The Role of Fire in Northern Circumpolar Ecosystems
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CHAPTER 3

Fire Frequencies During the Suppression Period

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ABSTRACT

Wildfires have been and currently are an important factor in the northern ecosystems of all circumpolar countries. Historical accounts of fires are general and often provide few quantitative data; therefore, we must rely on more recent data from the fire suppression period to draw conclusions about fire frequencies. In this chapter data on the frequency of wildfires in northern Canada, Alaska, USSR, Sweden, and Finland are reviewed, and problems with the interpretation of fire frequency data are discussed. From the limited data which are available it appears that the patterns of fires at northern latitudes in the USSR are very similar to those observed in Alaska and Canada.

3.1 INTRODUCTION

Fires in the field, whether wildfires or prescribed fires, have always been a source of interest. This interest has been maintained because of the emotional appeal, as well as the practical, economic, and scientific aspects of fire. Fire has a different impact for each of us, and it has a variable role in the system depending upon our perspective at the time of occurrence. If we are game managers and fire destroys needed habitat, it is detrimental, but on the other hand, if fire improves game habitat, it is beneficial. By the same token, when a wildfire threatens homes and population centres or high-value timber it is viewed quite differently than a fire in a remote area. These kinds of issues tend to bias many perspectives. Fire in the forest is neither good nor bad, *per se*, except in terms of the degree to which it promotes or hinders land management objectives (Chandler and Roberts, 1973).

For the purpose of this chapter we have tried to consider reference material from all circumpolar countries; however, the effort has been concentrated in

Canada and Alaska because of the amount and availability of information. Although statistical data exist for some areas as far back as the 1920s, the emphasis of review and commentary has centred around the decades of the 1950s, the 1960s, and the 1970s. The data synthesized have also been limited to the boreal forests and tundra–taiga regions which include Alaska, the Yukon, and Northwest Territories, and all Canadian provinces except British Columbia, which has little boreal forest, Newfoundland, where only limited data are available, and Nova Scotia, New Brunswick, and Prince Edward Island, which we consider to be outside the boreal forest zone.

Data compatability between and within geographic areas and time periods is almost non-existent, and it appeared most prudent to concentrate efforts on a few common items for comparative purposes. Simple ratios, percentages and annual fire numbers, causes and area burned provide the bulk of information discussed. Utilization of rigorous statistical techniques for analysis was not undertaken due to inconsistencies in data. Most of the numerical information has been gleaned from the records of governmental agencies responsible for the administration and protection of the areas involved.

For the purpose of this chapter we have defined the suppression period as that time for which organized fire protection and administrative record-keeping have been in existence. Although other definitions may be appropriate for the suppression context, such definitions are academic relative to summarizing fire statistical information. Historical records, as developed in the journals of early explorers and settlers, verify the existence of fire in qualitative terms (Lutz, 1953; Robinson, 1960), but they do not provide the quantitative measurements so necessary for more detailed analysis and testing of hypotheses.

Anyone who has tried to make order out of archive records, especially fire-related documents, understands the myriad of problems involved (Kiil, 1971). It is often difficult to obtain data which are continuous even for a period as short as 20–30 years. Also, changing recording procedures and the lack of documentation standards make it almost impossible to develop any continuity for more than a very few items at best. Fire data are recorded basically for administrative purposes, not research and future study. From a historical and research perspective the shortcomings become painfully obvious. Because most governmental agencies involved with fire are geared to budgets, and thus directly or indirectly to political pressures, administration policies change accordingly. These basic facts have an impact on the type, extent, and completeness of data available for analysis.

The type of data available is also a function of the interest of not only the agencies involved, but also the individuals responsible for field collection and recording. As already indicated, this is often related to political pressures. Administrative criteria impose further restrictions on data reported. For example, the delineation of administrative protection boundaries tends to concentrate the reporting of fires within their limits. If these boundaries do not encompass the entire land area, which is often the case, then only partial reporting occurs. In addition to partial reporting, there is also a bias established for administered versus non-administered areas. Often, as in the Alaskan and Canadian data, protected area statistics are apparently much more complete than those for non-protected areas. These data, however, tend to create problems when trying to examine a 'biological whole' and not an 'administrative part'.

The data presented in this chapter have been separated into two broad causative agencies, namely man-caused and lightning-caused. Average man-caused fire size should provide a relatively good indication of the effectiveness of suppression techniques. Lightning-fire analysis is confounded by two distinct problems: (1) recently enhanced detection capabilities have resulted in greatly increased lightning-fire 'arrivals' in recent years, so the number of lightning fires seems to be on the increase, but this really reflects better detection (particularly the use of aircraft in less-populated areas), and (2) many lightning fires occur in remote areas of 'limited protection' and are either suppressed or managed on a priority basis or allowed to burn unhindered resulting in inflated area-burned figures.

3.2 PRE-SUPPRESSION PERIOD FIRES

Prior to delving into our review of the suppression period itself some preliminary background seems appropriate. Much has been written regarding fire in a historic vein. Numerous authors have supported the fact that fire is not new to the North, including the Arctic tundra (Barney and Comiskey, 1973; Cochrane and Rowe, 1969; Hardy and Franks, 1963; Lutz, 1953, 1956, 1959; Rowe, 1970; Scotter, 1964; Shcherbakov, 1977; and Wein, 1974, 1976). These authors have all supported the fact that fire is a common feature in northern latitudes. Man and lightning have been historic forest fire causes and continue to be so. The importance of fire in developing the vegetative mosaics we see today cannot be denied. We know from early writings that fires have occurred throughout the North. The actual extent, numbers, and specific causal relationships are not easily established.

Numerous questions arise from early reports, especially when we compare them with reports developed with the assistance of modern technology. Were the fires really as extensive as reported by explorers, or was this merely a function of perspective? Too often inappropriate conclusions are suggested when viewing only a part of the entire picture.

A cursory review of climatic data and discussions with specialists indicates that for the general historical and administrative record period since the 1880s there have not been any significant major climatic shifts of a magnitude great enough to alter the broad fire regime. Therefore, from a broad-scale weather perspective, conditions today are not much different from when non-natives first moved into Alaska and northern Canada. The probabilities for lightning today are similar to perhaps 100 to 150 years ago. The number of days a fire could start, given normal fluctuation, are also well within an order of magnitude.

Most of the areas we are discussing in more detail were inhabited by a native population until the advent of some 'industrialization' event such as the discovery of gold. Until such events, the base populations were occasionally visited by explorers and then trappers and traders. Each major entry into an area at the northern latitudes was usually prompted by some major developmental event. All the major entries in the northern areas of Alaska and Canada were economically motivated. Fur trading, gold and other minerals, gas and oil have been the primary attractions for the development of this generally 'hostile' environment.

Several authors have stated that such developmental periods have been the cause of increased fire activity and damage. Lutz (1953) claimed that the increase in forest fires around the turn of the century brought about a change in age–class distribution and converted forest types from white spruce to birch and aspen. European man has been responsible for frequent and widespread fires in the boreal forests (Lutz, 1959). Scotter (1964) also attributes man's carelessness to causing more fires. Stoliarchuk (1974) stated that rapid economic and industrial development have as their consequence an increase in the number of sources of fire, and lead to the fact that forest fire incidence increased sharply, even in years having weather merely average for fire hazard. Wein (1976) agrees that man's increased industrial activity will increase fire activity, as it has in more southerly areas.

The general geographic areas we are discussing in this chapter have many similarities as well as differences. Although latitudinal extent varies for each area of boreal, taiga, or tundra associations, by definition they have similarities. Global weather patterns may cause differential ignition potential and lightning regimes. Lightning is generally recognized as a major causative agent of fires, even at these northerly latitudes. The ubiquitous evidence of charcoal (Rowe, 1970; Rowe and Scotter, 1973; Shcherbakov, 1977) substantiates the historic presence of fire throughout the North. More recently it has been formally recognized that the far northern tundra will also burn (Barney and Comiskey, 1973; Wein, 1974, 1975, 1976). Fuel conditions exist and lightning occurs in occasional combinations to result in fires. With or without any influence from man, fire has played a part in the total circumpolar ecosystem development and change through time.

In recent years there has been another human intrusion into the North. This time researchers have closely followed the industrial search for and development of petroleum and mineral resources, and have begun working throughout the area above the Arctic Circle. This has led to an increase in interest in fire as a study subject. There is a lack of historical (pre-industrial) data on both the productive boreal forest areas and the tundra and taiga associations. We hope we will eventually have detailed studies, similar to Heinselman's (1973) work in the Boundary Waters Canoe Area of northern Minnesota, for these northern regions.

3.3 FIRE FREQUENCIES DURING THE ACTIVE SUPPRESSION PERIOD

3.3.1 The USSR

Northern Russia and Siberia have long been noted as areas where forest fires have played an important role (Lutz, 1956). The Soviet agencies have, through time, developed a highly sophisticated, well-equipped fire suppression system. To support their operations they have developed danger rating procedures and support records on a centralized data base. Fire season potential for specific regions has been developed (Stoliarchuk, 1974).

According to Shcherbakov (1977), the Yakut Autonamous Soviet Socialist Republic is much like Alaska, especially the Fairbanks and Yukon valley region. [The total area of Yakutia encompasses 3.7 million km^2 and it is situated at 56–76°N latitude and 108–162°E longitude.] Yakutia has the highest number of forest fires in the USSR and possesses the most extensive burned-over area. During the period 1971–1976 this region experienced 3262 fires, which burned 335 600 ha. Humans are considered the major cause of fires as a result of burning activities; lightning caused 7–9% of the fires. Shcherbakov (1977) further indicates that fires are an ancient phenomena in the area, but known forest fires seem to have been relatively small. The implication appears to be that humans have had considerable influence in the area.

The Irkutsk region (760 000 km^2) averaged about 1250 fires per year, of which 5% are reported to be lightning-caused (Kourtz, 1973). The Karelian Republic has a somewhat lower annual fire average. This 700 000 km^2 area experiences 750 fires per year, of which 5% are lightning-caused. Kourtz (1973) reported that a 1960 study of an area in Siberia indicated that 80% of the fires were lightning-caused while 40% of Siberian fires overall were the result of lightning. The variations of cause ratios in Russia are similar to those observed elsewhere, and are undoubtedly a result of similar reporting and sorting problems. With a less dense population per unit area in Siberia, a larger ratio of lightning fires should exist. It appears from the limited information we reviewed on fire frequencies in Russia that patterns experienced at northern latitudes in that country are very similar to those observed in Alaska and Canada.

3.3.2 Alaska, the Yukon, and the Northwest Territories

A similar development pattern for formal fire suppression was experienced in Alaska, the Yukon, and the Northwest Territories. The Northwest Territories and Alaska are composed of about 30–40% boreal forest and 50–60% tundra. Fire control did not become formalized in Alaska until 1940, when the Alaska Fire Control Service was organized. Until this time, wildfire control had been opportunistic and a function of fire threat to individual property or centres of population (Lutz, 1953). As a result, data have been compiled for the period 1940–1978 (Barney 1969, 1971a,b; Hardy and Franks, 1963; and the US Department of the Interior, 1978). Prior to the time when formal records were kept, explorers, trappers, missionaries, and others entering the country made references to wildfire in diaries and other reports. These reports seemed to indicate, however, that an annual average burn of 607 300 to 1 012 150 ha might not be unreasonable for the 93-million-hectare interior Alaska region. Lightning and man are recognized as causative agents. Lightning fires have been reported as far south as the Ketchikan area in southeast Alaska and as far north as the Beaufort Sea (Barney and Comiskey, 1973). These far north tundra fires were not recognized formally until relatively recently. Others in Canada have also documented lightning fires north of what was previously considered a reasonable limit for occurrence (Cochrane and Rowe, 1969; Johnson and Rowe, 1975; Rowe *et al.*, 1975; the US Department of the Interior, 1978; Wein, 1976).

Until the advent of organized fire control and resource management activities, fire reporting was haphazard at best. Supporting records came only with the establishment of a fire organization. Once the population had a place to report fires for action, more were reported, recorded, and perhaps acted upon. Early detection of fires was a function of the transportation network and population concentrations. For example, records indicate that Alaska had no reported lightning fires until 1943, because early control efforts were centred around the Alaska Railroad and the existing road network. All fires reported were obviously considered to be caused by humans. As the control organization grew so did the capability to detect and report a greater proportion of fires. When early lightning fires are plotted, they are distributed near rivers, roads, and population centres, solely because these were the fires that were detected and reported. Even Lutz (1953), in his excellent work, was limited to a road net, essentially a transportation system perspective.

As time passed, fire control operations in Alaska, the Yukon, and the Northwest Territories became much more sophisticated, and aircraft became the primary transportation and detection mode. More fires were reported deeper and deeper into the former wilderness and less accessible interior areas. Smoke jumpers were put into use in Alaska in 1959, adding a new dimension to the fire control function (Hardy and Franks, 1963). Continued improvements in detection, especially storm location and follow-up patrols, and improved weather observations and forecasts all contributed to a changing recognition of the magnitude, extent, and control of fires in the vast interior region. The advent of helicopters, new roads, and petroleum development has also changed the scene.

In the early days of fire control the impact of the suppression effort was limited because of the small force and limited access. As time passed, an era of almost unlimited manpower resources, aircraft, and equipment resulted in an opposite kind of impact. Even with almost unlimited resources, the numbers and sizes of fires have often resulted in choices among fires; some were left to burn after becoming too large for effective control operations, or were detected under a set of conditions allowing their classification as 'economically inaccessible' or low-priority fires. Today, more detailed management planning, changing land ownership, shifts in management responsibilities, and a changed attitude toward fire have further altered fire suppression. Perhaps this era might loosely be called 'more permissive', although we would like to view it as 'better informed'. The net result is a changing pattern of areas burned if not the number of fire occurrences.

Probably two major events can be recognized as causing extensive immigration into Alaska and northern Canada. These were the Gold Rush era at the turn of the century and the recent petroleum industry development of the late 1960s with resulting pipeline construction activities in the 1970s. Statistically, fire numbers have increased since the advent of formal fire control efforts. This is not necessarily a cause–effect relationship, but a result of increased population, detection, and record keeping improvement over time. Except for traditional variations within seasons, total annual area burned seems to be decreasing. An increase of man-caused activities may be self-limiting with regard to the general impact on the total system.

Using the decades of the 1940s, the 1950s, the 1960s, and the 1970s for comparison, we see an increase in numbers from the 1940s to the 1950s, in fact a doubling of fires in Alaska (Table 3.1). The decades of the 1950s and the 1960s, however, have generally similar numbers of fires. For the nine years of records compiled for the 1970s there is more than a doubling of the average total fires per year. For this decade the lightning-fire occurrence average is almost three times that of the previous decade and man-caused fires numbers are almost twice as many as in the 1960s. Fire weather was no more severe during the 1970s, than in the 1960s, which leads to the conclusion

Table 3.1 Decade fire statistics summaries for Alaska, the Yukon Territory, and Northwest Territories

Period	Lightning-caused		Man-caused		Total	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
1940–1949						
Alaska	200	—	938	—	1138	5024727
Yukon Territory	—	—	—	—	—	—
Northwest Territories[a]	—	—	—	—	176	683194
1950–1959						
Alaska	745	3440860	1848	883449	2593	4324309
Yukon Territory	101[d]	—	273[d]	—	622[f]	1292196
Northwest Territories	—	—	—	—	781	2245550
1960–1969						
Alaska	853	1943126	1527	632721	2380	2575847
Yukon Territory	168[b]	777550[c]	327[b]	59578[b]	696[f]	845671[f]
Northwest Territories	364[d]	491578[d]	477[e]	813913[d]	1340[f]	1550554[f]
1970–1978						
Alaska	2203	2509883	2282	42961	4485	2552844
Yukon Territory	481	740925	626	15612	1107	756537
Northwest Territories	1675	3506057	897	268148	2572	3774205

[a]Only 4 years' data 1946–1945.
[b]Only 6 years' data.
[c]Only 9 years' data.
[d]Only 5 years' data.
[e]Only 4 years' data.
[f]Includes 10 years' data.

that an improved detection and reporting capability is the reason for this increase in lightning-fire numbers.

Although fire numbers were considerably higher, Alaska's mean annual area burned by lightning fires decreased about 10% during the 1970s, and the mean annual area burned by man-caused fires in the 1970s was about one-tenth of the area burned during the previous decade.

As in the evolution of most developing areas, major events are usually the cause of change. In 1958 Whitehorse, Yukon Territory, was threatened by a major conflagration and as a result a significant increase in fire control capabilities for the Yukon Lands and Forest Service was developed (de Lestard, 1979). Until this time, suppression efforts might be considered, by today's standards, to be minimal or of a custodial nature. The Yukon Territory was faced with the same problems as Alaska—a great responsibility but only a handful of dedicated people and with next to no physical or monetary resources.

Statistical data compilation for the Yukon Territory began in about 1950. Based on summarized data, the average annual number of fires in the 1950s was 62, in the 1960s 70 fires were reported per year, while the 1970–1978 period averaged 123 fires per year (Table 3.1). As with the Alaska data, one must be careful not to jump to the conclusion that there are now more fires. Although this might be intuitively reasonable, there were growth and changes in the fire control organization during this 30-year period. Improved reporting and detection capability are undoubtedly part of the explanation. The decade statistical summaries indicate a decrease in average annual area burned.

Lightning fires in the Yukon Territory are reported to be fewer than man-caused fires for each of the three decades of record. The decade of the 1970s, however, shows the difference diminishing, with 43% lightning and 57% man-caused fires. Although numbers may be changing, the vast majority of area burned is still due to lightning fires. The Yukon Territory reported that in the 1960s lightning caused 34% of the fires, which burned 92% of the total area reported. In the 1970s a larger percentage of the fires were lightning-caused, and they accounted for even a greater area burned. These ratios are similar for Alaska and the Northwest Territories.

As is usually the case with fire statistics, the majority of fires reported are less than 4 ha. Kiil (1971) reported that 65% of fires in the Yukon Territory were of this size, while only 20% of all fires exceeded 20 ha per fire. These later fires, however, include the largest ones and essentially account for the vast majority of the total area burned.

The history of fire suppression in the Northwest Territories parallels in many respects the history of the Yukon Territory and Alaska. This vast area, encompassing 3 379 686 km^2, is characterized by remoteness, a sparse population, and limited transportation networks. Fire management policy prior to the 1950s dealt primarily with control of fires threatening isolated communities. The Northwest Territories is composed of three districts: Franklin, Keewatin, and MacKenzie. Fire management is practised only in the MacKenzie District, and more specifically, only south of the tree line (de Lestard, 1979). This southwestern two-thirds of the MacKenzie District contains approximately 1 366 194 km^2. Under current policies, an average of 58% of all wildfires are fought. From the data we were able to assemble, wildfires burned over 2.2 million ha during the 1950s (Table 3.1). During the 1960s the number of fires recorded was almost double that of the previous 10 years' total. The area burned, slightly over 1.5 million ha, was considerably less. The 1970s saw essentially a doubling of both numbers and area burned over the 1960–1969 period.

The general distribution of fire sizes seems to be similar in the Northwest Territories, the Yukon Territory, and Alaska. Approximately 60–80% of all fires are less than 5 ha. Therefore a small number of large fires results in the vast majority of the area burned. Lightning-caused fires account for 43–65% of the number and in excess of 90% of the area burned. During the 30 years of records we reviewed, three individual years had an annual area burned in excess of 800 000 ha.

3.3.3 The Prairie Provinces: Alberta, Saskatchewan, and Manitoba

The Prairie Provinces as a whole are more than 80% boreal forest, with forested land in the north of each province and grassland in the south. Historically, fire records have been separated by administrative regions rather than forest region, so provincial records include combined data on wildfires in both grassland and boreal forest types. Heaviest populations are in the southern portions of the provinces, where farming is the lifestyle. A gradual movement northward has taken place since the start of the twentieth century due to mineral- and oil-exploration and the expansion of forest industries. Forest fire records date back to 1918, with separation of lightning- and man-caused fire numbers starting at that time along with total burned area figures. However, lightning- and man-caused fire sizes were not separated until 1951 in Alberta and Manitoba, and 1961 in Saskatchewan.

The number of man-caused fires occurring in this region has generally increased during the decades since the 1920s and averaged approximately 1600 fires per year during the 1970s (Table 3.2). Lightning-fire numbers have increased dramatically—a direct reflection of improved detection—and constituted approximately 36% of all Prairie Province fires during the 1970s.

Table 3.2 Average annual fire statistics (by decade) for the Prairie Provinces (Alberta, Saskatchewan, and Manitoba)

		Lightning-caused		Man-caused		Total	
Year	Province	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
1950–1959	Alberta[a]	36	18 918	197	80 071	233	98 989
	Saskatchewan	41	—	105	—	146	28 753
	Manitoba[a]	64	31 965	208	60 567	272	92 532
1960–1969	Alberta	172	14 898	334	44 296	506	59 194
	Saskatchewan[b]	126	129 876	209	48 863	225	178 739
	Manitoba	133	93 847	279	95 314	412	189 161
1970–1978	Alberta	256	20 578	429	6624	685	27 202
	Saskatchewan	157	139 512	222	26 971	379	166 483
	Manitoba	159	41 625	358	31 312	517	72 937

[a]1950 data are incomplete and not included.
[b]1960 data are incomplete and not included.
Note: To obtain approximate decade totals multiply these numbers by 10 except where footnoted. Use 9 for the 1970–1978 period.

Mean man-caused fire sizes have decreased during the past three decades, particularly in Alberta, no doubt due to improved detection and suppression capability. Lightning-fire sizes have also decreased somewhat in recent years, but these statistics should be considered only while keeping in mind the fact that lightning fires often occur in low-priority protection zones and are often not actively suppressed. The remoteness and inaccessibility of many lightning fires also contributes to larger final fire sizes.

Mean man-caused fire size is subject to fewer extenuating circumstances and is, therefore, the best indicator of the success of increased fire control activities. In spite of steadily increasing population levels, man-caused fire occurrence has remained relatively stable, perhaps due in part to increased public awareness and prevention programmes.

3.3.4 Ontario and Quebec

Virtually all of Ontario and Quebec above 47°N latitude is in the Boreal Forest Region. In both Ontario and Quebec, the southern portion of each province, where populations are highest, is in the Great Lakes–St. Lawrence Forest Region. As in the Prairie Provinces, however, fire statistics are not separated by forest region and therefore include wildfires from the whole of each province.

Ontario and Quebec have complete fire records, with separation of both lightning- and man-caused fire numbers and area burned, back to the 1920s. As in the Prairie Provinces, numbers of man-caused fires have fluctuated in Ontario and Quebec in recent decades, but have remained relatively constant, averaging more than 2200 fires per year, during the 1970s (Table 3.3). In addition, lightning fires reported have increased dramatically in recent decades and constitute 40% of all Ontario and Quebec fires during the 1970s (similar to the Prairie Provinces). Undoubtedly, these similarities between the Prairie and Ontario–Quebec Regions are due to increased detection in both areas. Total fire numbers, however, are higher in Ontario and Quebec, perhaps a function of higher population levels.

Mean man-caused fire sizes have been steadily decreasing in both provinces, particularly Ontario, whereas mean lightning-fire size has not. This is due to modified suppression activities on remote lightning fires in low-value areas, particularly in the northernmost section of each province. It is interesting to note, however, that lightning fires accounted for only 29% of the total fires during the 1960–1978 period, but were responsible for 90% of the total area burned. Conversely, in Quebec, lightning fires constituted 22% of all fires during the same period, but accounted for only 43% of the total area burned, with man-caused area burned being much more significant in Quebec.

In Ontario, where records of forest fires by size classes (including both

Table 3.3 Average annual fire statistics (by decade) for Ontario and Quebec

Year	Province	Lightning-caused		Man-caused		Total	
		No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
		Averages					
1924–1929	Ontario[a]	106	18 356	948	65 795	1054	84 151
	Quebec	39	1 199	507	20 030	546	21 229
1930–1939	Ontario	326	78 354	1283	82 912	1609	161 266
	Quebec	52	3 146	1008	82 717	1060	85 863
1940–1949	Ontario	271	13 640	1053	83 906	1324	97 546
	Quebec	113	9136	1053	106 808	1166	115 944
1950–1959	Ontario	295	25 431	996	14 033	1291	29 464
	Quebec	120	18 111	780	59 062	900	77 173
1960–1969	Ontario	318	50 789	1104	6986	1422	57 775
	Quebec	225	28 435	725	32 929	950	61 364
1970–1978	Ontario	646	162 186	1298	16 610	1944	178 795
	Quebec	241	22 636	907	32 538	1148	55 174

[a]Ontario does not have 1924 statistics but covers 1925–1929.
Note: To obtain approximate decade totals multiply these numbers by 10 except for Ontario 1925–1929. Use 9 for the 1970–78 period.

lightning- and man-caused fires) are complete for the 1920–1978 period, the strong influence of increased fire suppression capabilities and resources is obvious. The percentage of fires kept small (<0.1 ha) has increased from 25% in the 1920s to 47% in the 1970s, while the percentage of large fires (>40.5 ha) has decreased correspondingly, from 17% in the 1920s to 3% in the 1970s.

3.3.5 Sweden

Fire statistics for Sweden provide information which is somewhat similar in several respects to that of Russia. For the period of record available, which includes data from 1946 to 1978, 73 318 fires burned a total of 98 595 ha in Sweden (Table 3.4). From the data available, lightning fires are of relatively little consequence both in numbers of fires occurring and hectares burned. Approximately 6% of the fires in Sweden are lightning-caused whereas the remaining 94% are caused by man. Approximately 19% of the area is burned by lightning fires, with the remainder by man-caused fires. Based on the data available, the number of fires has been increasing dramatically since the period that we have on record from 1946. During the period of 1946–1949 only 5087 fires occurred (a mean of 1272 fires/year) while during the 1970–1976 period 28 225 fires were reported (a mean of 4032 fires/year). This

Table 3.4 Average annual fire statistics (by decade) for Sweden and Finland

		Lightning-caused		Other causes		Total	
Year	Country	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
1946–1949	Sweden	—	—	—	—	5087	9675
	Finland	—	—	—	—	—	—
1951–1959[a]	Sweden	1359	4872	16 364	16 260	17 723	21 132
1952–1959	Finland	388	11 060	3612	16 912	4000	27 972
1960–1969	Sweden	1235	5249	21 502	27 210	22 737	32 459
	Finland	738	20 224	4207	14 170	4945	34 394
1970–1978	Sweden	1531	—	26 240	—	27 771	35 329
1970–1976	Finland	1219	2212	3006	5619	4225	7831

[a]1950 data incomplete and not averaged.
Statistical data for Sweden from *Skogsstatistisk Årsbok 1946–76*, Stockholm, and personal communications with Olle Zackrisson, Swedish University of Agricultural Sciences, Umea, Sweden.
Statistical data for Finland from *Yearbook of Forest Statistics 1975, Official Statistics of Finland XVII A:8*.

is in excess of a threefold increase. The increasing trend holds constant for all decades. We suspect that many of the reporting criteria changes over time have greatly influenced the recorded number of fires as well as the total area burned.

3.3.6 Finland

Data available for Finland indicate a slightly different fire picture than for Sweden or Russia. Records from 1952–1976 indicate that approximately 18% of all fires were caused by lightning and these fires consumed approximately 48% of the total area burned in Finland (Table 3.4). A total of only 13 170 fires occurred in Finland during the period of record. These fires burned a total area, however, of 70 197 ha, a much larger area per fire than was the case in Sweden. The number of fires by decades has remained relatively constant in Finland while mean fire size has decreased steadily. In general, Finland has had a fire occurrence rate of only 20% of that reported for Sweden. Lightning fires appear to be twice as numerous and burn over three times the area in Finland than is the case in Sweden. As in Sweden and Russia and almost all other countries where statistics were reviewed, there appears to be a general increase in the number of fires reported and a commensurate increase in the area burned in total.

3.4 DISCUSSION

It is certainly well substantiated that fires have been and are an important factor in the northern ecosystems of circumpolar countries (Johnson and Rowe, 1977). Although the numbers, sizes, and causes vary with location, fires have been recorded well into the Arctic tundra (Barney and Comiskey, 1973; Wein, 1976), and fuel and weather conditions exist in almost all areas to provide a fire potential at some time. All that is needed is the timely addition of an ignition agent.

Historical accounts of fires are general (Kelsall *et al.*, 1977) and often provide only limited definitive data. Use of these data should be with proper perspective. There are also limitations in the more formal records and these should be recognized in interpretation (Kiil, 1971). Even though there are concerns with historical and formal fire reports, these types of data can provide insights.

Throughout time, man has been accused of increasing the number of fires as he has entered the less-populated northern environment (Lutz, 1953; Scotter, 1964; Wein, 1976). This certainly seems intuitively reasonable; however, numbers alone do not give the entire picture as to human impact on the system. Area burned also does not provide a total perspective. In the tundra and taiga areas, reburns are not uncommon. Kershaw *et al.* (1975) pointed out that if any fuel remains, a burned area is quite susceptible to reburning. Both authors of the present chapter have witnessed the reburning of areas during several wildfires. These kinds of occurrences tend to distort not only the formal record but also the impact in general because of overlapping and double counting.

Harrington and Donnelly (1978) mapped large (>200 ha) Ontario wildfires for the 1920–1976 period and reported a mean of 0.19% of Ontario's boreal forest region to be burned over annually during this period. When that portion of the northernmost boreal forest in Ontario (where fire control is minimal) is excluded, annual area burned dropped from 0.32% in the 1920s to 0.09% for the 1940–1976 period.

Fires in the tundra regions at more northerly latitudes have not received much attention in the past (Barney and Comiskey, 1973); however, more recent interest in these areas has begun to indicate that fire is and has been more prevalent than previously assumed. Wein (1976) reported 55 fires north of the 60° latitude. These fires occurred between 1960 and 1974 in the Hudson Bay area, Mackenzie Delta, between the Mackenzie Delta and Alaska, and in Alaska. As Rowe *et al.* (1975) pointed out, there are probably more tundra fires than those reported, but because they are not so intense many may escape detection. As a case in point, the Bureau of Land Management in Alaska (US Department of the Interior, 1979) has reports of 42 fires occurring north of the 68° parallel. These fires burned about 35 778 ha. Of these fires, the 76% attributed to lightning burned 97% of the total area, while 24% were man-caused. It is quite apparent from these statistics that lightning is indeed an important fire-agent at such northerly latitudes in Alaska. These data support the observation by Requa (1964) that in the remote area of the Yukon most fires are caused by lightning. An interesting sidelight about eleven man-caused fires, north of the Brooks Range, is that only four occurred after 1974, when the Alaska pipeline construction was in its early stages. Two fires were classed as recreation-caused and two were debris-burning fires. All four of these most recent man-caused burns covered a total area of 994 ha.

Trying to determine what the real human impact has been over time and how this impact might be changing is really a difficult task. As we have pointed out, the simplistic approach of counting numbers of fires each year or area burned is not an adequate measure and certainly not acceptable to explain a cause–effect type of relationship. The changes in fire organizations, shifting policies and reporting procedures, and perhaps improved technology, including detection capabilities, have all influenced the data we have presented here.

In order to examine these data more critically we can look at ratios of numbers of man-caused fires to numbers of lightning-caused fires. This procedure assumes that detection and reporting capabilities for each type of fire were relatively similar each year. Therefore, if the ratio becomes larger over time, we can say man's influence on the number of fires each year is increasing. If the ratio becomes smaller, then the converse is true. This same procedure can also be applied to the area burned, with the assumption that area reported is similar for each cause each year. This area ratio will indicate areas burned by general cause over time. In both cases we are trying to compensate or normalize the data from changes in procedures, administrative policy changes, improved detection, changes in reporting, and other external impacts over time.

In reviewing ratios developed on this basis there does not appear to be any overwhelming trend. In Alaska the fire number ratios could indicate a downward tendency over time. This could mean that there are fewer man-caused fires or that more lightning fires are being reported. In any event, these ratios, coupled with the area ratios, do not support the hypothesis that human carelessness is markedly influencing the area. If humans are causing an impact, they are probably reducing total area burned, regardless of cause (Viereck, 1973). Numbers are perhaps less important, since a large portion of all fires are less than 3–5 ha in size.

It must be remembered that the compilation of means of fire statistics tends to mask extremes. No one has been able to define a satisfactory 'normal' fire season. Furthermore, the recorded statistics for Alaska and the territories north of the 60° latitude are quite different from those of the areas to the south. First, it seems fair to say the southern data are more complete.

Secondly, the southern data are probably more accurate since these areas have been under some form of formal protection for a much longer time. The data for the mid- and late-1960s and the 1970s for the northern areas are perhaps most comparable with fire data elsewhere. The time span covered by records when compared with biological rotations are painfully inadequate; however, they do provide a very important basis for comparisons and future work. To maintain a proper perspective, it must be remembered that these data were basically collected for administrative reasons and not for research purposes.

Although numerous, more detailed stratifications for the present chapter might be desirable, they are not always possible. Readers who might wish access to the raw statistics should consult Stocks and Barney (1980). Normalizing data by protected versus non-protected areas would be useful; however, the protected zones can vary in size from year to year, and even weekly as a function of management and political priorities. In addition, some of the areas utilize a modified suppression policy which changes with time and conditions. This obviously will affect fire statistics data over time.

Perhaps most important for the general view is the stratification of fires by major cause, human or lightning. The increased detection and suppression capabilities have obviously had an impact, as has the ever-increasing human presence. Our decade comparisons indicate the worthiness of suppression efforts. We have tried to bring data together and thereby create an awareness of its shortcomings and problems. It is hoped, however, that the information assembled here, from a wide array of sources, will be useful in future investigations and management.

As our interest and concern for the ecosystems of the North increase we must continue to improve our records of fire disturbances in order to understand interrelationships. As pointed out by Rowe *et al.* (1974), the frequency of fires and fire reoccurrence intervals at any given place may appear to be random events but they are usually related to vegetation age and type. Fire frequencies and mean time since fire as determined from stand ageing and fire scars can be of questionable accuracy. Furthermore, Kershaw and Rouse (1976) and Rouse and Mills (1976) point out that burning in the lichen-woodlands leads to long-term microclimatic changes. These changes can be of considerable magnitude and last for periods in excess of 50 years. Large-scale burning could lead to regional aridity. These kinds of impacts point out the need for and importance of developing and maintaining good records and information on fire events, and related factors. These types of data are needed not only to understand the past and present but to plan for the future.

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