Forest Fire History: Ecological Significance and Dating Problems in the North Swedish Boreal Forest

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Abstract.--The past and present fire regimes are described, and the significance for the flora of this region is discussed. Methods used to reconstruct forest fire history are presented. The dating problems with false and absent rings in Scots pine, Norway spruce and two birch species are also dealt with.

INTRODUCTION

Descriptions of fire impact on the Swedish forest landscape are often found in literature from the 18th and 19th century. Already at that time fire was considered to have a purely negative effect, and fire prevention was considered desirable. This opinion found expression in the legislative measures taken to stop or prevent any use of fire to modify the forest ecosystem for agricultural practice.

At the end of the 19th century and the beginning of the 20th century, when the first more comprehensive forest biological research was carried out in North Sweden, the importance of fire for the origin and stability of the forest types was often discussed (Holmertz & Ortenblad 1886, Tamm 1920). The destructive influence of forest fires was very much stressed and a special forest organization was founded with the aim or reducing the impact of fire on the forests in the north of Sweden. Later, when the influence of uncontrolled fires was reduced, scientists tended to underrate the importance of fire as a natural ecological factor throughout history. Forestry research appears to have stressed man's role in causing forest fires, and often neglected or even denied the fact that many were caused by lightning.

Interest in fire ecology was greatly increased by the extremely severe fire year of 1933, and some very interesting work was consequently done (Högbon 1934, Wretlind 1934, Tiren 1937). Since the close of the 1930's very little research has been carried out on the natural importance of forest fires. One exception is the study by Uggl (1958) of a burned forest area in the Muddus region, North Sweden. Recently, a further series of papers on fire ecology of the whole circumpolar area has stimulated a fresh approach to, and renewed interest in, reconstructing fire influence on the boreal forest. The negative attitude toward the use of fire as a suitable management method for virgin-forest reserves has very slowly begun to change as knowledge of its actual function in ecosystems has increased. A more positive approach to the use of fire in modern forestry to improve regeneration by prescribed burning on soils with a thick, raw humus layer is also now detectable.

It is not until now that we have begun to realize how frequently the North Swedish boreal forests have been subjected to forest fires, and what effects they have had on the organisms found there.

CHANGES IN THE FIRE REGIME AND ITS SIGNIFICANCE FOR FOREST VEGETATION

Investigation of the forest region in the Vindelälven Valley, North Sweden has shown a forest fire rotation of about 100 years from the end of the medieval period up to the close of the 19th century (Zackrisson 1977). This figure includes different types of forest found within the whole river valley.

The Scots pine (Pinus sylvestris) dominated forest found on glaci-fluvial sandy plains along the river, has burned most frequently with a mean fire interval of about 46 years (fig. 1). In local stands, mean fire intervals of approximately 30 years for the last 600 years are found in the most fire-prone areas. Fire in this type of forest often gave rise to very uneven-aged stands, where successful regeneration often occurred a short period after the last fire.
Figure 1. --Local forest fire chronology of a lichen-pine forest stand in Harads, North Sweden. The fire years are marked with arrows and the intervals between fires are shown by figures between the arrows. The floating chronology to the left goes into the Viking age, but does not correspond exactly with the absolute chronology because of problems with absent rings in the oldest samples. The chronology is built up from 81 crosssections of pine. A mean fire interval of about 50 years is rather typical for most lichen-pine forests in the interior of North Sweden.

In mixed coniferous stands of the Vaccinium type found on morainic soils, intervals between fires are usually longer. Mean fire intervals are commonly 100 years. In this type of forest, Norway spruce (Picea abies) often forms the undergrowth regenerated after each fire. Scots pine often survives as overstory trees and can reach old ages (fig. 2).

In all these forest types previously influenced by frequent forest fires, fire impact has decreased drastically during the last 100 years (Zackrisson 1977). This is partly a consequence of severe restrictions in the rights of burn-beating and of burning for grazing improvement, as well as the introduction of an active fire-prevention policy. The latter received active support from the bulk of the population as soon as the value of forest for timber production was acknowledged.

Another very important factor in decreasing fire frequency was the passive fire elimination caused by extensive cutting out of dead standing trees from the 19th century and onward. Dry snags are of particular importance with regard to forest fires caused by lightning, since they catch fire much more readily than living trees do (Kourtz 1967).

In spruce forests on wet sites, fire has usually been rare. Fire-free intervals of up to 500 years can be found in exceptional cases. Normally, this type of long-term fire-free refuge seems to be a rather rare phenomenon in most of the boreal landscape. The special environment found in this type of late successional stage seems to be favorable for some very rare arboreal lichen species (Essen et al in press). Some rare vascular species could also be expected in the very late successional stages. It is important that such natural refuges be found and protected from clear-cutting, because several threatened species may be adapted to them.

Unfortunately, we have the same lack of knowledge concerning species dependent on frequent fire disturbance. There is therefore a great need for investigations describing different fire adaptations found among organisms in the boreal forest. By studying the strategies and mechanisms developed by different species to survive the long-term influence of repeated fires, we probably also will improve our understanding of floristic and faunistic changes currently taking place.

Some of the dynamics found today could be a direct effect of the drastically reduced influence of forest fires in the landscape. Organisms adapted to the special environment created by repeated fires may not always have been able to find other suitable sites for their survival, and so decreased both in number and distribution. To reduce these effects, a reintroduction of boreal pyro adaptations, as well as knowledge of the previous long-term influence of fire on different parts of the boreal landscape, is however very fragmentary. More detailed information is needed before fire can be
METHODS OF RECONSTRUCTING FIRE INFLUENCE ON THE FOREST

Historical sources such as land survey maps, court records, records of land inquiries, annual reports from district forest officers, and travel descriptions can be used to reconstruct the previous influence of fire on the forest landscape of North Sweden. These historical sources can be used to reconstruct burned areas and to check if the dating of a particular fire made by tree-ring counts is correct. Forest fires from this century can be traced by fire registrations at each fire fighting district.

For a detailed reconstruction of the fire history on a particular forest site, fire scar-dating is the easiest method to employ. In the forests of North Sweden, Scots pine can reach ages close to 1,000 years (Zackrisson 1979). Pine trees with multiple fire scars are common in areas less influenced by previous logging operations. Virgin forest types with Scots pine are also mostly quite uneven-aged, which is favorable when dendroecological methods are used to study the previous fire regime.

In the interior of North Sweden, dry standing trees, and stumps and logs on the ground are often well-preserved from rot because of the more continental climate found in this region. Dead wood of this type can be used for fire dating purposes (Zackrisson 1976).

Scots pine has traditionally been believed to produce annual rings even under very severe environmental conditions. This is probably true in most cases. The problem with partially absent rings, however, seems to be overlooked (fig. 3). When a cross section is taken, this problem can be eliminated in most cases, but when only a bore core is available, the problem is more serious unless cross-dating techniques are used.

Partial rings seem to be rather common in old, low-vigor trees. Cross sections taken at different levels of a pine stem could give different dates for the same fire scar. This phenomenon is described in fig. 4. Cross sections were taken close to the root neck and at breast height (1.3m). Dating by ring counts from the two samples in this case gave two different dates for the fires. The difference is no less than 13 to 19 years. The sample taken at the root neck level shows the accurate date of the last fire in 1758. This fire year has been verified by an extensive reconstruction of the forest fire history of the area. It is uncertain if this is a more general phenomenon found in most tree species, but this should be studied more thoroughly.

Asymmetrically developed rings, with sections of numerous rings missing, seem to be rather common in cross sections of Norway spruce and birch from some types of forest sites. An investigation made in a spruce stand in Arvidsjaur, North Sweden, influenced by a well-documented fire in 1831, will illustrate some of the dating problems caused by missing rings. The spruce stand was affected by a surface fire that killed some spruces but left others alive with fire scars at the base of the stem. Due to the fire, the spruce stand is composed of two different age classes. The younger spruces, all belonging to a lower tree layer, regenerated shortly after the fire in 1831.

Spruces with fire scars were sampled to study ring formation in the wood produced after the fire. As a consequence of the extensive fungal infections found in the older spruces previously damaged by fire, great problems arose in getting enough material for this pilot investigation. More than 200 trees with fire scars were cut, but only 24 could be used for ring counts. The cross sections accepted were taken out close to the root neck of the trees. In each cross section the tree rings were counted from three directions (fig. 5) under a Wild M 8 stereomicroscope.

Of the 72 counts made from different directions from the 24 cross sections, only 31 (43%) counts showed the accurate number of rings that should have been produced if one ring was formed annually from the damage in 1831 until
Figure 4.--Scots pine from Jokkmokk, North Sweden, scarred by well-documented fires in 1652 and 1758. The cross section taken at the base shows the accurate number of rings, while 13 to 19 rings are missing in the sample taken at breast height. These 13 to 19 rings are lost in the wood formation after the fire in 1758. A date made by ring counts at 1.3m would in this case have given quite incorrect dates for the fires. This is indicated in the figure by the false fire years 1771, 1777, 1671, and 1665.

Figure 5.--Norway spruce scarred by a fire in 1831. Ring counts were made at three directions as described in the text. Only one ring count (148 rings) made in the cross section taken out at the base of the stem could verify the actual fire year. The figure shows the rings found at different counts.

1980 (fig. 6). This pilot study also shows that 66% of the error found lies with ±1 year. Four percent of the counts showed more than 10 absent rings. In one observation, 21 rings were absent. When considering the counts with the highest number of rings found in each cross section, only 50% of the sampled cross sections could give an accurate number of rings in all three directions. Only in these trees would it seem reasonable to assume that a core taken out with an increment borer at the base of the stem would provide an accurate date for the fire by counting the rings found in the core.

In some cases, a false ring was produced close to the scar margin (fig. 7). This is also the reason why one extra tree ring is found in some counts in fig. 6. In most cases, this type of ring could rather easily be recognized as false if studied more closely. If studied at a higher magnitude, it mostly gives the impression of a frost-ring. How this type of false ring is formed is uncertain. One explanation is that heat from the fire could damage the xylem mother cells without lethally damaging the cambium. There are indications that xylem mother cells and undifferentiated tracheid cells are more sensitive to extreme temperature than the cambial cells (Aronson 1980).

The false ring formed close to the margin of the scar could, however, have a varying structure and could in some cases carry mimicking a real latewood formation with an abrupt transition to earlywood. It seems easy to recognize a false ring
Number of observations

![Graph showing number of observations for different trees.](image)

Figure 6. -- The results of ring counts made in 24 Norway spruce trees (Picea abies) scarred by fire in 1831. One cross section was taken out at the base of each tree, and ring counts were made in three directions in the wood formed after the fire (compare fig. 5). A total of 72 counts were made. The different numbers of rings found in the 72 observations are plotted in the figure.

(Fritts 1976), but in a specific case it could be very difficult to identify such a ring, especially if only a bore core is available. Taking into account all the problems involved in taking a core exact to the margin of the scar, it seems highly recommendable to use destructive sampling techniques when a more exact dating is needed. If cross sections are taken from a lot of spruces and at different levels of the stems, error could probably be minimized.

More severe dating problems arose when birch (Betula pubescens and B. verrucosa) from the same area described above was sectioned for dating purposes. Fullgrown trees of both the birch species often survive light surface fires and well-defined fire scars are formed. This was the case in the burned area from 1831. Because of a serious problem with decay, only 6 birches with fire scars could be used, and in one cross section, counts could only be done in two directions. As shown in fig. 8, no dating by counting rings in the healed-over wood gave the accurate date of the fire in 1831. In one case, no less than 36 (25%) rings were missing. Despite the lack of sample material, the results at least indicate that the problems of dating fires by using birch could be more severe than expected.

Rings in the birch species (B. pubescens and B. verrucosa) have often been used for calculating tree ages and reconstructing production capacities in birch stands (Fries 1964). However, the problem with absent rings has never been studied closely, but is sometimes mentioned as a possible error (Elkington & Jones 1974). To use birch for exact dating of fires seems rather hazardous without using a cross-dating technique, at least when very old trees are used as in this case. Between 253 and 369 rings were found at root neck level in the birch trees investigated, which indicates rather high actual ages for all of the stems. Some of the trees are probably around 400 years old.

![Graph showing number of missing rings for different birches.](image)

Figure 7. -- A false ring formed close to the fire scar margin to the right. In a cross section of the scarred area it is rather easy to identify this type of false ring. If only a bore core is used, false rings can be a problem.

Figure 8. -- The results of ring counts made on birch (Betula pubescens and B. verrucosa) scarred by fire in 1831. Ring counts were made in cross sections from 6 birches. In each cross section, ring counts were made in three directions in the wood formed after the fire. The number of missing rings in each ring count (observation) is plotted.
It is plausible that the difficulty with absent rings is closely connected with high ages, and that the problem of getting accurate dates by ring counts increases with the age of the tree. As pointed out by Kullman (1979), the problem of dating young stems of *Betula pubescens* by ring counts is probably very small. The impression received through previous investigations made by the author is that younger trees are more useful for dating fires. However, an error of ±1 year seems to be hard to avoid because of the special difficulties found in birch in determining whether the scar was produced late one growing season or early the next. This is a less severe problem in Scots pine or Norway spruce, where other wood structures could be used to specify the fire season.

**LITERATURE CITED**


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