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PRELIMINARY INVESTIGATIONS OF REGENERATION PATTERNS FOLLOWING WILDFIRE IN THE BOREAL FOREST OF NORTHWESTERN ONTARIO

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Abstract: A vegetation survey was initiated to monitor the pattern of natural revegetation resulting from a 1976 forest fire in the Ignace area of Ontario. During the period 1976 to 1980, a total of 316 site inventories on burnt and non-burnt sites was conducted recording 88 different species in 32 sampling days. Ground cover vegetation on burnt-over areas reached the same density as that of non-burn areas in the third growing season following the fire. By the fifth year following the fire, shrub cover was re-established at an approximate height of 2 m. and with a cover factor of 75% pre-burn conditions. No significant change in canopy cover on burnt-over areas was noted during the 5 year study. The greatest changes in species numbers occurred during the first 2 growing seasons. Two types of vegetational species changes were noted, annual succession and re-colonization. Each was identified during the first 3 growing seasons.

Wildfire has been the most important regenerative agent in the coniferous forests of North America (DeByle 1976). The chief effects of burning vary with the type of vegetation, the kind of soil, the season of burning, prevailing weather, and a variety of other factors (Daubenmire 1947, Bendell 1974). From a wildlife standpoint, fires create an abundance of woody browse quite rapidly (Peek 1974). The abundance of wildlife on a burn may be set by the amount of nutrient release, expressed through the quality of food (Bendell 1974). But regeneration is not always predictable, since the amount of plant production at a particular site is regulated by the influence of many environmental factors (Boyd & Goodyear 1971).

Secondary succession following fire is typically studied 5, 10 or more years after a burn. Furthermore, few studies deal with fixed sites through time. Often sampling is done using fire history records, an example being Shaffi's (1972) work in northeastern Ontario. Any consideration of fire cannot be based solely on retrospection. Failure to consider present conditions will result in natural variation resulting from site influences not being recognized (Ahlgren 1974).

This study was designed to examine secondary succession on fixed sites during the immediate post-fire years. Our specific objectives were: (1) to examine the structural habitat changes resulting from fire and secondary succession and (2) to determine if sampling sites could be objectively separated according to their community composition.

METHODS

Study area:

On May 24, 1976, a fire was reported burning on the south shore of Wintering Lake, (Lat. 49°44', Long. 91°19') approximately 50 km. north of Ignace, Ontario. When first reported, it covered less than 3.5 ha. By 28 May 1976 the fire known as Ignace 7 was in excess of 9,900 ha. and thoughts of extinguishing it evaporated. All efforts were directed towards containment (Croskery 1980).

By 30 May, Ignace 7 was 21,200 ha. It covered an area 19 km. by nearly 14 km. (Figure 1). Changes in wind direction, light rain and backburning all combined to halt its spread.

The area burned by Ignace 7 was located within Rowe's (1972) Upper English River Forest Section of the Boreal Forest Region. This section includes the upper drainage basin of the English River and is a transition between the Great Lakes - St. Lawrence forest to the south and the boreal forest to the north and east. The main body of the forest cover of this section consists of black spruce *(Picea mariana)* jackpine *(Pinus banksiana)* with mixtures of white spruce *(Picea glauca)*, balsam fir *(Abies balsamea)*, trembling aspen *(Populus spp.)*, white birch *(Betula papyrifera)* and tamarack *(Larix laricina)*.

In general, soils are thin over granitic Precambrian bedrock. Bedrock exposures and swamps or poorly drained areas are scattered throughout. The topography is classed as gently rolling.

Ignace 7 burned a variety of habitats common to the boreal forest of Northwestern Ontario, including recent cutover, mature and overmature

conifer, mixed-wood forests and man-assisted regenerated cutover.

A total of 5 areas, each containing burnt and non-burnt (control) sites, were selected for monitoring (Figure 1). Areas were denoted by numbers (i.e. 1 - 5) and individual sites within a specific area were denoted by letters (i.e. a - d). Except for area 2, only 2 sites (burnt and non-burnt) were selected per area. Area 2 contained 3 burnt sites and one non-burnt site. This area showed the greatest intra-topographic variation of any site and sampling was designed to account for this variation. All areas selected were less than 50 ha. in size.

During the fall of 1976, forest regeneration activities resulted in area 1 being treated as part of a forestry regeneration program. Because this disturbance was not consistent with our monitoring of natural regeneration, sampling of this area was discontinued.

Areas 4 and 5 were very similar, located in predominantly mature black spruce stands. Area 3 was a pine plantation which had been cultivated and tended prior to the fire. Area 2 had a combination of features including a mixed-wood stand, a hillside, and untreated cut-over (pre-burn). Features of the individual areas are listed in Table 1.

Sampling programs:

The field sampling program was initiated 21 June 1976. This was the first date following the fire in which the area could be safely walked. Each of the sites was examined on a regular 10-day basis.

FIGURE 1: Vegetative survey sample site locations within area burned by Ignace Fire 7 (Lat. 49° 44'; Long. 91° 19').

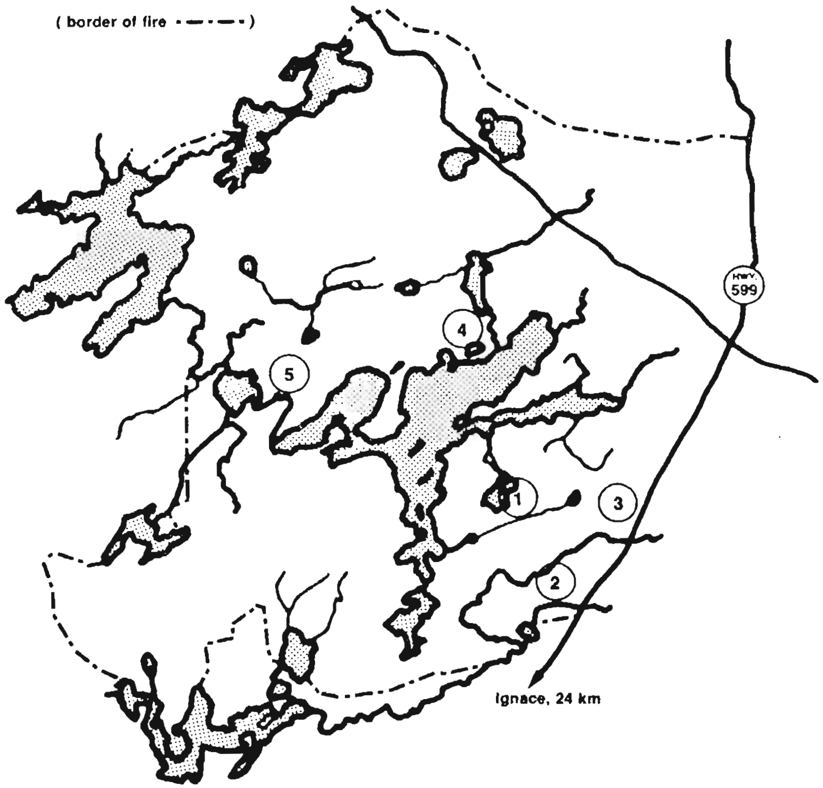


TABLE 1. Features of sample areas and sites selected for fire regeneration survey, Ignace, 1976-80

FEATURE	SITE 2a	SITE 2b	SITE 2c	AREA 3	AREA 4	AREA 5
Preburn	Mixed 75% Decid 25% Conifer	Shrubby Deciduous	Open Field	Pine	Black Spruce (Scattered)	Black Spruce
Age (Trees)	Mature	10-15 yr.	---	15 yr.	Mature	Mature
Slope	Steep Hillside	Slight	Flat	Flat	Flat	Flat
Substrate	Thin Soil	Humus	Coarse Sand	Fine Sand	Rocky Humus	Gravel Humus
Distrubance	Nil	Cutover	Cutover	Cutover Seeding Tending	Nil	Nil
Site Size	10 ha.	10 ha.	10 ha.	20 ha.	10 ha.	10 ha.

TABLE 2. Sampling program 1976-1980, Fire IGN-7 vegetative regeneration

Year	1st Sample Date	Number Sampled Dates	Number Sampled Sites	Number Sets	Last Sampled Date
1976	21 June	6	70	6	1 Sept.
1977	3 May	11	110	11	14 Sept.
1978	18 May	11	104	10	29 Sept.
1980	4 June	4	40	4	3 Sept.
TOTALS		32	324	32	

Sampling involved following random transects through the site recording each plant species according to its pattern of distribution (random, clumped, random clumps) and its density (abundant, moderate, trace). For each site, observations were also recorded for percent ground cover, percent shrub cover and percent canopy cover. During 1977, maximum and minimum thermometers were set at a number of the sites.

A summary of sampling is shown in Table 2. For the years 1976, 1977 and 1978 sampling followed the intended design. Severe fire conditions in 1979 and 1980 interfered with sampling. No data are available for 1979 and those for 1980 include only spring and fall.

A total of 324 site inventories were conducted, representing 31 data sets on 32 sampling dates. In 1978 alone, 8,800 species recordings were documented.

Data analysis:

We used discriminant analysis (Green 1971), a multivariate among-site statistical technique to determine if the 5 sampling sites could be separated according to their species composition. We corrected the data for seasonal changes. The problem was that many of the species increased or decreased in abundance as the season progressed. The variance of such data, simply due to time, may be so great that no technique would be able to detect differences among the sites. The data were modified so that:

(i) the mear value for the abundance c^ each spec·es over all 5 sampling sites was calculated fcr each samp·ing period; and

(ii) for every sampling period, the value for each species at each sampling site was transformed into a percentage of this mear value.

The time independent values for each species as calculated above (for a more detailed description of the method, refer tc Lee and Stewart (1981)) were then used in the stepwise discrimirant analysis program of Nie et al (1975) as implemented on the IBM 360 at Lakehead University.

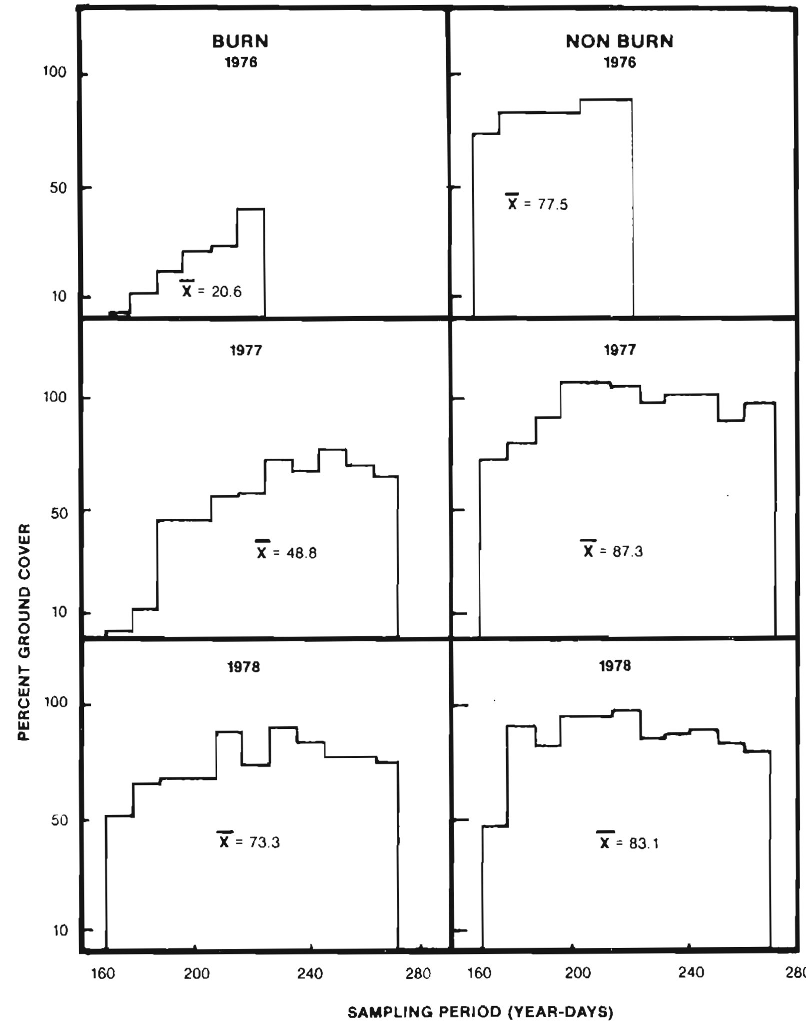
RESULTS & DISCUSSION

Ground cover:

The impacts and patterns of secondary succession following fire and logging have been compared by many authors. A major difference between these 2 types of disturbances is the remaining amount of ground cover. Within the logged site, ground cover remains approximately the same as precut conditions, whereas immediately following Ignace 7, ground cover values were less than 1% at all burnt-over sites. Changes in ground cover for both burnt-over and non-burn areas are shown in Figure 2.

The ground cover at the non-burn sites remained consistent over the 5-year period. Fluctuations were thought to be largely due to annual variation.

FIGURE 2: Changes in mean percent ground cover for burn and non-burn sites, Ignace Fire 7, for years 1976, 1977 and 1978.



At the burnt-over sites, ground cover showed a marked change. Immediately after the fire, ground cover values were less than 1%, but increased by the end of the 1976 growing season almost 40%. Mean ground cover on burnt-over sites was approximately ¼ of that at non-burn sites. During the second growing season (1977), ground cover on the burnt-over sites doubled and by 1978, was nearly the same as that on non-burn sites. The limited 1980 data suggested that ground cover on burnt-over areas exceeded that of non-burn areas by the 5th growing season.

Shrub-canopy cover:

Perhaps the greatest change made by fire to affect birds and mammals is the destruction of trees and large shrubs so that for some time most growth is close to the ground (Bendell 1974).

Immediately following Ignace 7, shrub cover was nonexistent on the burnt-over sites. By the second growing season (1977), shrubby vegetation started to appear, and reached a maximum cover value of 15% although it did not exceed 1 m. in height. In 1978, shrub cover increased to 20% and reached heights of 1.5 m. Changes noted in 1978 were largely a result of species changes. By the fifth growing season (1980), shrub cover increased to 40% with shrubs reaching to 2.5 m. All shrubby vegetation above 0.5 m. was deciduous. Conifer growth was still at low heights, as reported elsewhere (Ahlgren 1974), and did not contribute to the shrub cover.

No changes in canopy cover were recorded over the 5-year period for the burnt-over sites. Canopy cover was always less than 1%.

Ahlgren (1974) suggested that shrub cover development was most significant from the fifth growing season onwards. However, significant was undefined. Our data suggest shrubby vegetation was in limited availability as browse from the third growing season onwards and by the fifth growing season was an abundant browse source.

Temperature:

Removal of forest cover, blackening of the ground and exposure of light-colored mineral soil and rocks will change the input and reflectance of light (Bendell 1974). Examples of differences in recorded maximum and minimum temperatures for burnt-over and non-burn sites are shown in Figure 3. As may be seen, non-burn sites showed a lower maximum value and a higher minimum value than did the burnt-over sites. These data suggest that burnt-over sites generally show a greater temperature fluctuation than do no-burn sites and that this fluctuation is in the neighbourhood of 5^{o}C. These findings are comparable to those reported by Ahlgren (1974) who suggested that these differences will continue for up to 7 years following the fire.

Species:

A total of 88 different plant species was identified during this study. No effort was made to identify grasses, sedges, mosses, lichens, or fungi to the species level. These were simply grouped. The number of species recorded each year for each site is shown in Table 3. The lower species numbers for 1980 are a result of a shortened sampling season.

FIGURE 3: Examples of differences in recorded maxim um and minimum temperatures for burn and non-burn sites, Ignace Fire 7.

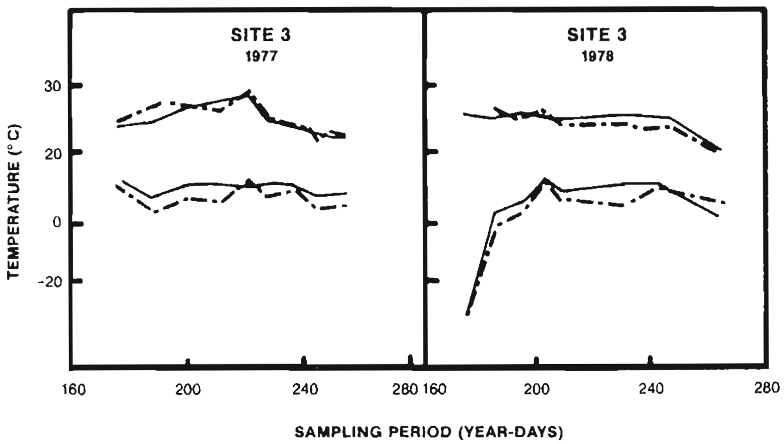


TABLE 3. Maximum number of species reported per site, 1976-80

SITE	1976	1977	1978	1980
1a	13	--	--	--
1b (control)	18	--	--	--
2a	11	30	38	34
2b	14	33	40	31
2c	15	37	38	36
2d (control)	21	35	40	27
3a	16	30	30	26
3b (control)	19	32	36	25
4a	15	36	51	33
4b (control)	21	34	42	31
5a	13	33	40	35
5b (control)	25	37	44	35

In general, the lowest number of species recorded was immediately following the fire. The highest number of species reported was in 1978 the third growing season following the fire. The greatest change in species numbers occurred during the second growing season (Figure 4). These findings are consistent with other studies (Ahlgren 1974) except that we found a greater variety of species during the first growing season.

As secondary succession continues, the number of species on burnt-over plots should exceed that on the matched non-burn sites. Several plots showed this pattern by the third growing season. All areas had a greater number of species on burnt sites than control sites by the fifth growing season.

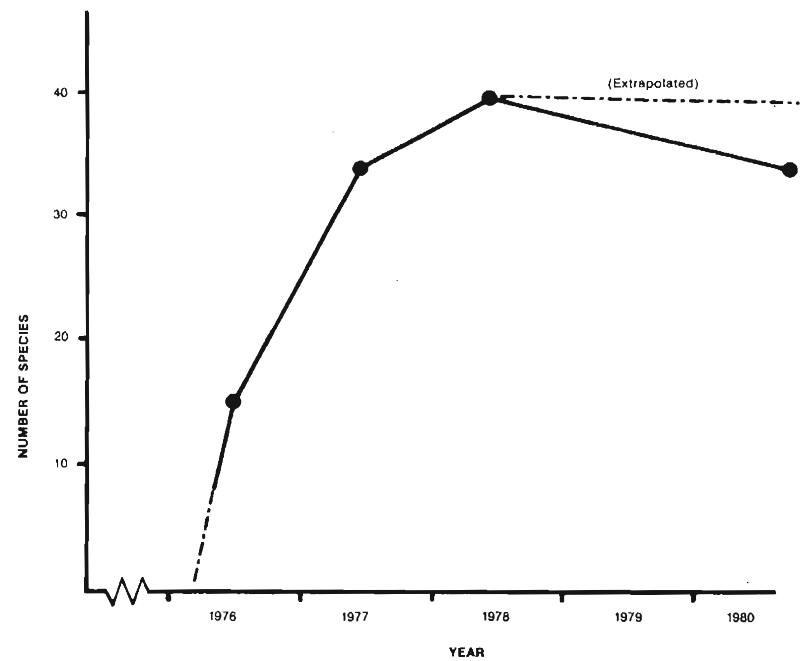
There were a variety of species which appeared in either the first or second growing season, became abundant, then completely disappeared from the sites. Examples include pale corydalis, *(Corydalis sempervirens)* and herb robert *(Geranium robertianum)*.

Another group of species showed a slow but steady increase in numbers over the 5 year period. During the first or second growing season, they made their first appearance in trace abundance on the burned site. By the fifth growing season they were abundant. Typical of this successional "style" were fireweed *(Epilobium angustifolium)*, twinflower *(Linnaea borealis)*, and bindweed *(Convolvulus sp.)*.

Discriminant analysis:

The discriminant analysis procedure was able to separate all of the

FIGURE 4: Changes in species numbers on burnt-over sites, Ignace Fire 7, 1976-80.



sampling sites with 100% accuracy according to the species' abundances. The characteristics of the first seven derived discriminant functions, which accounted for 95% of the among site variation are contained in Table 4. The first 3 functions were the most important in separating the 4 sites, accounting for 71% of the variation. By examining the standardized co-efficients (Table 5) and spatial separation of the sites it is possible to gain a better understanding of the derived discriminant functions.

Figure 5 illustrates the separation of the sampling sites according to the first 2 discriminant functions. The absolute values of the standardized species coefficients in Table 5 are a measure of the relative importance of each species to the discriminant functions.

The first function, explaining 32% of the total among-site variation, was comprised primarily of red pine (*Pinus resinosa*), spreading dogbane (*Apocynum androsaemifolium*), coltsfoot (*Tussilago farfara*), lycopodium (*Lycopodium sp.*), lily of the valley (*Convallaria majalis*), horsetail (*Equisetum sp.*), and northern bush honeysuckle (*Aquilegia canadensis*). The main effect of this function was to separate non-burn site 3 and burn site 4 from the other sites placing them at the opposite extremes of the axis (Figure 5). High abundance values for red pine, spreading dogbane, lily of the valley, and northern bush honeysuckle, with low values for the above remaining species at non-burn site 3 (vice versa for burn site 4) resulted in the observed separation. The fact that non-burn site 3 was the only site which was artifically regenerated may account for the pronounced difference from the other sites.

TABLE 4. Values of discriminant functions derived for the separation of 4 sampling sites, Ignace regeneration survey, 1978

DISCRIMINANT FUNCTION	RELATIVE PERCENTAGE EXPLAINED	CUMULATIVE PERCENTAGE
1	32	32
2	20	52
3	19	71
4	10	81
5	7	88
6	5	93
7	2	95

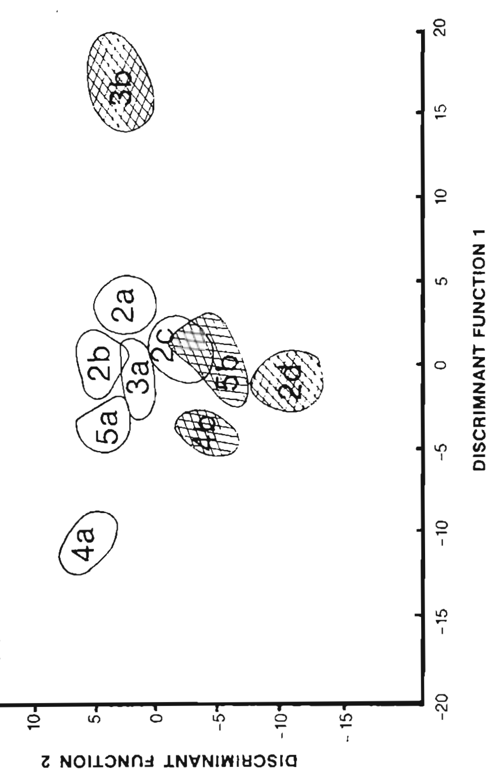
TABLE 5. Standard co-efficients of 7 derived discriminant functions, Ignace regeneration survey, 1978.

SPECIES	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	FUNCTION 7
SP 2	0.17373	0.38715	0.32009	0.26070	-0.17022	0.44333	0.44148
SP 7	0.48370	0.18767	-0.43996	0.02336	-0.15626	-0.43268	-0.27777
SP 10	-0.11951	0.24400	0.26175	0.21539	-0.03638	0.52936	0.10152
SP 11	0.20512	0.10241	0.14976	-0.43052	-0.20394	-0.18756	0.38437
SP 12	-0.79634	0.41356	-0.11131	0.09611	-0.12803	0.06211	0.29023
SP 14	-0.08949	-0.41478	-0.33181	0.25385	-0.25274	-0.67491	-0.05813
SP 15	-0.09400	-0.67833	-0.14190	-0.24365	0.25264	-0.17648	0.19777
SP 23	0.18489	0.19064	0.41686	-0.24890	-0.04585	-0.03602	-0.23391
SP 26	0.26687	0.01421	0.44188	-0.32452	-0.10824	-0.09813	0.13791
SP 27	-0.56194	0.12821	-0.09608	0.29646	0.47392	0.00276	0.18080
SP 29	0.27968	-0.11990	-0.43954	-0.30717	-0.75071	0.43470	-0.17985
SP 30	-0.44973	0.34744	0.43353	0.41975	0.12169	-0.27569	-0.00247
SP 32	-0.19562	0.13240	-0.51743	-0.51743	-0.14637	-0.29520	0.01540
SP 37	-0.16924	-0.59363	-0.12037	-0.24013	0.27562	0.29466	0.61424
SP 42	0.23435	0.10695	-0.04913	0.04775	0.14731	0.22234	-0.25321

TABLE 5. Standard co-efficients of 7 derived discriminant functions, Ignace regeneration survey, 1978

SPECIES	FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	FUNCTION 7
SP 45	0.56742	0.35932	-0.43113	0.49951	-0.03538	-0.07046	0.43507
SP 49	-0.07477	-0.00894	0.13982	0.71815	0.62293	0.09586	0.15051
SP 51	0.33058	0.09627	-0.17957	0.43015	0.37264	-0.27801	0.07592
SP 55	-0.02134	0.17504	0.36446	0.43697	-0.92843	0.48512	0.05973
SP 56	0.34614	-0.08900	-0.05019	0.19255	-0.06155	-0.48874	0.00878
SP 63	-0.81757	0.33403	-0.71528	-0.10609	-0.15333	-0.07997	0.14160
SP 70	-0.06112	0.03174	0.32337	0.11486	0.35662	-0.27788	-0.00347
SP 73	0.58795	0.02315	-0.49710	0.05959	-0.15568	-0.43896	0.04992

FIGURE 5:
Separation of the 4 sampling sites using the first two discriminant functions.
(open-burn, hatched - non-burn)

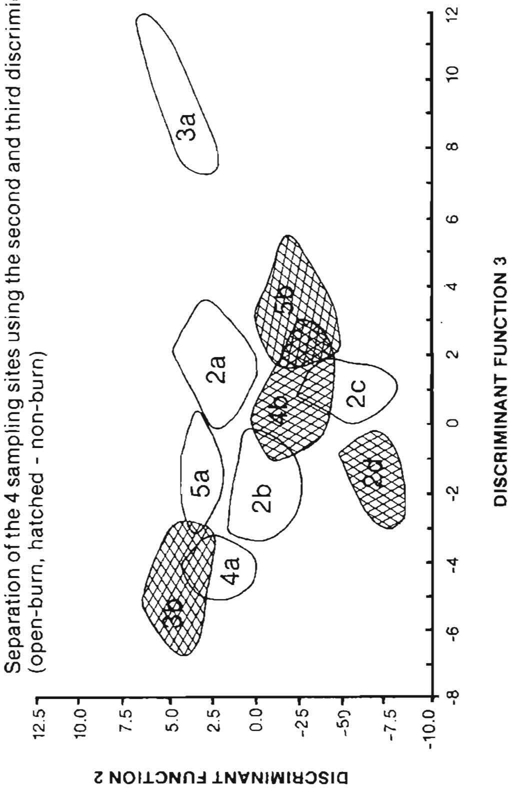


It is also noteable that burn sites 4 and 5, which were both primarily black spruce sites appeared to be quite similar. Since these sites were quite wet in nature and were characterized by high abundance values of species adapted to damp conditions, it may be postulated that discriminant function represented the increasing ability of plants to survive in wet habitats.

It was the second discriminant function accounting for 20% of the variance, which was the most important in separating the burned and unburned areas. This function was comprised mainly of ox eye daisy *(Chrysanthemum leucanthemum)*, dandelion *(Taraxacum sp.)*, red clover *(Trifolium pratense)*, wild rose *(Rosa sp.)* and raspberry *(Rubus sp.)*. The burned areas had greater abundances of wild rose and raspberry, and lower abundances of ox-eye daisy, dandelion and red clover, resulting in the burned areas generally having positive values for this discriminant function and the unburned areas, negative values (Figure 5). The one exception was burn site 2c which also had negative scores. Since this was the burned open field area, we suggest that the pronounced difference in the physical characteristics of the site caused a different type of secondary succession. The greater abundance in the burned areas of species such as ox-eye daisy, dandelion, and red clover, which are all adapted to rapid dispersal by wind, indicate that these species have not yet reached their full potential to colonize the burned areas. Instead, those species which were mostly present in the burned areas were perennials such as wild rose and raspberry able to survive the fire. This indicates that discriminant function 2 represented a measure of species' colonization ability after fire which favoured those able to survive the fire by virtue of their buried root system rather than those species able to re-vegetate a target habitat by seed dispersal. The fact that the open-field site (site 2c), which would encourage colonization by wind-borne species was considerably different from the other burned sites, gives further credibility to this hypothesis.

Discriminant function 3 (Figure 6) explained 19% of the among site variation. This function separated burn site 3 from the other sites. Since burn site 3 was the burned area for the artifically regenerated site (nonburn site 3) this illustrates that the initial disturbance caused by the regeneration procedure greatly altered the ability of this site (relative to other burned sites) to be recolonized following a fire. Of the major contributors to this function (Table 5), burn site 3 had low abundances of red pine, jackpine, coltsfoot, labrador tea, horsetail and lycopodium. It had the greatest abundances of twisted stalk (*Istreptopis sp.*), northern bush honeysuckle and ferns (*Polypodiaceae*). Discriminant function 3 may therefore represent an increasing measure of species ability to survive both a man-made disturbance and a fire disturbance. Jackpine was low in abundance on burn site 3 although on the control site (nonburn site 3) jackpine was more abundant than on the naturally revegetated areas. Although it would require a great deal more investigation to verify the point, it seems possible that although the artifically regenerated area had higher abundances

FIGURE 6:
Separation of the 4 sampling sites using the second and third discriminant functions. (open-burn, hatched - non-burn)



of jackpine than naturally regenerated areas, the site disturbance of the forest management practices of this purpose may lessen the future ability of such areas to naturally revegetate jackpine following a fire. The remaining 4 discriminant functions account for a total of only 24% of the among-site variance and are much more difficult to interpret. They seem primarily concerned with the separation of those sites which are still not well separated. For example, discriminant function 4, accounting for 10% of the variation, separates non-burn site 5 from non-burn site 4 and burn site 3. High loadings at site 5b for cow vetch (*Vicia cracca*), bindweed, northern bush honeysuckle, and low loadings for currant (*Ribes sp.*), and wild rose accounted for this separation. Similarly functions 5, 6, and 7 assisted in the further separation of the sites but are probably concerned with minor differences in species abundances among the sites than any broad trends in an ecological sense.

CONCLUSIONS

From a habitat structure standpoint, fire treats all types of areas similarly. Ground cover, shrubby vegetation, and canopy cover are all destroyed. However, pre-burn conditions dictate the pattern which natural regeneration will follow at any area. In other words, if areas are different in their plant communities prior to being burned, they will again express this difference in plant

communities following the fire.

Immediately following a fire, a group of colonizing species tend to dominate growth on the area burned. These species are quickly replaced during the second and third growing seasons with species more similar to those found on the pre-burn site. It is, however, the combination of all species that best expresses the differences in environmental features between areas.

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