern part of the study area. There were also relatively few samples covering the period from the mid-1700s to the present (Fig. 3). The shortest interval recorded between two fires in a single tree was 5 years. Fires almost ceased after the mid-1700s and no fires were detected in the tree-ring records after 1822 (Fig. 3).

We had no a priori hypothesis regarding spatial differences in fire history of the study area, but there appeared to be a west–east gradient in fire intervals (Fig. 4) (Spearman rank correlation of MFI of single samples on a west–east gradient, $r = 0.52$, $p < 0.001$). There was also an altitudinal gradient from the west to the east (Fig. 2). For further analysis, we arbitrarily split the data set into two halves (Figs. 2 and 3).

Fire frequency varied within the study area, with shorter fire intervals in the western part around Eldferdalen and generally longer fire intervals in the eastern part of the study area (Fig. 4) ($t$ test on log-transformed values of single sample intervals, $t = -6.6$, $p < 0.001$, $n_{west} = 150$, $n_{east} = 46$). In the western part, we recorded 55 different fires in 25 samples between 1487 and 1822 corresponding to a CMFI of 4.6 years (median 4.0) within an area of ~200 ha (area delineated by the western samples). Single sample MFI was 24.6 years (±14.3 SD, median 21.0). The CMFI of clusters of samples <200 m apart averaged 17.4 years. The CMFI of Eldferdalen Nature Reserve was 10.5 years compared to a single sample interval of 23.9 years (~6 ha, nine samples).

**Fig. 5.** Distribution of seasonal dating of fires split into the western and eastern parts of the study area. (see Fig. 2 for delineation). Fire scars with seasonal dating were classified as dormant season (D) scars, early earlywood (EE) scars, middle earlywood (ME) scars, late earlywood (LE) scars, and latewood (LW) scars. Fires with unknown seasonal date constituted 31% of the fire scars in the western part and 49% of the fire scars in the eastern part.




In the eastern part of the study area, 25 samples were cross-dated successfully (Fig. 2). Fire intervals were longer with an MFI for single samples of 49.1 years (±33.3 SD, median 41.0) for the period 1487–1822 and 54.3 years (±42.4 SD, median 42.0) for the whole period covered by these samples (1263–1822).

Our assessment of fire season determined from the intra-annual position for 157 of the 263 fire scars showed that 72% were formed during the growing season. Early-season fire scars, that is, D and EE, scars constituted 45% of all scars dated with seasonal resolution (1296–1822). The frequency of early-season scars (D and EE) was higher in the western than in the eastern part of the study area (Fischer's exact test, $p < 0.001$). In the western part of the study area, D and EE scars constituted 58% whereas D or EE scars constituted only 11% of the fire scars with seasonal resolution between 1487 and 1822 in the eastern part (Fig. 5).

In a spatial view, there seems to have been large variation in the spatial extent of single fires. Between 1487 and 1822, 55% of the fire years were recorded in one sample or in samples <500 m apart. However, MFI of fires with a distance between scarred samples between 2 and 5 km was 28.3 years. We also recorded 12 fire years with >5 km between scarred samples (i.e., every 31 years), but from the combination of seasonality of the fires and location, we interpreted the majority of these fires to be a result of two temporally different fire events within the same fire year.

## Discussion

### Comparison with the rest of Fennoscandia

Previous fire history studies from Fennoscandia have generally reported longer fire interval estimates than we found in our study area, especially in the western part around Eldferdalen Nature Reserve. The MFI estimate for the eastern part also lies in the lower range. In the northern parts of Sweden, Zackrisson (1977) and Engelmark (1984) reported MFI of 40–50 years in dry pine forest and up to 150 years on more mesic sites in the period from the late 1500s up to the late 1800s. In the same region, Niklasson and Granström (2000) found median fire intervals of 79 years prior to colonization in the late 1600s and 52 years after farmers settled the area and started to affect the forest fire regime. MFIs reported by Haapanen and Siitonen (1978) on medium dry vegetation types in northeastern Finland averaged 82 years in stands with multiple fires. Lehtonen and Kolström (2000) and Wallenius et al. (2004) found an MFI of around 60 years in two neighboring study sites in northwest Russia. Fennoscandian studies reporting MFIs closer to the range that we found in our study all come from areas where human activity has influenced the forest fire history. In the eastern parts of Finland, where slash-and-burn cultivation had affected the fire regime in the past, single sample MFI ranged from 30 to 60 years in four different study areas from around 1500 to the late 1800s (Lehtonen et al. 1996; Lehtonen and Huttunen 1997; Lehtonen 1998). The shortest fire intervals have been reported from the southern part of Sweden with single sample MFIs of 27 years (Page et al. 1997) and 20 years (Niklasson and Drakenberg 2001).

### Interpreting the fire intervals

All of our samples were found on dry to mesic sites. Forest fires seldom burn all parts of an area owing to small-scale variation in site moisture and vegetation (e.g., Wallenius et al. 2004). Such small-scale variation has also been demonstrated within Eldferdalen Nature Reserve (Tryterud 2000). Thus, the population MFI is likely to have a broader range than our estimates based on samples from the drier parts. Another possible bias in our MFI estimates as population MFI, even on the drier part of the forest, might come from the sampling strategy of partly targeting multiple-scarred samples. By targeting multiple-scarred trees, one is likely to sample the areas with the most frequent fires (Baker and Ehle 2001). Hence, our fire interval estimates should not be interpreted as population MFIs but as estimates for the drier portion of the forest that burned most frequently. Even though dryish to mesic site types largely dominate in the study area, small-scale heterogeneity suggests that the observed fire pattern should not be expected as an average throughout the whole landscape.

On the other hand, single sample MFI might underestimate the fire interval for the drier portion of the forest, as shown by the shorter CMFI for clusters of samples. This can reflect that the driest parts of the forest burned even more frequently, but not all fires were recorded in all trees. Another explanation is the occurrence of small controlled anthropogenic fires that actually did not burn the whole area included in the clusters.

### Possible explanations for the high fire frequency

The explanation for the high fire frequency in the present study could either be regional climatic variation resulting in a higher probability of forest fires in southern Fennoscandia or human activity influencing the ignition frequency. Background levels on lightning ignition frequencies are not available for Norway, but Granström (1993) reported an average of 23 ignitions·100 $km^{-2}$·100 $years^{-1}$ in the region with the highest present lightning ignition frequency in southern Sweden. In the western part, within the 200 ha area around Eldferdalen Nature Reserve (1/50 of the unit used by Granström (1993)), we recorded the equivalent of 23 fires·100 km$^{-2}$·100 years$^{-1}$ between 1511 and 1759, that is, markedly higher than the highest present background levels documented in southern Fennoscandia. The high ignition frequency and short fire intervals compared to that found in many previous Fennoscandian studies lead us to assume that anthropogenic ignitions explain a large proportion of the fires in the western part of the study area. Given the notion of anthropogenic fires in the west, we suggest that the difference in anthropogenic fire activity is the most probable cause for the difference in fire frequency between the eastern and western parts.

Anthropogenic fire in Fennoscandian forests has traditionally been ascribed to slash-and-burn cultivation (e.g., Steensberg 1993; Pyne 1996), probably owing to a rather ample literature on this subject and the importance of crop cultivation for survival. This use of fire has also been described in numerous historical sources in Norway since the 1500s (Østberg 1922), but the extent of this practice in Norway is not known. Studies from Finland have shown how escaping fires from slash-and-burn cultivation affected the fire frequency in surrounding forest (Lehtonen and Huttunen 1997; Lehtonen 1998). If escaping slash fires were the origin of anthropogenic fires in our study area, the extent of this practice seems to have been large and to our knowledge not reflected in the local historical sources.

Another fire practice was deliberate burning of forest to improve grazing conditions for domestic animals. This activity has hardly been analyzed or quantified in a systematic manner, probably because most of the sources of information build on anecdotes (e.g., Collin 1784; Frödin 1952). From the study area, we have found an undated anecdote where an elderly woman was accused of setting the forest on fire to "enhance the grazing conditions" (Holta 1927). The study area has been used for grazing and fodder collection for centuries, and local informants identified several historical summer dairy farms within the study area (Fig. 2). Summer dairy farms were located in the forest or close to the mountains and used during the summer season to increase the availability of grazing resources for domestic animals (Reinton 1955), and it is likely that intentional burning could have been carried out. Several vascular plant species common in the area are preferred grazing plants and known to flourish after burning (Nedkvitne and Garmo 1986). Examples are *Calamagrostis* spp., *Deschampsia flexuosa*, *Chamaenerion angustifolium*, and *Rubus idaeus* on slightly more fertile sites. On poorer sites in the area, the field layer vegetation is typically dominated by *Calluna vulgaris*, a species that was managed with frequent controlled burning in the suboceanic and oceanic parts of Europe in the past (Gimingham 1989). We propose that fire also was used in this area to burn the *Calluna*-dominated sites to initiate fresh shoots of *Calluna*.

### Seasonal dating of fires

In addition to the high fire frequency, the seasonal distribution of fires is another indication of anthropogenic ignition in the western part. A large proportion of the fires in the western part occurred outside the growing season or early in the growing season (57% D and EE fires) (Fig. 5). Assuming that most fires are lit by lightning during high summer under natural conditions, the seasonal distribution of fires in the western part might be a result of spring or early-summer burning of slash-and-burn fields or burning to improve grazing conditions. Spring and autumn are periods with both low lightning activity in eastern Norway (Rokseth et al. 2001) and low lightning ignition frequency in general (Granström 1993). However, burning for improving grazing conditions could have been carried out in these periods, especially in the spring when the previous year's dead organic material is dry. Burning of slash prior to cultivation was also carried out in the spring, generally before the middle of June. In the eastern part of the study area, the proportion of early-season fires was lower (11% D and EE fires). Together with longer fire intervals in the eastern part, we suggest that this is a result of differences in land use and anthropogenic ignition within the study area.

### Fire size

Our estimates of fire size indicate a large proportion of smaller fires that might have been fires under human control. Large-scale studies of the size of historical fires have shown that human influence can alter the fire regime towards more frequent and controlled smaller fires (Page et al. 1997; Niklasson and Granström 2000). Our data did not allow for detailed reconstructions of the size of individual fires (e.g., Niklasson and Granström 2000), but the measure of the longest distance between samples scarred during the same fire year gives an indication of the variation in spatial extent. These results should be interpreted with some caution owing to the uneven spacing of samples throughout the study area. More than half of the recorded fires seem to have been of small size, that is, there was <500 m between samples scarred in the same fire year. However, larger fires with a distance between scarred samples of 2–5 km occurred every 28 years and illustrate that the high fire frequencies were not only a result of spot fires or very small fires. The fire of 1667 was the fire with the largest spatial extent and the highest proportion of scarred samples in our data. Interestingly, 1667 is documented as a large fire year in both Tiveden National Park (Page et al. 1997) and Norra Kvills National Park (Niklasson and Drakenberg 2001) in southern Sweden, so it appears to have been a large fire year of southern Fennoscandia.

### Possible explanations for the cessation of fires

The period of frequent fires ends around the mid-1700s (Fig. 3). A similar pattern has also been found in all previous fire history studies from Fennoscandia, but generally occurring a century later around the second half of the 1800s (Zackrisson 1977; Engelmark 1984; Lehtonen et al. 1996; Lehtonen and Huttunen 1997; Page et al. 1997; Lehtonen 1998; Lehtonen and Kolström 2000; Niklasson and Granström 2000; Wallenius et al. 2004). This dramatic change in the forest fire regime has been ascribed to the introduction of large-scale commercial forestry and active fire control and suppression. Forest fire regimes are also strongly influenced by climatic variation (e.g., Swetnam 1993; Kitzberger et al. 2001). A climatic influence on the fire regime in Fennoscandia might have some support in the simultaneous nature of the hitherto found ending of fires in Fennoscandia after the mid-1800s, although this has not yet been analyzed. The observed regional difference between the north and south (this study; Niklasson and Drakenberg 2001) could be due to regional variation in response to changes in climate (cf. Bergeron and Flannigan 1995). However, with the present scant knowledge of the relationship between climate and fire regime in this region, we suggest two possible anthropogenic explanations for the surprisingly early cessation of fires in our study area.

Kongsberg Silver Mines, the largest industrial enterprise in Norway in the 1700s, is situated only 20 km east of Elferdalen Nature Reserve. A "forest circumference" was established in 1721, giving the mining enterprise exclusive rights to the forest properties around the mine (Berg 1998). The circumference reached a little west of the present county border (Fig. 2), and thus, several of our samples are located within the old circumference. Human-induced fires within the circumference were a common subject of conflict between local farmers and the silver mine authorities (Niemann 1809; B.I. Berg, unpublished data). The observed cessation of fires in the eastern part of our study area might be explained by the increased influence from the silver mine administration.

The mining corporation did not administrate the forests west of the county border (Fig. 2). In Southern Norway, and also in this area, commercial forestry with logging for sale and export had already started in the 1500s, that is, at least two centuries earlier than in the northern and remote parts of Sweden and Finland (Østvedt 1963; Tveite 1964; Östlund 1993). The period from the mid-1700s to the beginning of the 1800s was a period of economic growth in Europe, with a doubling of timber prices in Norway (Tveite 1964). This increased value of timber in general might have led to increasing interest in conserving the timber resources, that is, decreased intentional burning, and maybe local interest in fire exclusion. Several legislative measures to prevent forest fires were also taken from the late 1600s onwards (Skogdirektøren 1909). It has, however, been considered that practical problems with detecting originators of forest fires and lack of interest among forest owners and others in tracking the originators limited the impact of these measures until well into the 1800s (Meidell 1858), but they reflect an increasing interest in conserving the timber resources at that time.

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