Frequency and Characteristics of Arctic Tundra Fires

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ABSTRACT. Characteristics of over 50 tundra fires, located primarily in the western Arctic, are summarized. In general, only recent records were available and the numbers of fires were closely related to the accessibility of the area. Most of them covered areas of less than one square kilometre (in contrast to forest fires which are frequently larger) but three tundra fires on the Seward Peninsula of Alaska burned, in aggregate, 16,000 square kilometres of cottongrass tussocks. Though tundra fires can occur as early as May, most of them break out in July and early August. Biomass decreases, and so fires are more easily stopped by discontinuities in vegetation, with distance northward.

RÉSUMÉ. *Fréquence et caractéristiques des incendies de toundra de l'Arctique.* L'auteur résume les caractéristiques de 50 incendies de toundra ayant eu lieu principalement dans l'Arctique de l'Ouest. En général il disposait seulement d'une documentation récente et le nombre des incendies était étroitement lié à l'accessibilité de la région. La plupart des incendies couvrait des surfaces inférieures à un kilomètre carré (en contraste avec les incendies de forêts), mais une totalité de 1600 kilomètres carrés de tussacks de linaigrette brûlèrent au cours de trois incendies sur la péninsule de Seward en Alaska. Même si déjà en mai des incendies de toundra peuvent s'allumer, la plupart ont lieu en juillet et au début d'août. Au fur et à mesure que l'on monte vers le Nord la quantité de végétation (c.-à-d. de combustible) diminue et les incendies sont ainsi plus facilement arrêtés par les intervalles qui séparent les surfaces couvertes de végétation.

РЕЗЮМЕ. *Частота и характерные черты пожаров в арктической тундре.* Суммируются характерные черты свыше 50 тундровых пожаров, наблюдавшихся преимущественно в западной Арктике. Имелись в основном только недавние данные, а число пожаров было явно связано с доступностью района Большинство пожаров распространялось на участки не более одного километра /в отличие от лесных пожаров/, однако, в трех из них, имевших место на п-ве Сьюард/Аляска/, было уничтожено в общей сложности 1600 кв. км растущей на кочках пушицы. Хотя тундровые пожары могут возникать уже и в мае, большинство из них приходится на июль и начало августа. Из-за снижения растительной массы/т.е. горючего материала/пожары наиболее легко затухают в северном направлении на лишенных растительности участках.

INTRODUCTION

Little has been written on the subject of Arctic tundra fires and almost no detailed quantitative information on them exists in the recorded literature, but fires occurring near the treeline both in the Arctic and in alpine areas have received much more frequent mention. For instance, it has been demonstrated in alpine treeline studies that forested areas may become tundra-like after fires, because trees re-establish extremely slowly (Billings 1969; Douglas and Ballard 1971; Stahelin

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1943). Similar comments have been made about treeline areas in the Arctic (Clark 1940; Hustich 1954; Lutz 1956; Ritchie 1962).

Before 1970, the only data available on tundra or forest-tundra fires in the Canadian Arctic were those supplied by Brokx (1965), Cochrane and Rowe (1969), and Cody (1964, 1965). More recently, the 1968 tundra and forest-tundra fire near Inuvik in the Mackenzie Delta area has been examined from the point of view of disturbance (Mackay 1970; Heginbottom 1972) and plant recovery (Wein and Bliss 1973).

One of the first steps in assessing the importance of Arctic tundra fires is to obtain data concerning the frequency and characteristics of past outbreaks. Such information is presented in this paper.

METHODS

Records of tundra fires have been accumulated since 1970 by the present author as a result of his field work in the Northwest Territories and in the northern Yukon Territory. A questionnaire was sent to researchers, who have worked or are working in the North, requesting observations on fires, and Canadian government fire records were examined also. With the aid of high-altitude satellite imagery which has recently become available, fires of recent occurrence were located, some definitely, but even more provisionally. Recent large fires in sparse vegetation can be located with relative ease, but ground investigation is essential to be certain of identification. Those who are particularly interested in an example should examine the summer-1972 satellite imagery of the fire which occurred in 1968 immediately east of the town of Inuvik, Northwest Territories. The northern part of the burned area is in the tundra zone and the boundary between the burned and unburned areas is very distinct. When small areas of tundra were burning at the same time as satellite imagery was in progress, a plume of smoke provided easy identification. An example of this has been published in Shilts (1975).

RESULTS AND DISCUSSION

Few respondents to the questionnaire reported tundra fires. The general type of response is indicated by the personal communications of two researchers who have spent considerable time in the tundra. Dr. J. P. Kelsall, of the Canadian Wildlife Service, has stated: "In all my years working on the tundra I never did see a fire of any significant size." Dr. D. M. Hopkins of the U.S. Geological Survey noted several tundra fires on the Seward Peninsula of Alaska in 1947, and although he visited the area regularly he did not recall seeing burned areas again until 1971 when lightning strikes during frequent thunderstorms ignited many. In essence, the respondents indicated that tundra fires occurred infrequently, and were invariably small in areal extent.

Frequency and distribution

The frequency of tundra fires is very low when compared to that in forested areas of Canada (Simard 1975) and there are insufficient recording stations in the remote areas of tundra to make direct comparisons. Most of the fires recorded in Tables 1-4 are dated within the past few years, because more aircraft flights have provided better surveillance and government personnel have made more complete records. Much more research on various forms of disturbance has been carried out recently and researchers from diverse backgound are recording fire locations. Records are more numerous and are available for a longer period of time in the Mackenzie Delta area, but as more research is conducted along the west side of Hudson Bay in anticipation of a gas pipeline, it is probable that more burned areas will be located.

No records are available from the northeastern part of the District of Mackenzie, N.W.T., or in the northwestern part of the District of Keewatin, N.W.T. Fires have occurred as far north as 64°45′N in the District of Keewatin, 69°27′N in the District of Mackenzie, 68°00′N in the Mackenzie Delta, and 70°05′N in Alaska. Fire has also been recorded as far north as 70°N latitude in the U.S.S.R. (Kryuchkov 1968a, b). Fires will probably be found in other parts of the mainland Arctic in the future, because there is sufficient biomass (i.e. weight of vegetation per unit area, sometimes referred to as "fuel") to carry a fire, at least in local areas. No fires are expected in the Canadian Arctic Archipelago, because biomass there is insufficient and too discontinuous.

Tundra fire records for the eastern Arctic are rare. Several reasons might account for this, among which would be the inaccessibility of the area to people who could start fires, and the climatological conditions that result in low fire weather indices (Simard 1973). The only record from the tundra of northern Quebec was from Rousseau (1968 p. 500) who indicated that tundra fires were important and started easily when lichens became dry. The Forest Protection Service of the Government of Quebec had no record of tundra fires up to and including 1975, and Wilton and Evans (1974) recorded no fires for tundra areas of Labrador.

Fire size

The size of area over which a fire spreads is strongly influenced by meteorological conditions. When these conditions are conducive to burning, biomass and topographic variability within the area determine the ultimate extent of the fire. As biomass diminishes, topographic discontinuities become more important. This is exemplified by records of fire sizes between Inuvik and Tuktoyaktuk in the Mackenzie Delta area (Table 2). Fires near the treeline are larger, because the biomass and subsequent release of energy is sufficiently great to permit the fire to jump across drainage channels and other small areas of normally-wet vegetation. Further north, the limited biomass does not generate enough energy to burn readily through the moist areas, into the wind, or down-hill.

In the District of Keewatin variation in biomass is not as great as near the Mackenzie Valley; therefore, one would expect fire size to depend on topographic discontinuities.

Causal agents

Lightning, until recently, has been the main causal agent of tundra fires, although indigenous peoples and early fur traders may have left campfires along river transportation routes which burned from the forested lowlands up into the tundra. Meteorological records indicate that lightning storms decrease in frequency with increased distance north, and about three times as many lightning storms occur in the eastern part of the District of Keewatin as in the western part of the District of Mackenzie (Kendrew and Currie 1955).

Very often a lightning storm will cause a number of fires. On 14-15 August 1973, nine fires broke out just south of the treeline (60°07′N, 101°48′W to 60°23′N, 101°44′W) (H. W. Gray, Northwest Lands anf Forest Service, personal communication). A similar grouping of five fires started by lightning about 4 July 1974 were recorded from 57°07′N to 57°42′N south of Fort Chimo (A. Guay, Forest Protection, Government of Quebec, personal communication). Shilts (1975) (Table 1) determined multiple tundra fires from one storm in the District of Keewatin when satellite imagery took place at the same time as the fires burned, and the smoke plumes provided ready identification.

As industrial activity increases on the tundra, there will probably be an increase in the percentage of fires caused by man, just as in the boreal forests. Man has ignited 10 of the 12 tundra fires of known cause between Inuvik and Tuktoyaktuk (Table 2).

Dates of fires

Fires can be ignited as soon as the snow melts and the vegetation dries. This can be as early as mid-May or as late as the end of August. Great length of day early in the season is conducive to melting the snow and drying vegetation and plant litter. The possibility of fire in September is small because of the higher humidity levels associated with the reduced length of day. The fire at 68°53′N, 133°42′W (Table 2), which started on 13 June 1974, burned in spite of patches of snow in depressions and in the leeward of shrubs. This fire burned only the standing vegetation, because the surface soil was saturated. It is to be expected that fires which occur later in the season under drier conditions will remove more surface-soil organic matter and kill more plant parts, so that there will be slower rates of regeneration of the plant community. This hypothesis, however, requires testing with experimental fires.

Fire dynamics

Tundra fires have burned through a considerable variation in landscape types, but there is insufficient detail in the records to determine the specific communities burned. Dwarf heath-lichen, dwarf willow-birch, cottongrass, and even sedge meadows in years of low precipitation, have burned (Shilts 1975; Wein and Shilts 1976).

Fire dynamics are poorly quantified at present, but a few generalities can be given from a burn located at 68°25′N, 133°35′W (Table 2). This fire burned from 8-13 August 1968 after a drought period of 86 days. It spread north from the open forest-tundra near Inuvik to about 15 km into the tundra. Near Inuvik the groundfire was blocked by fire-guards, by streams that normally have flowing water in summer, or by small lakes. In the tundra of the northern part of the burn, small streams or even polygon cleavages were sufficient to block the fire.

Tundra with scattered trees was more susceptible to fire than the tundra to the north, but not all of the former vegetation type burned. White spruce trees and alder shrubs located along stream channels survived, because the wet moss understory did not carry the fire. Some small areas of paper birch on the southwest-facing slopes survived because the understory of grass, shrubs and litter layer carried only a light fire. In moss-dominated depressions fire burned large areas of dry moss. There were, however, some areas where the moss was sufficiently wet to permit the survival of a few black spruce trees. Narrow bands of lakeside sedge communities usually did not burn.

Tundra vegetation also carried the fire, but here the fire boundary was irregular. Lowland areas of polygons usually burned; however, a few raised polygons were protected from fire where the surrounding trenches were sufficiently deep. Even small drainageways protected some areas. The streamside willows usually were not damaged, and the fire stopped within a number of communities where vegetation cover was discontinuous. In communities with discontinuous plant cover the fire stopped, at least in part, because of the lack of fuel, although many other ambient environmental factors such as precipitation, wind and topography were important.

Few data exist, as yet, on the rate of spread of fire in Arctic vegetation. Some calculations made from Hill (1969) indicated that the 1968 fire travelled about 3 km per day in the forested areas, while in the tundra the movement was about 2 km per day. Shilts (1975) has observed tundra fires moving very rapidly across sedge meadows and one fire that burned at a rate of one metre per minute against a 10-15 km-per-hour wind. Experimental studies to objectively determine fire rate-of-spread and the magnitude of controlling factors remain to be conducted.

CONCLUSIONS

Arctic tundra fires do occur, although there are few actual records of them. With increased industrial activity fire frequency will probably increase as it has in more southerly areas. Most tundra fires are infrequent and are relatively small when compared to fires in the forest-tundra or closed forest farther south. Little is known about the ecological significance of tundra fires, but if they are to be studied in the future an accurate record of them should be maintained. If fires are not recorded within a few years, there may be sufficient vegetation regrowth for the burn not to be readily noticed. It is hoped that this paper will stimulate sufficient interest in tundra fires for at least the locations of them to be recorded.

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TABLE 1. Recorded fires in tundra vegetation west of Hudson Bay, District of Keewatin.

LOCATION	DATE	CAUSE	SIZE IN HECTARES*	VEGETATION CHARACTERISTICS	REFERENCE
64° 45′ N, 93° 15′ W	29 July 1973	Not known	13-16 x 10^2	Not recorded	Shilts 1975
64° 37′ N, 94° 10′ W	29 July 1973	Lightning(?)	31-39 x 10^2	Not recorded	Shilts 1975
64° 26′ N, 94° 25′ W	August 1973	Not known	4 x 10^2	Not recorded	Shilts 1975
64° 24′ N, 99° 00′ W	19 June 1960	Lightning	Not known	Not recorded	Cochrane and Rowe 1969
64° 23′ N, 95° 05′ W	29 July 1973	Not known	8-10 x 10^2	Not recorded	Shilts 1975
64° 22′ N, 94° 22′ W	30 July 1973	Lightning(?)	8 x 10^2	Not recorded	Shilts 1975
64° 00′ N, 95° 30′ W	28 July 1973	Lightning(?)	10 x 10^2	Dwarf birch lichen on peaty mat	Shilts 1975
63° 54′ N, 96° 42′ W	1970	Not known	Spot	Lichen mat and heath species on old raised beach	Wein and Shilts 1976
62° 51′ N, 92° 12′ W	24 June 1968	Man	65	Lichen mats, low heaths, mixed lichen heaths	Cochrane and Rowe 1969
62° 51′ N, 92° 11′ W	Late summer 1967	Man	120	Lichen mats, low heaths, mixed lichen heaths	Cochrane and Rowe 1969
62° 50′ N, 92° 10′ W	July or August 1973	Man	Several (hectares)	Not recorded	Shilts 1975
62° 26′ N, 95° 43′ W	August 1973	Lightning(?)	4	Sparse vegetation in bouldery out-crop areas	Shilts 1975
62° 07′ N, 95° 20′ W	13 August 1973	Debris from another fire(?)	26-32	Sedges	Shilts 1975
62° 09′ N, 96° 01′ W	24 July 1973 to 2 August 1973	Man	4-8	Dwarf willow birch	Shilts 1975
62° 00′ N, 95° 27′ W	2-19 Aug. 1973	Lightning	13 x 10^2	All vegetation types common to Kaminak area	Shilts 1975
61° 10′ N, 94° 15′ W	1 May 1973 to 20 July 1973	Not known	4-20 x 10^2	Not recorded	Shilts 1975
61° 22′ N, 95° 26′ W	15-18 Aug. 1973	Not known	16 x 10^2	Dwarf willow-birch and lake-bed sedges	Shilts 1975
60° 32′ N, 94° 35′ W	May to mid-June 1973	Not known	23 x 10^2	Moss, lichens and grass-sedge	Shilts 1975

*10^2 hectares = 1 km^2

TABLE 2. Recorded fires in tundra vegetation east of the Mackenzie Delta, District of Mackenzie.

LOCATION	DATE	CAUSE	SIZE IN HECTARES*	VEGETATION CHARACTERISTICS	REFERENCE**
69° 27′ N, 132° 57′ W	31 August 1971	Campfire in driftwood	1	Not recorded	N.W.L.F.S. 11-71
69° 26′ N, 131° 20′ W	10 May 1968	Not known	6	Tundra	N.W.L.F.S. 7-68
69° 25′ N, 133° 01′ W	26 June 1969	Not known	4	Shrub-tundra	N.W.L.F.S. 28-69
69° 24′ N, 133° 03′ W	2 July 1973	Campfire in driftwood	Spot	Sedges	N.W.L.F.S. 6-73
69° 23′ N, 133° 09′ W	9 July 1972	Campfire in driftwood	1	Sedges	N.W.L.F.S. 3-72
69° 23′ N, 132° 57′ W	24 July 1974	Campfire in driftwood	Spot	Moss	N.W.L.F.S. 22-74
69° 20′ N, 133° 02′ W	1 August 1968	Not known	8	Tundra	N.W.L.F.S. 25-68
69° 17′ N, 133° 05′ W	16 July 1970	Clean-up fire	24	Tundra	N.W.L.F.S. 5-70
69° 05′ N, 131° 10′ W	30 July 1973	Lightning	2	Shrubs	N.W.L.F.S. 19-73
69° 03′ N, 133° 48′ W	22 June 1973	Clean-up fire	Spot	Tundra	N.W.L.F.S. 7-73
69° 00′ N, 130° 40′ W	1954	Not known	2,000 x 10^2 (400 x 10^2 tundra)	Spruce in south to tussock-shrub in north	Cody 1964
68° 59′ N, 133° 27′ W	9 July 1972	Campfire	1	Non-forested	N.W.L.F.S. 4-72
68° 54′ N, 133° 33′ W	11 May 1968	Signal fire	2	Shrub tundra	N.W.L.F.S. 5-68
68° 53′ N, 133° 42′ W	13 June 1974	Clean-up fire	32	Shrub tundra	N.W.L.F.S. 4-74
68° 49′ N, 134° 11′ W	1971	Lightning	17	Birch-heath	N.W.L.F.S. 5-71
68° 44′ N, 132° 02′ W	11 August 1968	Not known	Spot	Not recorded	N.W.L.F.S. 20-68
68° 31′ N, 132° 25′ W	19 June 1971	Not known	6	Tundra	N.W.L.F.S. 7-71
68° 25′ N, 133° 35′ W	8 August 1968	Campfire	350 x 10^2 (115 x 10^2 tundra)	Spruce in south to heath tundra in north	N.W.L.F.S. 34-68

*10^2 hectares = 1 km^2
**N.W.L.F.S. (11-71) refers to Northwest Lands and Forest Service (fire no. 11 in 1971)

TABLE 3. Recorded fires in tundra vegetation between the Mackenzie Delta and the Alaska border.

LOCATION	DATE	CAUSE	SIZE IN HECTARES*	VEGETATION CHARACTERISTICS	REFERENCE**
68° 00′ N, 137° 15′ W	1971	Not known	1 x 10^2	Shrub-tundra	Wein (personal observation)
67° 38′ N, 136° 40′ W	18 June 1972	Lightning	5	Shrubs	Wein (personal observation)
67° 26′ N, 135° 23′ W	2 July 1969	Not known	12	Shrub-tundra	N.W.L.F.S. 30-69
67° 22′ N, 135° 30′ W	16 July 1972	Lightning	40	Shrub-tundra	N.W.L.F.S. 5-72
67° 22′ N, 135° 21′ W	2 July 1968	Not known	1	Tundra	N.W.L.F.S. 9-68
67° 16′ N, 135° 17′ W	18 June 1971	Lightning	1	Shrub-tundra	N.W.L.F.S. 6-71
67° 16′ N, 135° 45′ W	1971	Lightning	1	Tussocks	Wein (personal observation)
67° 10′ N, 135° 15′ W	1972	Lightning	4	Shrub-sedge	Wein (personal observation)
67° 10′ N, 135° 15′ W	1971	Lightning	1	Shrub-sedge	Wein (personal observation)
67° 07′ N, 135° 41′ W	17 July 1972	Lightning	1	Shrub-tundra	N.W.L.F.S. 7-72

*10^2 hectares = 1 km^2
**N.W.L.F.S. (30-69) refers to Northwest Lands and Forest Service (fire no. 30 in 1969).

TABLE 4. Recorded fires in tundra vegetation of Alaska.

LOCATION	DATE	CAUSE	SIZE IN HECTARES*	VEGETATION CHARACTERISTICS	REFERENCE
70° 05′ N, 147° 50′ W	1969	Lightning	2	Wet coastal plain	Barney and Comiskey 1973
69° 40′ N, 148° 59′ W	1970	Man	28	Wet coastal plain	Barney and Comiskey 1973
69° 04′ N, 148° 41′ W	1971	Lightning	2	Dry moraine hills	Barney and Comiskey 1973
69° 02′ N, 155° 55′ W	1971	Lightning	4	Dry moraine hills	Barney and Comiskey 1973
68° 49′ N, 153° 33′ W	1969	Lightning	16 x 10^2	Well drained ridges	Barney and Comiskey 1973
66° 00′ N, 152° 00′ W	5 July 1957	Lightning	Not known	Not recorded	Komarek 1964
67° 30′ N, 159° 00′ W	3 June 1948	Lightning	Not known	Not recorded	Komarek 1964
Seward Peninsula	1974	Lightning	Extensive	Cottongrass tussocks	D. M. Hopkins (personal communication)
Seward Peninsula	July 1971 (3 fires)	Lightning	1,600 x 10^2	Cottongrass tussocks	D. M. Hopkins (personal communication)

*10^2 hectares = 1 km^2

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