CHAPTER 1

An Overview of Fire in Northern Ecosystems

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ABSTRACT

An introduction to the spatial and temporal diversity of fire is given for northern circumpolar ecosystems. Both physical and biological parameters make northern ecosystems different from those in temperate regions; these parameters, such as long day length through the summer months, presence of permafrost, and low biological productivity, are discussed in terms of their effects on the role of fire in the North. Aspects of fire behaviour and ecological effects of fire that contrast with fires in more temperate or tropical ecosystems are stressed, and the use of fire as a resource management technique is discussed.

1.1 INTRODUCTION

Peoples of northern countries for many years have lived with the fear of uncontrolled fire, and have recognized the usefulness or necessity of controlled fire in their lives. Early settlement of the New World by industrial cultures led to some of the largest fires ever documented. For instance, the Great Miramichi Fire of 7 October 1825 burned through an estimated 15,500 to 20,700 km² of the Province of New Brunswick, Canada and the State of Maine, USA. An estimated 160 people were killed in New Brunswick (Holbrook, 1943). More recently, an estimated 140,000 km² (or about 8% of the area surveyed) burned in Siberia, USSR, in the extremely droughty year of 1915 (Shostakovich, 1925: 368). Large fires are still a common occurrence in remote areas of North America (Rowe, 1979).

As the industrial usage of forests increased in economic importance during the present century fire suppression became the primary goal of management agencies in most areas. The economic cost was and is still high. For example,
in Canada the mean annual loss to uncontrolled fire was over $17 million for the years 1965–1974, and the forest fire control cost during 1977 amounted to more than $29 million (Brady, 1979). Over the past two decades there has been a growing awareness that as fire suppression techniques and equipment became more effective and the areal extent burnt annually decreased, ecological backlashes were surfacing. Simultaneously, an increased interest in the role of fire in ecosystem functioning has gathered momentum, until now there is a shift away from fire control or suppression and a shift towards fire management.

Much of the older literature on North American fire ecology, primarily oriented towards temperate ecosystems, has been successfully summarized through a series of conferences sponsored by the Tall Timbers Research Station of Tallahassee, Florida (Proc. Tall Timber Fire Ecology Conferences, 1962–1976). We applaud this pioneering work in bringing together scientists and land managers to discuss fire in a management-oriented, descriptive, and geographic context. In addition, there are several other widely available volumes that have made significant contributions to the science of fire ecology (e.g., Heinselman and Wright, 1973; Kozlowski and Ahlgren, 1974; Wright and Bailey, 1982). Three recent conferences (Mooney and Conrad, 1977; Gill et al., 1981; Mooney et al., 1981) have also succeeded in drawing together fire researchers. These conferences and proceedings records have focussed attention on ecosystem functioning and on the environmental aspects of fire primarily in temperate regions.

Research into the role of fire in northern ecosystems has understandably not yet attracted as much interest as in temperate regions but considerable research has been conducted. We recognize a number of important early northern works (e.g., Lutz, 1956, 1959; Ahlgren and Ahlgren, 1960) of authors who struggled under adverse North American conditions to record observations upon which we have built our present understanding of fire effects in northern ecosystems. In 1971 an important conference was held in Fairbanks, Alaska (Slaughter et al., 1971) which brought together for the first time individuals who were interested in the role of fire in the more northern parts of North America. More recent fire ecology synthesis papers have summarized certain aspects of the growing body of North American literature (e.g., Rowe and Scotter, 1973; Viereck, 1973; Viereck and Schandelmeier, 1980).

In Europe and northern Asia scientists have long studied fire control and effects. Artsybashev (1974), Kurbatskii (1974), Ovsannikov (1978), Shcherbakov (1979), and Vakurov (1975) have synthesized much of the literature from the USSR, while Norwegian, Swedish, and Finnish fire research has been summarized by Braathe (1973), Viro (1969), and Sirén (1973), respectively.
1.2 THE NORTHERN ENVIRONMENT

We define northern circumpolar ecosystems as the tundra, the northern and central boreal forest, and, in some cases, part of the commercial southern boreal forest. We do not include the High Arctic tundra ecosystems and even parts of the southern tundra in discussions of fire because there is insufficient fuel to support fires, and we also exclude the temperate mixed-wood forest which is located to the south of the boreal forest. Within this vast expanse of landscape there is considerable geographic diversity in environmental parameters that influence fire behaviour and the ecological diversity on which fire impinges. Only a few brief examples are given here to identify some of the unique features of northern ecosystems. For more detailed descriptions of the boreal forest features the reader is referred to works such as Larsen (1980).

1.2.1 Physical Parameters

Figure 1.1 shows how day length changes as a function of latitude during the summer months. Researchers involved in fire behaviour studies recognize that the fire season in more northern latitudes comes with a great rush in the spring and recedes quickly in the autumn. At higher latitudes, there are longer day lengths, so fuels remain dry due to a longer exposure to insolation. Instead of fires slowing in ‘late afternoon’ due to higher air humidities, as in the southern part of the boreal forest, fires tend to continue to spread much later in the day because air moisture and therefore fuel moisture remains low.

![Figure 1.1 Day length duration (number of hours with the sun above the horizon) as a function of month and increasing latitude (adapted from Hare and Thomas, 1974, p. 130)](image-url)
Insolation is a major driving variable in the thermal and water budgets of the vegetation and soil surface. With increasing distance northwards, the annual energy balance is less positive. Therefore perennially frozen ground (permafrost) is deeper and the summer thaw depth is more shallow. Figure 1.2 shows the extent of continuous permafrost in the northern extremes of the continents, and also demonstrates the strong influence of continental climates on permafrost distribution. This is particularly obvious for central Siberia. Burning of the vegetation cover and organic soils results in a deeper summer...
thaw depth, which strongly influences processes such as nutrient cycling rates and therefore biological productivity. The blackening of the surface and the removal of the insulating material results in a decreased albedo and increased conversion of radiation to heat which influences both water and thermal budgets. Water budgets are important in determining how much energy is released to contribute to fire spread and how much vegetation cover and soil organic matter are removed during a fire.

It must be remembered that there is a great deal of climatic variation in northern regions. From an examination of climatic diagram maps such as those produced by Walter et al. (1975) it is obvious that the fire regime can be dramatically different because of regional differences in precipitation and evaporation.

In much of the circumpolar North sufficient fuel is usually available to carry a fire. Fire frequency will then be determined by weather conditions and, of course, an ignition source. Figure 1.3 is a simplified version of the Forest Fire Weather Zones of Canada map produced by Simard (1973) to show the degree of variability in fire weather across Canada. In his map, Simard has contoured the mean Fire Weather Index (FWI), which is a numerical rating of fire intensity, for June, July, and August on 2 FWI units. In Figure 1.3 zones are divided into 'very low' (FWI = 0–4), where fires tend to extinguish

Figure 1.3  Forest Fire Weather Zones in Canada, based on mean Forest Fire Weather Indices for June, July and August (adapted from Simard, 1973)
naturally, 'low–moderate' (FWI = 4–10), and 'high–extreme' (FWI > 10). In eastern Canada, fires tend to be light surface fires but in western Canada the FWI is higher and reaches values in excess of 32 in the interior of southern British Columbia. Under these conditions individual tree crowns burn during surface fires. There are also two large areas, in Alberta–Northwest Territories and in the Yukon Territory, that have Fire Weather Indices between 10 and 14 (light surface fires). Simard (1973) has indicated that Fire Weather Indices of 4, 10, and 32 represent fire intensities of 90, 260, and 8650 kW/m, respectively.

1.2.2 Biological Parameters

Within the tundra and boreal forest zones there is considerable geographic variation in dominant species (Figure 1.4). Fire plays almost no role in the High Arctic ecosystems and only a minor role in the Low Arctic tundra, so there has been little work in these areas linking fire effects to major plant community types. In the forest-tundra and boreal forest, however, fire effects have been more closely linked to major vegetation zones since there are similar ecological responses to fire in communities with dominant ecological equivalents within the pine, spruce, larch, or fir genera. Vegetation divisions have been well documented by authors such as Rowe (1972) and Tseplyaev (1965), but unfortunately reviews of fire effects are not yet available for many of these divisions.

Throughout the circumpolar boreal area pines are found on drier sites. Species change from *Pinus contorta* Dougl. var. *latifolia* Engelm. in western Canada to *Pinus banksiana* Lamb. in eastern Canada, to *Pinus sylvestris* L. in Europe to *Pinus cembra* L. in eastern USSR. The spruce–fir associations found on moister sites change from largely *Picea mariana* (Mill.) B.S.P. and *Picea glauca* (Moench) Voss in western North America to *Picea mariana*, *Picea glauca*, and *Abies balsamea* (L.) Mill. in eastern North America. In northern Europe and in the Karelian taiga, *Picea excelsa* Link. is dominant on moist sites but with distance eastwards there is a change to *Picea obovata* Ldb. In the western Siberian taiga, located in the lowlands east of the Ural Mountains and to the Yenisey River, the dominant species are *Picea obovata*, *Larix sibirica* Ldb., *Abies sibirica* Ldb., *Larix Sukacevii Dylis, and Pinus sibirica* Rupr., Mayr. Farther east in the Yakut taiga, *Larix dahurica* Turcz. and *Pinus sibirica* co-dominate, but still farther east, in the mountain taiga of northeast Siberia, only *Larix dahurica* is abundant.

Rodin et al. (1975: 13), among others, have estimated that a substantial proportion of the world's terrestrial phytomass is located in the northern boreal (18%), southern boreal (12%), and polar (1%) ecosystems. Primary production rates of about 1.6, 6.5, and 7.9 tonnes/ha for the above zones can be compared with 14.2 tonnes/ha for subtropical regions and 18.5 tonnes/ha
Figure 1.4 Distribution of the boreal forest (Hare and Ritchie, 1972), peatlands (Sjörs, 1961) and dominant forest community types (Mirow, 1967, p. 264, 265, 276, 277; Hosie, 1969, p. 50, 52, 56, 64, 72, 88; Anonymous, 1971, map 32, 53; Schmidt-Vogt, 1977, p. 128–129) of the circumpolar north
Figure 1.4 Distribution of the boreal forest (Hare and Ritchie, 1972), peatlands (Sjörs, 1961) and dominant forest community types (Mirov, 1967, p. 264, 265, 276, 277; Hosie, 1969, p. 50, 52, 56, 64, 72, 88; Anonymous, 1971, map 32, 53; Schmidt-Vogt, 1977, p. 128–129) of the circumpolar north.
<table>
<thead>
<tr>
<th>Fire rotation periods (years)</th>
<th>Location</th>
<th>Size of area (ha $\times 10^6$)</th>
<th>Record type and period</th>
<th>Dominant trees</th>
<th>Reference</th>
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<td>22</td>
<td>Itasca State Park, Minnesota</td>
<td>0.013</td>
<td>Historic records, fire scars on <em>P. resinosa</em> (1650–1922)</td>
<td><em>Pinus banksiana, P. resinosa, P. strobos</em></td>
<td>Frissell (1973)</td>
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<td>60</td>
<td>Northeastern New Brunswick</td>
<td>0.120</td>
<td>Fire report records (1931–1975)</td>
<td><em>P. banksiana, Acer rubrum, Betula papyrifera, Prunus pensylvanica</em></td>
<td>MacLean and Wein (1977)</td>
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<tr>
<td>60–70</td>
<td>Boundary Waters Canoe Area, Minnesota</td>
<td>–</td>
<td>Lake sediments (1000–0 BP)</td>
<td>Great Lakes–St Lawrence*</td>
<td>Swain (1973)</td>
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<tr>
<td>70</td>
<td>Barron Township, Ontario</td>
<td>0.019</td>
<td>Historic records, fire scars on trees (1696–present), fire reports (1939–1974)</td>
<td><em>P. strobos, Populus spp.</em></td>
<td>Cwynar (1977)</td>
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<tr>
<td>80</td>
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<td>–</td>
<td>Lake sediments (AD 770–1270)</td>
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<td>Cwynar (1978)</td>
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<td>100</td>
<td>Abitau–Dunvegan Lakes, Northwest Territories</td>
<td>–</td>
<td>Examination of post-fire stands</td>
<td>Boreal* (<em>Picea mariana</em>)</td>
<td>Maikawa and Kershaw (1976)</td>
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Table 1.1  contd.

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<th>Location</th>
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<td>Historic records, fire scars on trees (1727–1910)</td>
<td><em>P. banksiana</em>, <em>Picea mariana</em>, <em>Abies balsamea</em>, <em>B. papyrifera</em></td>
<td>Heinselman (1973)</td>
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<td>200</td>
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<td>5.35</td>
<td>Land survey records (1900–1910)</td>
<td>Acadian^a</td>
<td>Adapted from Fernow (1912)</td>
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<tr>
<td>800</td>
<td>Northeastern Maine</td>
<td>1.65</td>
<td>Land survey records (1793–1827)</td>
<td>Great Lakes–St Lawrence and Acadian^a</td>
<td>Lorimer (1977)</td>
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^a Forest regions designated by Rowe (1972).
In North America, much of the deciduous and mixed-wood forest biomes plus smaller areas within the boreal region were cut over for lumber and cleared for agricultural production by fire during the nineteenth century (Holbrook, 1943). Although it has been suggested by a number of authors (e.g., Day, 1953; Lutz, 1959; Lewis, 1977) that the North American Indian utilized fire as a tool in ecosystem management, most of the early literature concerning native peoples and fire was written and heavily interpreted in the light of the current attitude of Europeans toward fire.

The use of fire as a tool to influence timber production, wildlife, or other resources has been experimented with and discussed, but is still little-practised. Kayll (1974) has provided an overview of prescribed burning in the major biomes but the lack of references from northern ecosystems points out that fire has been used very little. In the western USSR slash burning to promote revegetation was used from about 1962 to about 1966; however, this very expensive programme has been curtailed. Apparently there has been little prescribed burning in the Yakutian forests (Shcherbakov, 1977).

Prescribed burning has been used as a site-preparation method in the Fennoscandinavian countries but has recently fallen into disfavour. For example, Weetman and Nykvist (1963) pointed out that in 1962 about 40,000 ha per year were burned in north Sweden. In Finland, about 30,000 ha were burned annually between the peak activity years of 1955 to 1965 (Viro, 1969; Uggla, 1973). In Norway, where moist climatic conditions have always restricted the use of fire, about 1500 ha were burned annually in the 1950s when this technique was at its maximum use (Braathe, 1973). Due to the availability of site-preparation machinery and the damage caused to seedling pines under low-intensity prescribed burns by the fungus Rhizina undulata Fr. ex. Fr., little site-preparation with fire is practised at present. Prescribed burning has had a long history in managing heathland and ecosystems for birds (Gimmingham, 1970) and for wild berry production (e.g., Vaccinium spp.—Hall et al., 1979) but these areas are of limited extent and are found mainly in the southern boreal forest.

Prescribed burning could be used as an effective management tool if the effects were sufficiently predictable and personnel were sufficiently experienced. Fuel reduction is needed around remote villages and around transportation or communication installations. Prescribed burning for wildlife, forestry, or agriculture is ecologically sound (and probably required) in ecosystems that have been influenced by fire for thousands of years. Also, prescribed burning is a very cost-effective management tool, and with rising energy and labour costs it may be necessary to restrict the use of energy-consumptive machinery in the future. Understanding the role and effects of fire in natural ecosystems is the key to releasing stored energy in ecosystems through prescribed fire in such a way as to reach ecologically sound goals.
1.5 THE 'STATE-OF-THE-SCIENCE'

When it is considered that almost no area of the southern Arctic tundra or boreal forest has escaped fires in the past it is surprising that recent books on boreal forest subjects (e.g., Larsen, 1980; Pruitt, 1978; Tamm, 1976) discuss fire to such a limited extent. This might be an expression of personal bias but it may also be an expression of how few fire studies are published in the international literature. Although there is not a great volume of literature to quote there is much more than is generally appreciated. Fire ecology studies have traditionally been only part of other studies, and there certainly has been no major interdisciplinary International Biological Programme-type of study on the subject.

Fire ecology studies have tended to be poorly quantified and descriptive and large subject areas have been examined in only a very cursory manner. Almost any area within the field of fire ecology could benefit by a more theoretical and quantitative interdisciplinary approach, so it is difficult to suggest high-priority studies. The role of fire in some very large vegetation types of the boreal forest has not been synthesized, yet those literature surveys can be done at any time. More emphasis should be placed on original research on subjects such as the following. Almost all fire ecology studies have been conducted during the summer months and yet organisms must tolerate year-round conditions. It would therefore seem profitable to investigate winter and spring environments of areas in different stages of post-fire succession. It is also striking, after reviewing the literature on fire, to find that relatively little is known about the hydrology of northern landscapes that have been influenced by fire or how the associated lake and stream ecosystems are influenced. An interdisciplinary watershed approach to the study of fire ecology could prove to be an extremely productive approach.

1.6 REFERENCES


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