RESOURCES AND DYNAMICS OF THE BOREAL ZONE

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FIRE HISTORY AND ECOLOGY OF FOREST ECOSYSTEMS IN KLUANE NATIONAL PARK: Fire Management Implications

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Abstract: To aid in the development of a fire management plan for Kluane National Park, a study of the fire history and ecology of the park's forest ecosystems was undertaken to determine the ecological role of fire in vegetation renewal and succession. Results of the study indicated that lightning is a very infrequent ignition source. Man-caused fires were important in vegetation renewal, especially since the late 1800s as indicated by the difference in fire frequency between remote and heavy human-use study areas within the park. The present vegetation mosaic is partially the result of man-caused fires (early Europeans and Indians) and supports a wide variety of wildlife. In addition to fire, glacial movements have exposed new material, caused lake formation and drainage, and resulted in vegetation renewal and succession. The fire management strategies developed by Parks Canada for Kluane National Park should consider these vegetation cycling mechanisms. Decisions will be made as to what vegetation mosaic will be perpetuated by Parks Canada as "the natural resources within the park". If only lightning fires were considered for re-cycling vegetation, the average age of forest stands would increase, stand composition would change, and vegetation mosaics would tend towards less landscape diversity.

Fire's role in national park ecosystems was not recognized in Parks Canada policy until 1979 (Parks Canada 1979). This policy statement recognizes wildfire as a natural phenomenon and expresses the need to incorporate fire as a force in ecosystem development.

Implementation of this policy will require development of fire management plans in Canadian national parks. This investigation was undertaken to assist in the preparation of a fire management plan for Kluane National Park, Yukon Territory. The present study was initiated in 1980 and field work was conducted during the summer of 1981. Information on fire history and ecology has been collected in other national parks such as Nahanni, Northwest Territories and Wood Buffalo, Alberta and Northwest Territories. Alexander and Dubé (1983) presented a review of past and current fire research and status of fire management plans and programs in Canadian parks and other nature reserves of northern circumpolar countries.

Early work by Johnson and Raup (1964), as part of their geobotanical and archaeological investigations in southwest Yukon Territory, examined the role of fire in vegetation succession in the Kluane area during the late 1940s. They found that fire and lake formation were major factors in vegetation renewal. Theberge's (1972) initial investigation into the fire history of Kluane National Park was limited in detail and left some unanswered questions on the ecological role of fire in vegetation renewal and succession. The two major questions were (1) what was the past fire regime, and (2) to what extent did early Europeans and natives influence this fire regime.

The objectives of the present paper are:

- to describe the ecological role of fire in vegetation renewal and succession in the vegetation types,
- to determine the fire history of selected areas to examine the importance of man-caused fires (i.e., early Europeans and natives) in the more recent fire history and the influence of climatic regions on mean fire intervals as described by Romme (1980), and
- to discuss the fire management implications of the fire history and ecological information.

Study Area Description

Kluane National Park encompasses approximately 22,100 km^2 in the southwestern corner of the Yukon Territory and borders the Wrangell-St. Elias reserve in Alaska on its western border (Figure 1).

Only 18 per cent of the park is covered with alpine, subalpine and montane forest vegetation. The rest of the park area consists of permanent snow and ice fields, water, rock and gravel floodplains. Montane forest vegetation encompasses only seven per cent of the park area mainly along the river valleys in the eastern and northern sections of the park. Much of the forest is concentrated along the eastern border which is formed by the Haines and Alaska highways.

The forested areas are classified by Rowe (1972) as the Kluane Section (B.26d) of the boreal region and by Oswald and Senyk (1977) as being in Ecoregions 6-Coast Mountains, 7-St. Elias Mountains, and 8-Ruby Range. The major forest species found are white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), while lodgepole pine (*Pinus contorta* var. *latifolia*) and paper birch (*Betula papyrifera*) are represented by only a few individuals (Douglas 1980). Three major vegetation zones have been described (Douglas 1980).

Most of the fire history and ecology work was concentrated in the montane zone where fire has been more prevalent than in the subalpine and alpine zones. The montane zone occurs on the lower valleys and slopes (up to 760 to 1080 m) of the Kluane Ranges and is dominated by essentially continuous white spruce forests with some mixtures of trembling aspen and balsam poplar (especially areas with recent disturbance by fire, snow or water). Within the montane zone there are also numerous marsh, fen, shrub and herbaceous vegetation types (Douglas 1980).

Methods

Selection of Study Areas

The vegetated area of Kluane National Park is much too large for a detailed fire history study of all areas in the time available for this study. The study approach used was similar to that developed by Barrett (1980) to determine the influence of Indian fires in the forests of western Montana prior to European settlement. The importance of man-caused fires in the more recent fire history of the park was to be determined. This fire history included those caused by early Europeans from the 1880s (start of Dalton Trail and placer mining activities — see Wright (1980)) to present and Indian fires before and after the 1880s.

Figure 1. Location of Kluane National Park in southwestern Yukon Territory. Wrangell-St. Elias National Monument and Glacier Bay National Monument are also identified.

Barrett (1980) used a sampling method where a number of stands were examined for differences in fire frequency (here defined as the number of fires per unit time in some designated area (which may be as small as a single point) (Romme 1980)) due to differences in Indian use. Kluane National Park can also be stratified into areas which have had concentrated use by early Europeans for mining, trapping, hunting and surveying (Stevenson 1978; Wright 1980) and the Southern Tutchone Indians for fishing, hunting, trapping, and settlements (Workman 1978). Figure 2 identifies six areas which were chosen for the fire history and ecology portion of the study. These areas were selected on the basis of amount of human use (i.e., 'heavy human-use' or 'remote human-use' areas) and the climatic region as described by Douglas (1980). The areas that were selected are:

1. Northern climatic region:
   A. heavy human-use — Slims and Jarvis Rivers
   B. remote human-use — Upper Donjek River

2. Central climatic region:
   A. heavy human-use — Kathleen Lakes — Quill Creek
   B. remote human-use — Dusty and Disappointment Rivers and Trout Lake.

3. Southern climatic region:
   A. heavy human-use — Alder Creek, Fraser River and Dezadeash Lake
   B. remote human-use — Bates Lake and River and Onion Lake.

Data Collection and Analysis

Data were collected on the ecological role of fire in vegetation renewal, succession and fire history. Information from Douglas (1980) was used to document the community type. Ten to 15 fire history and ecology plots were established in each study area depending on the complexity of fire history and time available for sampling.

The fire history information collected was different from that of Barrett (1980) due to the difference in the type of fire history information that was available. Barrett (1980) was working in an area which had a high frequency of low-intensity surface fires which left multiple fire-scars on individual trees. The reconnaissance survey in September 1980 indicated that most fires were stand lethal and left few scarred trees except on fire boundaries. White spruce was the main conifer species and therefore had the most fire scars.

The shortage of fire scar information meant that one or more of the following three options was used to estimate the fire interval(s) (defined as the number of years between two successive fires in a designated area with the size of the area clearly specified (Romme 1980)) on each fire history plot (the plot size was a small stand and could be considered a point estimate).

The first option was used when two or more fire-scars were available to date multiple fires. The difference between the dates of any two successive fires gave an estimate of one fire interval. The most common calculation was the difference between the most recent fire date and the date of the previous fire which originated the stand. This option seldom occurred since white spruce is killed by even low intensity fires and the probability of a particular tree surviving two fires is low.

The second option was used when one or more fire scars was available to date the most recent fire but only the standing dead (snags) or nearby live stand was available to obtain

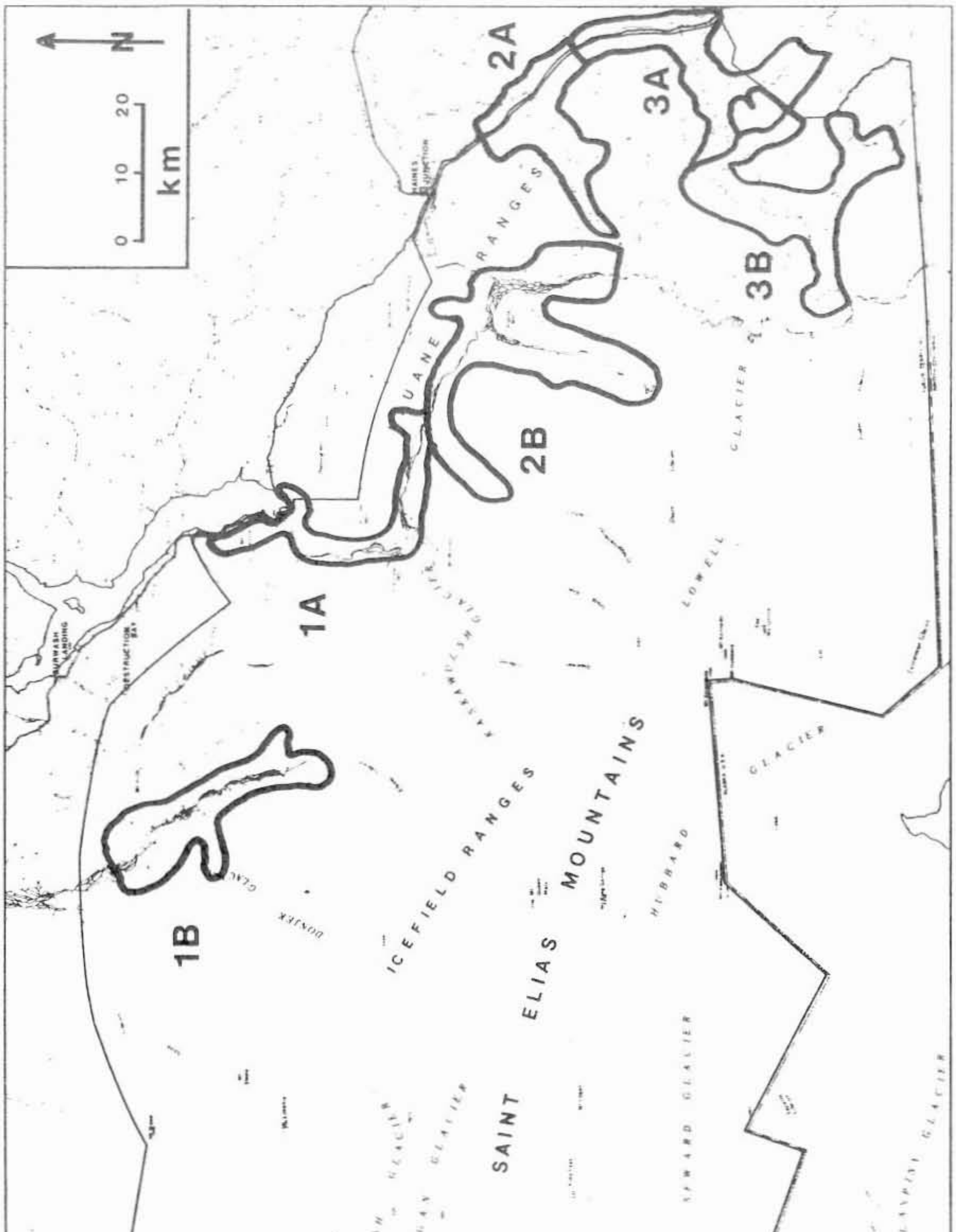


Figure 2. Fire history and ecology study areas located in Kluane National Park.

the approximate year of stand origin. Not all stands originated following fire. Fire origin was indicated by the presence of charcoal in the duff or soil or on a stump or snag. Stand origin (for fire or other causes such as glacial retreat, old lakebeds, floodplains or outwash fans) was determined by taking the age of the oldest tree found and adding a correction factor for regeneration delay after stand disturbance. This correction was determined by comparing the average age of regeneration to that of the fire (date from fire scar record). The regeneration delay ranged from 7 to 55 years with an average of 25 years. The fire interval for this option was calculated by subtracting the date of stand origin from the fire date.

The third option was used when no recent fire evidence, such as a fire scar, was found to date the present stand, but fire evidence such as the presence of charcoal and early fire successional species, such as trembling aspen, were still present. Stand origin was estimated by aging several of the dominant overstory trees and adding the correction factor for regeneration delay (25 years). Stand origin of stands with no evidence of past fires was estimated in the same manner as those with evidence of fire.

The first two options were used most frequently in heavy human-use and remote human-use areas, respectively. The third option gave the least reliable estimate of the fire interval of a stand because the stand has not burned again to document an actual fire interval and charcoal was difficult to find due to movement by wind or water where a stand may have originated from fire.

Fire interval estimates from fire history and ecology plots were averaged to give mean fire intervals (defined as the arithmetic average of all fire intervals determined in a designated area during a designated time period (Romme 1980)) for each of the six study areas and the three climatic regions. Mean fire intervals were calculated for each study area and climatic region from all plot fire intervals.

Fire dates were not corrected for false or missing rings with cross-dating as described in Stokes (1980). Fire dates were confirmed in many cases by exact agreement between the number of fire scars in the same area. Madany *et al.* (1982) felt this approach was accurate enough for most managerial recommendations and some ecological interpretations.

Fire boundaries were mapped from aerial photographs and observations made from a helicopter. These boundaries were used to estimate area burned during the pre-suppression period of 1880 to 1940.

Results and Discussion

Post-fire Vegetative Recovery

Recent reviews by Viereck and Schandelmeier (1980) and Kelsall *et al.* (1977) provide information on the effects of fire on vegetation, soils and wildlife in the boreal forest. This discussion will be directed to the immediate effects of fire on vegetation and post-fire vegetative recovery with some references to soils in terms of fire's effect on organic layer reduction, seedbed condition and nutrient availability. Vegetative recovery will be presented as a general picture of secondary succession after fire in the closed white spruce montane forest. Nomenclature and authorities of plants follow Douglas (1974).

Fire immediately kills most or all of the above-ground parts of plants, consumes part, but rarely all, of the organic layers, leaving variable amounts of below-ground portions of vegetation to sprout, and creates some exposed mineral soil seedbed for germination of seed from nearby plants. Wildfires have left a mosaic of vegetation on any individual burn which has developed from sprouts, seedlings and vegetation which survived the fire due to the variability of fire intensity and depth of burn. This variability is due to variations in moisture conditions of the surface fuel, organic layers and soil both spatially and over the duration of the burn.

Viereck and Schandelmeier (1980) concluded that the effects of fire on soil nutrients vary depending on fire intensity and depth of burn, site condition and original soil properties. They stated that nutrients which were tied up in the vegetative (tree) overstory and the moss and organic layers (such layers in Kluane National Park were over 20 cm deep in stands greater than 100 years old) are released after a wildfire. No specific studies were undertaken to determine the effect of fire on nutrient cycling, although some work in the boreal forest indicates that the shrub/herbaceous community that dominates the early years of post-fire vegetation probably utilizes a large portion of these available nutrients (Auclair 1982).

Low soil temperatures can also limit plant productivity in northern climates by slowing the activity of decomposing and nitrogen fixing organisms (Viereck and Schandelmeier 1980). The organic layer and closed tree overstory limits summer warming of the soil and, in northern areas of Kluane National Park, such as the Donjek River valley, keeps the level of permafrost close to the surface. Wildfire removes most or part of the overstory and organic layer and blackens the soil surface allowing the soil to absorb more of the sun's heat. An increase in juvenile diameter growth was observed in a fire-disturbed white spruce stand which showed no evidence of previous fire and was located in the northern area of the park where permafrost is common and organic layers are deep.

Depth of burn was difficult to estimate on most fires in Kluane National Park because all fires were older than 40 years and the immediate effects of the fires were no longer in evidence. Where depth of burn was estimated from the burned organic layer depth compared with a nearby remnant stand, it varied from 58-95 per cent reduction of the original 6-26 cm depth. This estimate has been influenced by decomposition and accumulation of litter since the fire. Less than five per cent mineral soil exposure could be found on any of the burns sampled in 1981. More might have been found immediately after some of the fires. This amount of duff reduction suggests that the organic layer moisture must have been low for most of these fires, which suggests early to late summer burns.

To become established after a burn, white spruce requires a mineral seedbed for germination and seedling survival, survivors nearby to provide seed, a good seed year (these can be ten or more years apart), and a lack of vegetative competition (Viereck and Schandelmeier 1980). The latter two factors are probably the most important in white spruce regeneration delay. White spruce was found to establish itself under a deciduous shrub community if mineral soil was still exposed or was being exposed by the previous fire-killed stand falling down. The seed source was usually the survivors present because of the mosaic nature of the burns.

Trembling aspen and balsam poplar are better adapted for revegetating burns because they have numerous light seeds and can also sprout from live roots in the mineral soil and unburned portions of organic layers. Agreement of stem ages of aspen with known fire dates indicated an immediate sprouting of some individuals. Seeding by live trees nearby was illustrated by stem ages less than the age indicated by the fire date.

Foote (1982) described six general developmental stages of forest succession in Alaska: newly burned, seedling/herb, tall shrub/sapling, and three tree dominated stages. These are used to describe a general picture of vegetative recovery after fire in the closed white spruce montane forest (Figures 3-8).

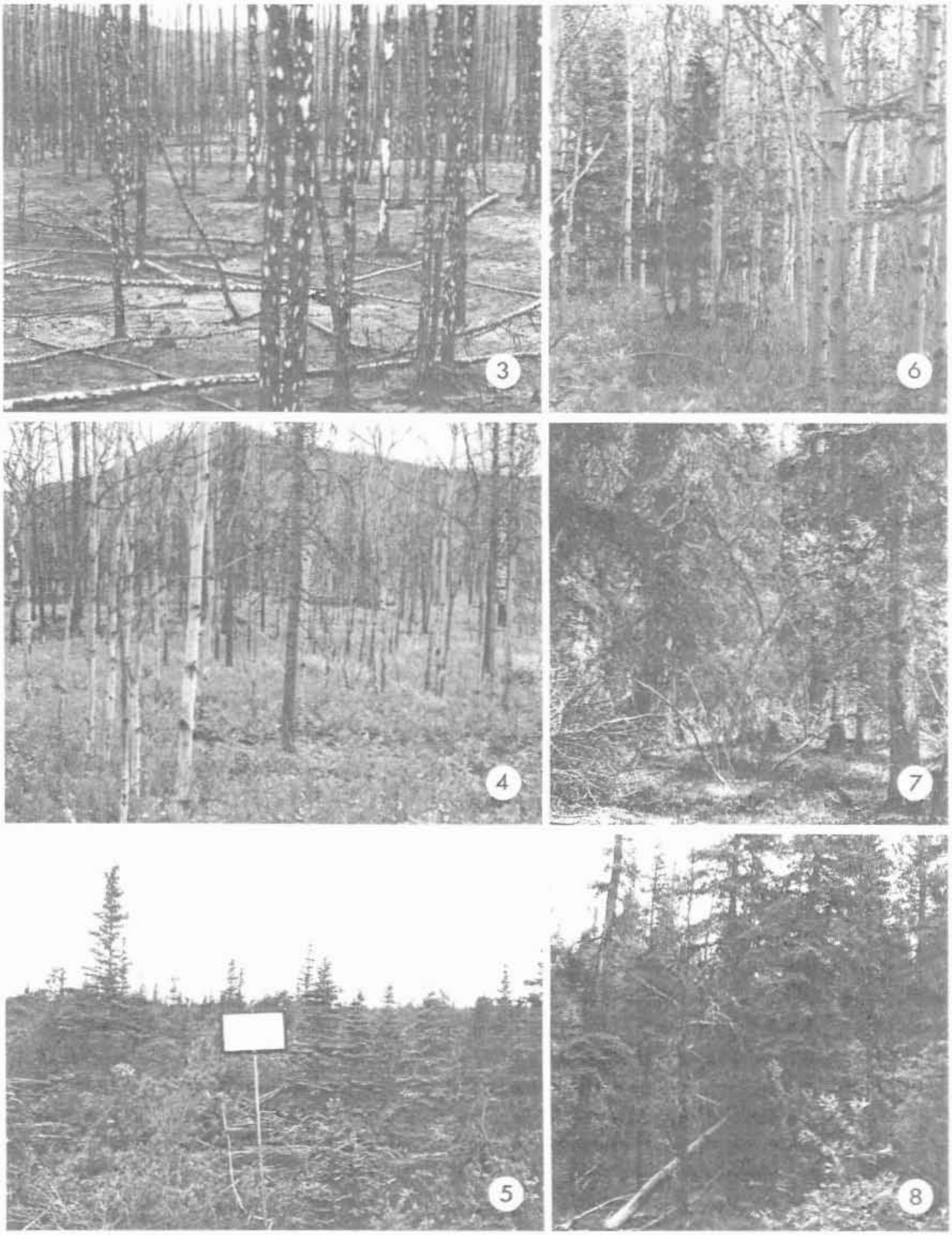
The newly burned stage probably lasts from a month to a year depending on the time of year the burn occurred, the depth of burn and the available seed source. Fires outside Kluane National Park had to be used to describe the newly burned and seedling/herb stage. The forest floor is dominated by charred mosses, shrub snags and mineral ash. No live vegetation is present in this stage. This is illustrated in Figure 3 which shows a white spruce stand one year after a fire in 1980 near Canyon Creek. The area in the photograph was dominated by exposed mineral soil.

The seedling/herb stage probably lasts from one to 15 years. If depth of burn is low to moderate, sprouts from live roots and rhizomes in the organic layer and soil start to appear within several weeks after the fire. Shrub and tree species such as trembling aspen, balsam poplar, willows (*Salix* spp.), alder (*Alnus* spp.), buffaloberry (*Shepherdia canadensis*), rose (*Rosa acicularis*) and shrub birch (*Betula glandulosa*) sprout quickly if the depth of burn is low to moderate. Herbs such as fireweed (*Epilobium angustifolium*) and grasses sprout or seed in from nearby areas. Pioneer mosses such as *Polytrichum juniperium* invade on mineral soil. Except for the feathermosses (*Pleurozium schreberi* and *Hylocomium splendens*) and lichens, most of the plant species, including the tree species, become established in this stage and early in the next stage. An example of this stage, shown in Figure 4, is the site of the Canyon Creek fire one year after a fire in 1980. This photograph shows a burned area with a lesser depth of burn than in Figure 3 and a trembling aspen pre-fire stand.

The next stage, the tall shrub/sapling stage lasts from five to 80 years. In this stage the tall shrubs (willows and alder) and sapling trees (white spruce, trembling aspen and balsam poplar) dominate the vegetation. The *Salix glauca* shrub community is the most common vegetation type described by Douglas (1980) in this stage. An extreme case was a *Salix glauca* shrub community mapped by Douglas (1980) that was present 120 years after fire due to a 55 year white spruce regeneration delay. This stage is illustrated in Figure 5 which shows the Kathleen Lake burn near Haines Road, which occurred around 1915.

The pole stage lasts from 50 to 100 years and is dominated by pole size trees of small diameter with the canopy starting to close. This stage can be dominated by deciduous, mixed deciduous-conifer, or conifer trees. The shrubs and herbs have been shaded out and feathermosses start to dominate the forest floor in the conifer dominated stands. The deciduous and mixed deciduous-conifer stands still have an extensive low shrub/herb understory. Figure 6 illustrates a trembling aspen pole stand which originated around 1889 with a well developed shrub and herbaceous understory that includes some white spruce saplings. White spruce pole stands are most common near fire boundaries where seed supply was adequate after the last disturbance.

The next stage, the mature tree stage, which lasts from 100 to 200 years, is dominated by mature deciduous, mixed deciduous-conifer, and conifer stands. The hardwood components, if present, are reaching their pathological age and are being replaced by the longer lived white spruce. The understory of shrubs and herbs is still extensive in the mature hardwood and mixed stands. The mature white spruce stands have mainly feathermosses in their understories. Figure 7 illustrates this stage with a mature white spruce stand which originated around 1835 with few shrubs and herbs remaining in the understory.



Figures 3-8. Six developmental stages of postfire forest succession in Kluane National Park: white spruce stand (3) and trembling aspen stand (4) near Canyon Creek burned one year previously; *Salix glauca* community (5) near Haines Road in 1915 Kathleen Lake burn; trembling aspen pole stand (6) between Kathleen and Dezadeash Lakes in 1889 fire; mature white spruce stand (7) near 1835 Kathleen Lake burn; and mature white spruce stand (8) located near Kathleen Lake campground in 1592 fire. See text for further details.

The final stage is a mature white spruce stand 150 to 400 years old where only minor changes in overstory and understory cover might occur. White spruce tends to develop stem rot resulting in decreasing stand density and openings in the stand. White spruce is also susceptible to the spruce bark beetle (*Dendroctonus rufipensis*) at this stage. An outbreak in the 1940s in Kluane National Park created many openings in the white spruce canopy. The forest floor is still dominated by feathermosses, but the shrub and herbaceous understory is moderately developed. Figure 8 illustrates a mature white spruce stand which originated around 1592 with much windfall and a shrub and herbaceous understory. Deciduous trees are usually no longer in the canopy.

In southern areas of the park the most common succession of shrub to forest community is from *Salix glauca* to *Picea glauca/Salix glauca* (Douglas 1974). More common in northern areas is succession from the *Salix glauca* community to the *Picea glauca/Thuidium abietinum* or *Picea glauca/Aulacomium palustre* forest communities. A deciduous forest community sometimes occurs between the shrub *Salix glauca* and conifer forest communities. The common deciduous forest communities in this role are *Picea glauca — Populus tremuloides/Shepherdia canadensis — Linnaea borealis*, *Populus tremuloides/Arctostaphylos uva-ursi*, and *Salix scouleriana/Shepherdia canadensis*. In the eastern portion of the park along the Haines Road on the drier sites, the succession indicated by Douglas (1980) is from *Shepherdia canadensis*, to a deciduous type, and then to the *Picea glauca/Shepherdia canadensis* closed or open forest community. In the Slims River Valley, succession would be from a dry shrub type like *Juniperus horizontalis* or *Shepherdia canadensis* to the *Picea glauca/Arctostaphylos* spp. or *Picea glauca/Hypnum revolutum*.

Early Miner and Indian Use of Fire

The early Europeans started trading and placer mining activities in the 1880s and continued until the 1930s. Hunting and guiding were important activities from the early 1900s to the establishment of the Territorial Game Sanctuary in 1942. The native Southern Tutchone Indians had settlements at Klukshu Lake and near Dalton Post at Nesketakeen.

Johnson and Raup (1964), in their investigations during the late 1940s of the Southwest Yukon for geobotanical and archaeological features, noted that "there can be no doubt that fire has been a major factor in the life of the valley from the beginning of occupance". They could trace charcoal in loess and silts back to the end of the last ice age, about 12 000 years ago. The Southern Tutchone have lived with fire as part of their environment for centuries, but also have used this powerful tool to manipulate their environment (Workman 1978). Lewis (1982) has recently reviewed the use of fire by North American and Australian hunter-gatherers and points out that the few existing studies of the use of fire by North American Indians show that fire technologies were employed to control the distribution, diversity, and relative abundance of plant and animal resources. Lewis (1982) also points out that the most important general feature of aboriginal applications of fire is that they differed significantly from natural fires in terms of seasonality, frequency, intensity and selectivity.

Early work by Catharine McClellan in the work *My Old People Say* reported in Workman (1978) shows that the Southern Tutchone in historic times used fire to create moose browse. Fires were also used in the early spring by women to burn off banks of streams and lakes to thaw the ground to dig and collect *Hedysarum alpinum* roots (McClellan as cited by Workman 1978). In times of starvation, the Indians would build fires to melt snow so they could collect old bearberries and crowberries in winter and spring. Wright (1980) reported that in early May, 1891, Dalton and Glave travelled up the main Shakwak Valley and their Indian guides would light up a spruce tree when they reached an exposed position to see if there was any answering column of smoke. Fire was, of course, used for cooking and smoking purposes.

The use of fire by placer miners is not well known, although they apparently burned off the vegetation and organic layers along creeks to help melt the permafrost to ease removal of placer deposits (Larry Tremblay, personal communication, 1982). These would have been early spring fires. Many of the placer miners that came to the Yukon Territory were also hard rock miners and prospectors and wanted to remove the forest to get a better view of the underlying rock. Also, the miners preferred fire killed and dried timber rather than green wood for shaft building (Larry Tremblay, personal communication, 1982).

Mean Fire Intervals by Climatic Region and Study Area

The mean fire interval seems to increase from the southern to the northern climatic region (133-234 years) (Table 1). Statistical testing of fire history data to determine if the mean fire interval is significantly different among climatic regions or heavy and remote human-use areas was not possible because the fire history plots were not randomly located within each study area. Most fire history plots were established near fire boundaries to help locate fire scar information and document fire effects on more recent fires. The mean fire intervals reported in this paper are probably shorter than if plots had been randomly located, because more older stands would have been included in the selection.

Mean fire intervals by study area ranged from 113 to 238 years with individual fire intervals ranging from 9 to 403 years (Table 1). Mean fire intervals for the heavy and remote human-use study areas were similar except in the southern area (113 years for 3A-Mush Lake and 162 years for 3B — Bates River). An extensive review of the history of Kluane National Park after completion of sampling, indicated that remote and heavy human-use areas in the central and especially in the northern area had similar early European and native use. The southern area (3A-Mush Lake) had the most concentrated and lengthy use by Europeans and natives.

The overall park mean fire interval was 179 years (Table 1) which might increase to 200-300 years if man-caused fires since the late 1800s were eliminated. This mean fire interval is longer than those reported for other parts of the boreal forest, such as the 40-100 years mean fire interval reported by Johnson (1980) for an area east of Great Slave Lake in the Northwest Territories of Canada.

Records of recent fire occurrence were obtained from Yukon Lands and Forest Service for the period 1963-1981. During this 19 year interval, eight recorded fires burned less than 0.5 ha in total. These fires were man-caused and, in common with observations in the rest of the Yukon Territory, had no distinct seasonal (May-October) peak (Kiil 1971). The main source of man-caused fire was recreational activity. The number of man-caused fires was low, probably because of recent fire prevention activities and the low level of human use in this area.

There were no recorded lightning-caused fires during this 19 year period. Unpublished data from the Bureau of Land Management, Alaska indicate that lightning fire occurrence

Table 1. Mean fire intervals and average fire size in Kluane National Park. Ranges are given in parentheses

	Plots (n)	Mean fire interval (Years)	Average fire size (ha)
By climatic region			
Northern	25	234 (80-403)	
Central	31	164 (9-373)	
Southern	27	133 (14-274)	
By study area*			
1A-Slims River	14	231 (80-403)	983 (92-2700)
1B-Donjek River	11	238 (135-301)	179 (2-819)
2A-Kathleen Lakes	15	152 (30-290)	200 (5-790)
2B-Dusty River	16	175 (9-373)	394 (5-1800)
3A-Mush Lake	16	113 (14-274)	1600 (1-5000)
3B-Bates River	11	162 (105-218)	140 (3-329)

* Overall mean fire interval is 179 years (113-238).

for the period 1957-1979 in the Wrangell Mountains of Alaska was one fire every 24 years for a forested area the size of Kluane National Park. The park is south of the main lightning fire occurrence belt which extends from Beaver Creek up to Dawson, and swings southeast across the Yukon Territory. The Wrangell Mountains and Kluane National Park fire occurrence and history data indicate that lightning-caused fires in the park occur once every 20-50 years.

Fire Size, Shape and Behavior

The 3A-Mush Lake study area had the largest average fire size (1600 ha) (Table 1), and the 3B-Bates River study area (140 ha) the lowest. These average fire sizes are for fires which occurred up to 200 years ago. After stands reach this age it is difficult or impossible to determine older fire boundaries from aerial photographs or observation from an aircraft, especially if there is little or no deciduous component. Except for one fire (approximately 1759 in 3A-Mush Lake) fire size and shape could not be determined prior to the 1850s. Only a systematic survey of stands older than 120 years would provide such information and this was beyond the scope of this study.

The range in fire size was the largest in 3A-Mush Lake (1-5000 ha) and reflects the variable fire weather, topographic and fuel conditions which can occur. There has not been a fire greater than 1.0 ha in size since 1940. This probably results from both better fire suppression capabilities and fewer man-caused ignition sources.

Three study areas had fires over 1000 ha in size (1A-Slims, 2B-Dusty River, 3A-Mush Lake). These large fires usually have elongated shapes which reflect the influence of the frequent strong down-valley winds. Smaller fires tend to have variable shapes and impacts on surface and aerial fuels, which probably indicates less severe and more variable fire weather conditions during the burn.

Fire behavior of past wildfires was difficult to determine because of their age (≥40 years). Estimates of past rate of spread and fire intensity are almost impossible to make, although visual evidence of consumption of crown foliage-bearing twigs and branches indicates crown fires have occurred. This would be especially true where slope and strong valley winds have played a part in fire behavior.

Fire Management Implications

The data and literature on fire history and plant succession indicate that fire has played a role in ecosystem renewal and development. Parks Canada policy (Parks Canada 1979) indicates that natural fire regimes will be re-introduced into Canadian park ecosystems wherever possible.

There are three key issues and challenges for Parks Canada in implementing this new fire policy in Kluane National Park.

1. There has been no distinction between lightning and man-caused fires in the discussion of fire management strategies. Van Wagner and Methven (1980) stated that what the park manager really desires is not the natural fire regime *per se*, but rather the vegetation complex that the natural fire regime would have created. The only worthwhile distinction then is between wanted and unwanted fires, the ignition agent being irrelevant. Van Wagner and Methven (1980) clearly point out that the vegetation plan is the major consideration for decisions regarding wanted vs unwanted fires. If this philosophy is adopted in Parks Canada policy, it will give some flexibility for developing fire management strategies. For example, prescribed fire may have to be used in high human-use areas where a fire exclusion policy is necessary because of public safety.

2. Parks Canada staff will have to make a decision on what vegetation complex to perpetuate before a fire management plan can be developed. A number of vegetation management options are open to Parks Canada depending on their decision as to what constitutes the "natural" vegetation complex. The decision may be to perpetuate the vegetation complex that would result from only a lightning fire regime. If this option were implemented, the average age of forest stands would increase, species changes would take place (i.e., trembling aspen to white spruce), and vegetation mosaics would tend toward less landscape diversity because of the influence of man-caused fires in the more recent fire history. These changes would take place slowly as indicated by the vegetation succession rate.

   Alternatively, Parks Canada may decide to perpetuate the vegetation complex that would result from a fire regime which included lightning and Indian fires. This would be the vegetation complex that probably existed before Europeans arrived around 1880. If this option were implemented, the previously stated results would also occur but to a lesser degree, especially in the highest Indian-use areas.

   Or again, Parks Canada may choose to perpetuate the vegetation complex that resulted from a fire regime which included lightning, Indian- and European-caused fires. Such a vegetation complex would be very similar to what is found today except there would probably be more stands in the younger age classes (<40 years) (i.e., there is a lack of area burned since 1940 (<0.5 ha)).

Finally, it is impossible to perpetuate the vegetation complex that exists today which has resulted from a combination of lightning and man-caused ignitions sources and reflects some influence of fire suppression activities, because the present age class distribution could not be maintained.

3. Whatever vegetation complex is chosen by Parks Canada to perpetuate, the fire management plan should include a long range goal of the average area burned per year which will create the age class distribution desired. Fluctuations in the number, location and seasonality of fires from year to year necessitate a long term approach in vegetation management. Flexibility in fire management strategies is needed to deal with constraints imposed by park boundaries and facilities, public safety concerns, scale problems due to park size and location, and designated special preservation areas.

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