

PROGRESS REPORT OF RESEARCH ACTIVITIES, SEPTEMBER 2000

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PART I: WHITE SPRUCE REGENERATION DYNAMICS AFTER FIRE NEAR
THE TREELINE IN THE INUVIK AREA, NT

PART II: WHITE SPRUCE PRODUCTIVITY AND REGENERATION IN THE
MACKENZIE DELTA REGION



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WHITE SPRUCE REGENERATION DYNAMICS AFTER FIRE NEAR THE TREELINE IN THE INUVIK AREA, NT

Summary report 1, September 2000, Part I, Jessika Schoplick

Introduction

Three studies were carried out to get a better understanding of white spruce regeneration at its northern limit. As fire is the driving factor that shapes the northern boreal forest, regeneration of the upland spruce is closely related to the local fire regime, the intensity, rotation and time of the fire. To show the dynamics and complexity of the regeneration dynamics, each stage from seed to the mature forest were examined. In an experimental study as well as in a field survey seed potential of white spruce after fire was tested. Regeneration plots were established right after a wildfire to determine the time of establishment of the seedlings as well as differences in the establishment when the fire burned during different times in the growing season. The third study focuses on the age distribution of mature stands that represents the long term establishment rates after a fire. The three studies will be included to build a regeneration model, that uses stand density, slope, time of fire and seed potential. All studies were carried out in the upland area adjacent to the eastern Mackenzie Delta. For accessibility, study sites were chosen that were located along the Dempster Highway. Only for the plots that were located in the EV006 fire of 1999 helicopter access was required. Three sites in this fire were established as permanent sample plots to monitor the further stand development.

PROJECT 1: WHITE SPRUCE SEED VIABILITY AFTER FIRE

Introduction

Among the tree species of the North American boreal zone cone serotiny is found in Black Spruce (*Picea mariana*) and two pine species (*Pinus banksiana* and *P. contorta*). After crown fires the seed stored in the many-aged cones open and seed is released quickly. In Black Spruce the cones may release seeds over several years (HEINSELMANN 1981). Other boreal conifer species such as White Spruce (*Picea glauca* [Moench] Voss) do not show this ability to store seeds; instead, they produce and disseminate seed each year. Seed storage is thought to be an important factor determining post-fire vegetation recovery.

The fire season in the boreal forest decreases in duration with distance northwards (SIMARD 1975), with the main fire season occurring during the months of May to September in central Alberta to June to August in the northern Northwest Territories (MURPHY et. al 1980). Fires that occur early in the season would kill the trees and only seeds that have matured by that time would be viable. It is generally held that White Spruce only slowly re-occupies burned areas through seed transport over long distances from the unburned forest edge or unburned refugia within the burned area.

The objective of this present study was to test the potential of burned white spruce trees to release viable seeds after fires that kill trees at differing times during the growing season. In essence we wished to determine how late in the growing season seed bearing trees could be killed and still release viable seed. It is hypothesized that seeds from areas that burned at different times during growing season have the ability to mature on the dead tree to a certain extent. Seeds from the early growing season (i.e. June) will show a lower viability than from areas that burned in August, when the embryo was already developed to a more mature stage.

Methods and Materials

Study area

The study area was located on the upland areas bordering the eastern Mackenzie Delta, Northwest Territories, covering two physiographic regions, the Campbell Lake Hills and the Hyndman Lake Hills. The rolling terrain was mainly dominated by White Spruce on well drained till and Black Spruce in moist depressions (MACKAY 1963). The Mackenzie delta area is characterized by subarctic climate with annual mean temperatures of -9° C and a total annual precipitation of 260 mm with the peak precipitation occurring in late summer (Climatic records supplied by Environment Canada, 2000).

Field studies

For an experimental approach to determine seed maturation in relation to date of burning, a White Spruce study site was located near the town of Inuvik at about $68^{\circ}20'10.9''$ N, $133^{\circ}39'22.7''$ W. Fifteen cone bearing White Spruce trees were selected randomly for treatments that simulated killing by low intensity fires at different times during growing season. Cone bearing branches were selected randomly and on August 4, 11, 18 and 25 one branch on each tree had a two centimeter ring of bark removed close to the bole. On the same date, samples of five cones were collected from untreated branches on each tree to establish the level of seed germination and an additional three to determine the embryo development stage at this date. On August 29, five cones were collected from each treated branch and one untreated branch. For the germination study, the cones were airdried until they opened and then the seeds were stored in a frozen condition until tested for germination. For the embryo maturation study, the three cones from each date were frozen immediately after collection and held in that condition until the seeds were extracted manually and examined for state of maturity.

A field survey study was conducted on a fire that started on June 16, 1999 at $67^{\circ}34'27''$ N, $132^{\circ}47'47''$ W and burned 172,000 ha during the summer. The location of the fire fronts were well documented by fire suppression personnel during the season so it was known when stands of White Spruce were killed. At the end of August when cone opening started, four study sites with a range of burn dates were selected and twenty fire-killed trees were selected randomly in each area. The trees were cut down and a minimum of ten cones was collected from at least five branches.

Laboratory studies

Cones from both experimental and survey germination studies were airdried until they opened and seeds were extracted. A random sample of approximately 200 seeds if available from each tree for the survey and from each branch for the experimental study, respectively, was placed into a petri dish lined with moist filter paper to which a mild fungicide (Thiram) was applied. Seeds were moist stratified at 3° C for a period of 21 days. Germination tests were carried out under 18/6 hr light/dark cycles and diurnal temperature fluctuations of 25/10°C (NIENSTAEDT &



Photo 1: Spruce cones were air dried and seeds extracted

ZASADA 1990). Seeds were germinated over a period of three weeks and counted as germinated when the radicle emerged from the seed coat.

Seed maturation

To determine the date of embryo maturation, the frozen cones were cut in half. Embryos of the exposed seeds along the cone axis were examined to estimate four development stages following HAMILTON (1993). An embryo that filled the seed cavity more than 75% was considered as mature. The cones origin-

ated from the same 15 trees that were selected for the experimental study and were collected from each tree once a week between August 11 and August 25.

Results

Seed maturation

Seventy nine percent of the seeds tested from Aug. 25 had the seed cavity filled by more than 75% and were considered fully mature (Table 1). Thus, seed maturation took place within the week between Aug. 18 and Aug. 25. Field observations noted the first cone opening and seed release was observed around August 29. However, only 17 % of all examined seeds collected between Aug. 11 and Aug. 25 were filled. Twenty-seven percent were empty while 56 % were damaged by insect larvae. The different collection dates show no significant difference in the percentage of filled or damaged seed ($P>0.05$).

Experimental study

No significant difference was detected among germination rates from seed of branches girdled at different dates and collected at Aug. 29. The overall germination rate of seeds was higher than the untreated collected in early August than in earlier embryo development stage. Germination rates approximate as maturation date approaches. Desiccation of the girdled branches did not occur during the four weeks of observation. Germination rate (mean \pm SE) of $57 \pm 4.5\%$ of the

branches girdled at Aug. 25 was slightly higher than untreated branches collected on Aug. 29, showing a rate of $55 \pm 6.0\%$ (Fig. 1). A comparison of the branches girdled on Aug. 04 and the trees burned on Aug. 06 shows no significant difference (Fig. 2).

Field survey

The White Spruce seed collected on the 1999 fire had a germination rate that increased from $21 \pm 4\%$ (mean \pm SE) in areas burned in June to $41 \pm 4\%$ in areas burned in early August. Germination was lower in the area burned later in August ($36 \pm 6\%$). Germination rates between June and early August differ significantly (Mann-Whitney-Test, $P < 0.01$).

Discussion

The date of fire has a pronounced effect on the maturation and viability of Black Spruce seeds; the later the fire occurred in the growing season, the greater the number of viable seeds. Depending on weather conditions, seed maturation of *Picea glauca* will take place in late summer or early fall. Seed fall occurs mostly in late summer or fall but can also be extended into the spring of the next year (WALDRON 1965). In 1999, the year of this study, which was an exceptional seed year, seed maturation occurred between Aug. 18 and Aug. 25. Differences in the germination rates between seed from treated and untreated branches showed that seed can after-ripen on a dying branch. As girdling only interrupts the carbohydrate transport out of the branches, the green foliage is still able to photosynthesize and supply the seeds with storage products. The low germination rate of the seeds from trees burned early in June can be a consequence of an undeveloped embryo.

The results of the present study are supportive of an earlier survey, where White Spruce re-occupied large burned areas in northern Alberta, where there were no post-fire residual trees that could have functioned as a seed source (SCHOPPLICK 2000).

Regeneration potential can be high within a burned area of white spruce if favorable factors coincide. If favorable weather conditions in the year before the fire provides a seed crop (ALDEN 1985), if fire occurs later in the growing season when the embryo is already well developed, and if fire intensity is low enough that some branches continue to live.

Acknowledgements

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Figures and Table

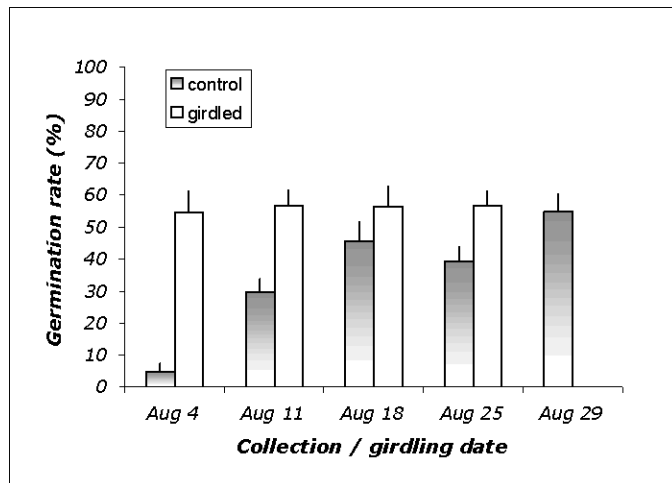


Fig. 1. Experimental study: Germination rates (mean \pm SE) of seed from 15 *Picea glauca* trees near the town of Inuvik, NWT. White bars represent the germination rates for seeds from 5 cones collected from 1 untreated branch from each tree at each date. Cones from the same trees were collected on Aug. 29, 1999 from 1 branch of each tree that was girdled on the given dates. A total number of 27658 seeds was tested, the number of seed per sampled branch ranged from 63 to 411.

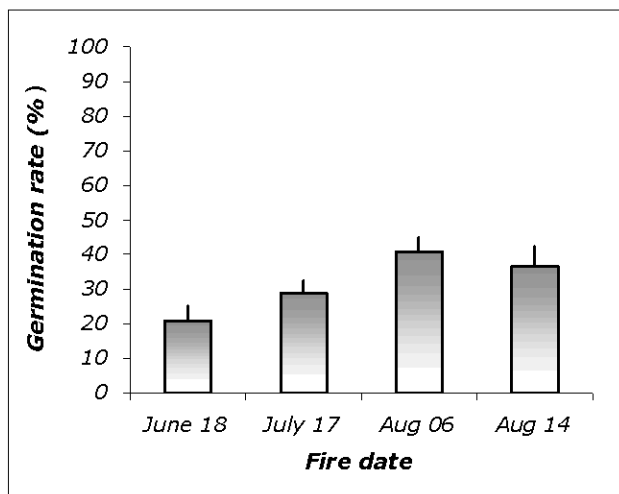


Fig 2. Survey study: Germination rates (mean \pm SE) of *Picea glauca* seeds, collected in the 1999 fire southeast of Inuvik, NWT. Seeds were extracted from cones collected on August 27, 1999 from different branches of 20 white spruce trees for each site that burned on different dates within this fire. A total number of 15181 seeds were tested, the number of seeds per sampled tree ranged from 36 to 356.

Date	n	Percentage seed cavity fill			
		< 25 %	25-50 %	50-75 %	> 75 %
Aug-11	1244	7.3	81.0	11.7	0.0
Aug-18	1177	0.0	11.6	79.3	9.2
Aug-25	1267	0.0	2.4	18.7	78.9

Table 1. Progression of seed filling by date at Inuvik, NWT in summer 1999. On August 25, the seed cavity of 78.9 % of all seed was filled more than 75% and was therefore considered mature. Seed was extracted from three cones per collection date.

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PROJECT 2: AGE DISTRIBUTION OF FIRE ORIGINATED UPLAND WHITE SPRUCE IN THE INUVIK REGION, NT

Introduction

Three study sites were selected to determine age distribution of white spruce stands in the upland area east of the Mackenzie Delta. After disturbances like fire, it can be hypothesized that recruitment takes place in waves and therefore forms even aged stands. After the seedrain of the cones that remained on the burned trees produces a first generation of seedlings with a relative low population, a second “recruitment wave” will follow after this first generation reaches the stage of maturation and cone production.

Methods

Age distribution:

Nine white spruce sites were selected along the Dempster Highway between Inuvik and Fort MacPherson. On each site, a 5m wide transect was laid out in a randomly chosen direction. Measurements were taken from the first 60 trees within that transect, or if the population of the site was too small, from 30 trees. Tree cores were taken at a height of approximately 20 cm. Trees with a diameter smaller than 5 cm were sampled destructively, discs were taken from 0 cm and 20 cm to estimate the missing rings for the cores through a linear regression. Seedlings smaller than 30 cm were collected and the age will be determined in the laboratory.

Fire history

In each site evidence of an old fire was recorded if present (fire scars, charred stumps..) and the year of the last fire was determined by counting the tree rings from the present ring to the scar following methods described by Arno and Sneek (1977)¹ and McBride (1983)².

Study sites

Site 1 (N 68^o18.267', W 133^o19.079'):

The site consists of white spruce trees of different height classes. The dominating height class is the sapling stage <1.30 m. Individual black spruce trees are found within the stand. The surface is hummocky with patches of standing water. The shrub layer is dominated by *Salix* species and *Betula glandulosa*. The site is located on a gentle southfacing slope. The tree density is 9231 stems/ha including white spruce from all size classes, predominantly small seedlings. However, the crown closure is below 20%. Sixty trees were sampled in a 13 x 5 m plot on June 14, 2000.

Site 2 (68^o11.283'N, 133^o26.886'W):

The white spruce stand is located on a south facing slope (ca. 8^o)with rock outcrops of limestone of the Campbell hills range containing patches of loose gravel. The stand appears to be mature white spruce, but single black spruce individuals are mixed in. Slope and aspect support a good

¹ Arno, S.F. and K.M. Sneek. 1977. A method for determining fire history in coniferous forests of the mountain west. US Department of Agriculture General Tech. Report INT-42

² McBride, J.R. 1983. Analysis of tree rings and fire scars to establish fire history. *Tree-Ring Bulletin*, Vol. 43, p. 51-67

drainage and the shallow soils are rather dry. The ground coverage consists of *Vaccinium vitis-idea*, *Arctostaphylos uva-ursi*, *Arctost. rubra*, *Empetrum nigrum* and some *Alnus*. Crown closure varies from single trees to an almost closed canopy. Sixty trees were sampled in a 71.5 x 5 m transect on June 15. Tree density is 1678 stems/ ha.

Site 3 (67°23.14.840'N, 134°14.840'W)

The stand is located between Tsiigehtchic and Ft. MacPherson on a southwest facing slope (20°) of a hill that was formed by glacial deposits. Due to the small site and black spruce individuals within the stand, only 30 trees were sampled on a 31 x 10 m transect on June 16. The density of white spruce is 968 stems/ha. The ground cover consists of *Juniper*, *Arctic Lupine*, *Vaccinium vitis-idea*, *Arctostaphylos uva-ursi*, *Arctost. rubra* and *Rosa acicularis*. Even though there were some old charred stumps, no fire scars were found.

Site 4 (68°06.858' N, 133°27.844W)

The stand is located on a western slope (18°) of an esker between Campbell Lake and Caribou creek. Ground vegetation consists of *Empetrum nigrum*, *Vaccinium vitis-idaea*, *Arctostaphylos rubra* and *Rosa acicularis*. The stand appears to be old, many dead trees were lying on the forest floor and many of the standing trees were rotten in the center. 60 trees were sampled in a 30 x 10 m transect on June 19.

Site 5 (68°20.179'N, 133°39.400'W)

The stand is located close to the town of Inuvik on a gentle southwest facing slope. The hummocky terrain is fairly wet and covered by *Salix*, *Betula gland.*, *Arct. Rubra*, *Empetrum nigrum* and *Vaccinium vitis-idaea*. The stand appears to be young, only a few tall individuals are present, but small trees dominate the stand. 60 trees were sampled on a 28 x 5 m transect on July 5.

Site 6 (68°12'19.4" N, 133°24'18.2"W)

The site is located on a 24° south slope along a gravel road to an old quarry site across from Campbell lake. Shallow soils and rock outcrops are characteristic for this stand. The ground cover consists of *Ledum groenlandicum*, *Vaccinium vitis-idaea*, *Shepardia canad.*, *Salix*, *Cladina* (?), *Arctostaphylos rubra* and *Juniperus*. White spruce dominates the stand, but Black Spruce and Paper Birch are present. 60 trees were sampled on a 24 x 10 m transect. The tree density is 2500 stems / ha.

Most of the discs show a very poor growth for the last 40 years.

Site 7 (991) (68°12.666' N, 133°23.922'W)

The site is located close to Site 6 on a gentle western slope. The ground cover is denser than in the adjacent stand and the organic matter is thicker. Generally, the site is located in a moister regime with some *Equisetum* growing on the forest floor. Other species are *Potentilla fruticosa*, *Vaccinium uliginosum*, *Ledum groenlandicum*, *Alnus*, *Salix* and *Carex* species. Thirty trees were sampled.

Site 8 (992) (68°18.682' N, 133°19.198' W)

Site 8 is located on a 5° southfacing slope. White spruce grows with mixed in black spruce in a very high density of 5607 st./ha. Thirty trees were sampled. Ground vegetation consists of

Empetrum nigrum, *Vaccinium vitis-idea*, *Arctostaphylos rubra*, *Ledum groenlandicum*, and *Shepardia Canadensis*.

Site 9 (993) (67°23.430' N, 134°12.793' W)

Site 9 is located on a steep hill formed of glacial deposits between Arctic Red and Fort MacPherson. Species such as *Dryas*, *Arctostaphylos uva-ursi* and *Juniperus* indicate a dry environment, due to the southfacing 20° slope and the well drained parent material. Thirty trees were sampled.

Expected results

White spruce sites that appear to be uneven aged stands according to a high variation of heights and diameters will show an even age distribution, that consists of dominant age classes. A “recruitment wave” is expected to occur approximately 60 years after the first trees have established and started to produce cones in quantity.

Different patterns of age structure are likely to be found depending on each sites fire history. The season of fire occurrence is expected to be the factor determining the age class distribution of the mature stand. According to a previous study (Schoplick & Wein, in prep.), fires that burn late in the growing season result in a higher seed viability of burned white spruce than fires that occur in spring. Spring fires may result in a very small generation of seedlings that will establish immediately after the fire from either surviving trees or the low number of viable seeds from the burned trees. Since more trees are likely to survive a spring fire, the surviving trees will spread their seed gradually over the following decades. A late summer fire is likely to kill the majority of trees. However, these trees killed by the fire are still capable to produce viable seeds since the embryo is almost fully developed when the fire occurs. These stands will form an age distribution that consists of a high number of trees that establish immediately after the fire from seed of the burned trees. The establishment will take place during the first two years after the fire since white spruce seed release most of their seed in the year of seed production. Some cones may remain on the tree for one more year. Since the dying trees cannot produce new cones after the fire, establishment ceases after a short period of time. Once the first generation reaches the age of cone production which is after approximately 40-50 years.

Preliminary results

Fire history

In six of the nine stands fire scars were found and the date of the last fire could be determined. Map 1 in the appendix shows the location of these sites.

(...)

Ten more sites will be sampled in the summer of 2001.

Acknowledgements

I would like to thank Donald Andre (1999 field season), Ernie Francis and Johnny Edwards (2000 field season) for their help in the field. The Gwich'in Renewable Resource board and the G.N.W.T. Dept. of Resources, Wildlife and Economic Development supported the project administratively, logistically and financially.

PROJECT 3: MONITORING THE EV 006 FIRE OF 1999: REGENERATION AND STAND DEVELOPMENT

Introduction and objectives

In the summer of 1999, a fire burned an area of 172,000 ha of mostly treed land southeast of Inuvik. The fire that started in June burned all summer until late August. In August 1999, seed were sampled from burned White Spruce in areas that burned in June, July and August. Germination tests showed that the germination rates were highest for seed from trees that burned late in the growing season when the embryo was almost fully developed at the time the fire burned these trees (Schoplick & Wein 2000 in prep.).

As the germination tests were carried out under optimum conditions in the greenhouse, this project will test the actual establishment of spruce seedlings in the burned area. It is hypothesized that the establishment of spruce seedlings will be highest on sites that burned late in the growing season.

It is further hypothesized that seedling establishment is related to the ground vegetation that establishes within the first two years after the fire. While bare ash or exposed mineral soil is expected to be too dry for germination, a moss cover that stores the moisture will support germination. Species like the liverwort *Marchantia polymorpha* which is a pioneer species in the moister parts of a freshly burned area is expected to provide a poor seedbed due to its dense coverage of thick leaves that “seal” the surface.

In order to detect variations in the ground vegetation as well as in seedling establishment on sites that burned at different dates during growing season, permanent sample plots will be established and monitored throughout the burned area.

Methods and materials

Location of sample areas:

Burned white spruce areas were identified from the air that burned in June, July and August (map 2). The sites were accessed by helicopter.

Data collection:

On each selected site, a square plot of 30 x 30 m was established, where every tree was mapped using the two sides of the plot as x and y axis of a coordinate system. It was recorded if the tree is alive or dead, standing or fallen down. Further characteristics of each tree were recorded such as the percentage of green/brown/dead branches and needles, exposed roots, scorched stem and if the tree carried cones. The general slope and aspect were also recorded. All spruce seedlings, if present, were mapped and the associated vegetation recorded. All occurring species were listed on each site.

Expected results

Seedling establishment will be higher in plots that burned later in the growing season. However, spring fire plots may show regeneration since more trees survive a spring fire when conditions are moister.

On a long term basis, sites that burned at different times of a year, are expected to develop different age structures. While the surviving trees of a spring fire may produce seedlings for a long period of time, the potential of viable seed of the burned trees is limited to the present number of cones. These seed will be released during the first two years after the fire, since White Spruce cones do not keep their cones for many years like Black Spruce does.

Description of sites

Site 1

Site 1 is located in the area where the fire started in June at 08W 0594159 ; 7497092 (UTM). A stand of white spruce with single black spruce and birch individuals on the southwest slope



Photo 2: Site 1 in the EV 006 fire of 1999 burned in June

(248°) of 10° of a small hill lies within a large area of mainly black spruce. Helicopter landing is possible at a nearby lake if the water is not too high. The white spruce stand did not burn completely. Most of the ground vegetation and duff layer was removed by the fire but some of the spruce trees were not burned to the top and still carry green needles. The vegetation one year after the fire mainly consists of species that reproduce through suckering such as *Betula papyrifera*, *Salix*, *Alnus*,

Vaccinium vitis-idea, *Ledum groenlandicum* and *Vaccinium uliginosum* as well as invading species like *Epilobium angustifolium* and *Ceratodon purpureus*. Grasses start to cover the ground to a minor extent. About 20% of the total area is currently covered with regrowth, the rest is exposed mineral soil or a layer of partly burned duff.

Site 2

Site 2 (08 W; 0587150; 7501409) is located near the Rengleng River within the area that the fire reached in mid July. The white spruce stand contains some mixed in black spruce individuals and birch. Some small unburned patches were within the plot. Even though initially the study wanted to show the regeneration from completely burned areas through the seed of burned trees, this type of white spruce stand appeared representative. A flight over the 172,000 ha of burned land showed, that most white spruce stands did not burn completely but always have some remaining trees that survived the fire or at least still have green needles one year after the fire. The stand is located on a slight southeastern slope (168°) of 1° and is surrounded by black spruce swamps except of white spruce that growth along the creek. The ground fire intensity was rather low as the higher remaining ground cover and only few exposed spruce roots show. However, only a small percentage of trees survived the fire. Cones were found on about half of the trees, including dead and living individuals.

Site 3

This site (67°42.933'N, 133°35.064'W) is located in the eastern part of the burned area where the fire went through in mid August. The burned white spruce stand is located on a 18° southwestern slope that shows evidence for an intense ground fire since mineral soil is exposed in most of the area and some of the dead tree's roots are exposed above the surface. However, some trees survived the fire. A high number of seedlings that germinated during this summer (2000) was found and mapped.

Preliminary results

In the two areas that burned in June and July no seedling was found in the plots of 30 x 30 m. Some trees were still alive but most of them had more than 50 % dead branches. Even though the stems were not girdled, some trees started to change the color of their needles which started to turn yellow, due to damaged, burned or exposed roots. These trees are expected to die within the next year. Some of the trees that apparently survived the fire fell over after the fire, since they still had green needles. Some white spruce trees that were damaged but not killed by the fire had fresh cones in the crown. Since a seed pool seems to be still present, the hypothesis will be altered. The establishment of new spruce seedlings is not limited to the dead trees and will be present for the time period until all trees are dead. On the site that burned in August when the seeds were already further developed, a relatively high number of seedlings (67 seedlings in the 900 m² plot = 744 seedl./ha) were found. This corresponds to earlier findings from the seed study where germination rates were highest for the trees that burned in July. Most seedlings were found in depressed microsites that appear to be moister than the upper exposed mineral soil. The seedbed was covered by moss or liverwort for a number of species which seem to hold the moisture better than bare soil.

Further visits in the following years will show how the structure of the burnt stand will develop and how regrowth will invade in relation to the number of dead, surviving and cone bearing trees.

Justification for study

Since the location of the fire fronts were well documented by fire suppression personnel during the season, it is known when stands of White Spruce burned. Unlike many older fires where this critical information is mostly missing, the prerequisites for a long term monitoring project are advantageous. Monitoring the burned area from year one after the fire also enables us to give a detailed description of the starting conditions, such as the number and distribution of surviving trees, number of cones left on surviving trees etc. The knowledge of the germination rates of the burned trees in the sample area will also help to make predictions for further establishment as well as to develop a regeneration model.

Avoiding common monitoring problems:

When conducting a long term study, most likely the people who collect the data will change over time. Most importantly, all sites must be clearly marked using rebar and spray paint. A GPS reading was taken from the helicopter landing point as well as from the plot itself. A compass bearing and distance was also recorded from a fixed point.

To avoid a loss of data over time, we have to make sure that all data are entered in a database immediately after each revisit. Data should also be analyzed after each year's visit and summarized while field work is still fresh in your mind. Even if this study will not be continued for a long time period, observations over the next two years will help to understand establishment patterns after fire and the observation of the sites regarding surviving trees and trees that die within the first years after the fire due to exposed roots, stem girdling or dryness, will release important information that will explain age structures and establishment sequences of the mature stands.

FURTHER RESEARCH (Summer 2001)

In the 2001 field season, more plots will be established for the fire regeneration and monitoring study within the 1999 fire to get a statistically sound data base. The permanent sample plots will be revisited but no new PSP will be established. Locations for smaller plots for seedling establishment will be chosen randomly and will be distributed throughout the burnt area, in each of the areas that burned in June, July and August. This information will complete the picture of white spruce upland regeneration and can be used for modeling, together with the findings of the two other, already completed studies (Seed viability and Age structure).

Acknowledgements

I would like to thank Ernie Francis for his valuable assistance in the field. The Gwich'in Renewable Resource Board supported the project financially and administratively. Helicopter transportation was provided by the Polar Continental Shelf project. The G.N.W.T. Department of Resources, Wildlife and Economic Development supported the project logistically and provided field assistance.

WHITE SPRUCE PRODUCTIVITY AND REGENERATION IN THE MACKENZIE DELTA REGION

Summary report September 2000, Part II, Jessika Schoplick

PROJECT 1: PRODUCTIVITY AND GROWTH RATES: DELTA WHITE SPRUCE VS. UPLAND WHITE SPRUCE

Introduction

In the Mackenzie Delta Region, forests have always been utilized for firewood, building material and medicine. Periods of extensive cutting started in the beginning of the century, when fuel was needed for steamships. Later, big logs were needed for pilings when the town of Inuvik was built in the 1950s. Today most of the wood that is harvested is used for firewood and building material. Today as well as in the earlier periods of harvesting, cutting takes place mainly in the Delta, along channels that are easily accessible by boat in summer and snowmobile or dogsled in winter. While some areas in the center of the delta are still almost untouched, forested areas close to the communities of Inuvik, Aklavik and Fort MacPherson are heavily reduced in their stand densities. Observations throughout the delta show that even stands that were harvested in the beginning of the century did not grow back to the present day. This study focuses on the productivity of white spruce in the Mackenzie Delta as well as in the adjacent uplands to answer the question how long it takes the trees to grow under these extreme conditions close to the tree line.

Ecological background: Two ecosystems – Delta and Uplands

Even though White Spruce is found both in the Delta and on the uplands, the growth conditions vary greatly in those regions. In the uplands, shallow active layers, poor drainage and thick organic duff layers provide poor growth conditions and restrict the occurrence of white spruce into favorable sites with better drainage, deeper active layer and shallower organic layer. These sites are found mainly on south and west facing slopes where the sun can heat up the soil and drainage is better than in the large boggy areas where water is held by the permafrost. However, three different white spruce types could be classified in the upland areas:

1.1 Rocky outcrop sites (Uplands)

These white spruce sites are characterized by a shallow soil that covers rock outcrops such as in the Campbell lake area. Here, the parent material consists mainly of limestone which provides a nutrient rich environment. White spruce usually grows in low densities on a soil that is too dry to support a thick organic matter built up. The ground vegetation is rather sparse and includes species like *Juniperus* and *Arctostaphylos uva-ursi* which indicate a dry environment.



Photo 3: White spruce site on rock outcrops, near Campbell Lake

1.2 Glacial deposits (Uplands)

South of the town of Inuvik as well as in the area between Tsiigehtchic and Fort MacPherson, small pointy hills rise over the vast flats and swamps that are mainly covered with stunted black spruce. The hills themselves are covered with trees that are much taller than the surrounding black spruce trees. These distinct landforms are evidence of the last glaciation when large ice sheets moved over the area. Gravel was deposited both from glaciers and later from meltwaters after the large ice sheets retreated. Sites were created that provide different growing conditions because of their well draining parent material as well as the relative steep slopes.

1.3 Lowland white spruce (Uplands)

When driving along the Dempster highway, the vegetation appears to be very uniform with small trees and large areas of shrubland. Even though these trees are small and don't look like Christmas trees at all (which is the characteristic that is often used to distinguish white spruce from black spruce), some of these poor growing trees are white spruce. A close look at individual trees shows the smooth surface of the new shoots whereas black spruce twigs are covered by a reddish "fuzzy" hair. The longer and bigger cones of white spruce can also be used as an identification help. While the smaller, eggshaped black spruce cones are often clustered in the upper crown with older, partly opened cones all along the stem, white spruce cones are usually

evenly distributed on the upper branches and usually these cones remain on the tree for only one year.

These white spruce sites that are often mistaken for black spruce grow on level ground or very slight slopes on a poorly drained ground that is often hummocky. Usually, black spruce is mixed within these stands. The ground vegetation consists of *Ledum groenlandicum*, *Vaccinium uliginosum*, *Salix* spp., *Alnus*, *Betula glandulosa* and often thick layers of *Sphagnum* mosses.

2. Delta white spruce sites

Most of the forested areas within the Mackenzie Delta are covered by white spruce. Only areas that have not been flooded for a long period, often on larger areas with a growing distance between two lakes or channels, are covered by black spruce. White spruce trees in the Delta are often much taller than trees in the upland areas which is the reason for more intensive cutting, especially when large logs are needed e.g. for pilings. Due to periodical flooding and sedimentation, the forest floor is not covered by thick organic layers but often covered with mineral soil. Air circulation and drainage on these Delta white Spruce sites is more favorable than on many upland sites. Due to these special soil conditions as well as a relatively warm mesoclimate, it was suggested that these delta sites are the most productive sites at this latitude.



Photo 4: White spruce covers most of the Mackenziedelta land surface.

Objectives

This study focuses on the productivity of the sites described above. Identifying the most productive sites as well as comparing annual growth rates will help for making decisions on where timber should be cut or rather spared because of extremely slow growth rates.

The following hypotheses are going to be tested:

- Even though many favorable site characteristics suggest high growth rates in the Delta, growth rates are higher on small exceptional sites on the uplands.
- The lack of fire in the Delta is the reason for slow growth.
- Trees in the Delta are taller than in the uplands. This is not because they grow faster but because they are much older due to the lack of fire.
- Trees in the Delta are much older than we think they are. Counting tree rings at ground level will not result in an exact age determination because stems are buried by sediment and grow adventitious roots along this buried stems.

Methods

A total of 65 tree discs was sampled from 30 sites that cover the area between Inuvik, Aklavik Fort MacPherson as well as from different upland site types along the Dempster Highway. Additional tree discs and cores sampled for the regeneration study will also be included into the analysis. The height and diameter from each tree was measured. The age will be determined by counting the tree rings. All tree discs have to be sanded down with sandpaper as fine as 400 grit since tree rings are so close together that even the finest scratches from sandpaper would make an exact ring count impossible. Wood volumes and growth rates will be calculated from these measurement as well as from the annual ring widths. The tree discs will be analyzed using the program DENDROSCAN. To even out pressure wood, ring widths from at least four cross sections of each disc will be measured to obtain an average for annual growth rates for each tree, each site and each site type.

To find out, how deep the delta trees are buried and how many years we might miss when counting the tree discs, 14 trees were washed out from cutbanks along the east channel using a wajax 26 fire pump. The stump was then taken from the ground level down to the first roots. Rings will be counted from discs that are cut every inch to find the origin of the stem and its true age.

Preliminary results

A first ring count using a hand lens after sanding the discs with a 120 grit sandpaper showed some preliminary trends: The large trees (up to 20 m in height and 40 cm diameter in 1.30m height) in the Delta are up to 500 years old. Considering the sedimentation that buried the stem, these trees might even be one hundred years older! Some even larger tree discs from the uplands were only 140 years old. The analysis will show the final results and will classify the most productive site types within the study area.

Field work for this project will be continued and finished in the summer of 2001 after preliminary data analysis will determine the final sample size.

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PROJECT 2: TREE RELEASE AFTER SELECTIVE CUTTING

Introduction and objectives

After partial cutting as it is practiced in the Mackenzie Delta, gap dynamics may play a major role in the growth of the remaining trees. As competing trees are removed, the neighbor trees may receive more sunlight as well as a higher intake of nutrients. While there are various studies that describe the phenomenon in the southern forests, the impact of partial cutting on spruce in the northern alluvial environment is not described yet. This study will focus on the growth of neighbor trees following selective cutting in the Mackenzie Delta. We expect that the growth rates will not increase after a tree is removed since light and nutrient supply are not expected to be critical factors for spruce growth in the Delta.



Photo 5: A disc is cut to determine age and growth rates of the tree neighboring a stump.

Methods and materials

Study sites were chosen throughout the Delta. Willy Simon, a local logger from Inuvik guided me to sites where he logged in the 1960s and 1970s. The knowledge of the date of cutting will help to identify possible increasing growth rates after that year to the present. These 8 sites are located along the East channel between Inuvik and Jackfish Creek and along the Kalinek channel. More logged sites were identified by Rob Wishard, who collected information about historic and recent cutting methods, dates and locations in the summer of 1999 and 2000. An additional 5 sites were chosen along the channels between Inuvik and Aklavik. A date for those sites is not available. Sites were identified by walking into stands along the cutbanks where evidence of cutting was visible or “suspected”, such as old abandoned camp sites, old trails or girdled trees along the banks that indicate recent and future logging. On each site, one stump was chosen randomly and a tree disc from the nearest neighbor was sampled. A control tree that was

located outside of the influence of cutting but within the same stand was also sampled. For each of the 20 sites, one pair of trees was sampled.

Using the computer program DENDROSCAN, the rings of at least four cross sections will be measured from each tree. The chronologies of each pair of trees will be compared to find out if the growth increases after removing a neighbor tree.

Field work for this project is completed and analysis will be finished in the winter 2000/2001.

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PROJECT 3: REGENERATION AFTER SELECTIVE CUTTING IN THE MACKENZIE DELTA

Introduction

White spruce stands in the Mackenzie Delta are affected by flooding but gap dynamics may play a major role in regeneration dynamics on older levees that are elevated above the regular flood level. At the northern limit of trees there are severe growing conditions, such as low soil temperatures, a poor nutrient regime, a short growing season as well as heavy browsing by hares. Seed availability may be poor so that regeneration is therefore highly susceptible to minor changes in environmental conditions.

Selective cutting was practiced for decades in the Mackenzie Delta where wood was used for community fuel and shelter. Larger harvests were taken for pilings and steam ships on the major rivers. The harvests created gaps in the old growth spruce forests of the higher levees and within these gaps, microclimatic and nutrient conditions change as soon as the canopy is opened.

Objectives

The general hypothesis is that White Spruce regeneration will be slow after partial cutting. More specifically, it was predicted that the removal of trees may enhance the recruitment of seedlings depending on the size of the opening but establishment and survival of seedlings will be limited by factors such as the depth of organic matter, shrub competition and the browsing of hares.

Methods

In a pilot study during the summer of 2000, regeneration was measured on two sites in the delta where the date of cutting was known.

For a radius of 5m around the stump (Figure 1), seedlings were measured for height and age. Organic matter depth at each seedling's microsite was measured, damage by hares recorded and

the canopy closure of competing shrubs was estimated in a 50 cm diameter circle around each seedling.

Findings and observations of the pilot study and altered hypotheses

The pilot study as well as observations on other logged sites showed that young regeneration is present throughout these stands but enhanced regeneration or intermediate trees are absent. This finding raised the new hypothesis:

A lack of intermediate trees indicates that a stand replacement will not take place neither under undisturbed conditions nor after selective cutting. The age structure of mature White Spruce stands is expected to be even aged where “even aged” is defined by a stand that consists of ages with a range of two generations of spruce. These trees are likely to have established under different growing conditions during the buildup of the levees under a deciduous willow, alder and poplar canopy. Once the first spruces overtop this canopy and produce seed, they produce the second generation of spruce. As the density of spruce increases, the levee keeps building up until it raises above the annual flooding level. Once the mature spruce stand has established, the conditions for seedling establishment have changed and regeneration will cease. Old growth spruce will slowly be washed out at the cutbanks or, if further inland, will die and turn into untreed tundra-like areas. If this hypothesis will be confirmed by the study we can assume that old trees that were cut will never be replaced!



Photo 6: A former white spruce site turns into thick alder and willow brush after cutting. No regeneration is found.

Future methods (summer 2001)

To find out regeneration and establishment patterns, the age distribution of delta sites will be determined. Harvested sites that were already identified during the summer of 2000 for the release study will be used for the present study. A representative number of trees that will be randomly selected within each stand will be cored to determine the tree ages. Even though it is known that a considerable number of years might be missed because of buried stems, the age structure will represent the relative age class distribution. It will show if the mature spruce stands consists of many generations like on the uplands or if they are evenaged stands with trees that all established in a different environment such as under a willow canopy.

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Appendix 1: Scientific and common names of species mentioned in the report

Scientific name	Common name
<i>Picea glauca</i>	White spruce
<i>Picea mariana</i>	Black spruce
<i>Betula papyrifera</i>	Paper birch
<i>Betula glandulosa</i>	Dwarf birch
<i>Populus balsamifera</i>	Balsam poplar
<i>Arctostaphylos rubra</i>	Red bearberry
<i>Arctostaphylos uva-ursi</i>	Common bearberry, Kinnickinnick
<i>Empetrum nigrum</i>	Crowberry, blackberry
<i>Vaccinium vitis-idaea</i>	Cranberry
<i>Vaccinium uliginosum</i>	Blueberry
<i>Ledum groenlandicum</i>	Labrador tea
<i>Shepardia canadensis</i>	Buffaloberry
<i>Juniperus communis</i>	Juniper
<i>Lupinus arcticus</i>	Arctic lupine
<i>Salix</i> spp.	Willow
<i>Alnus</i> spp.	Alder
<i>Linnea borealis</i>	Twinflower
<i>Equisetum</i> spp.	Horsetail
<i>Polytrichum juniperinum</i>	Juniper hair-cap
<i>Ceratodon purpureus</i>	Fire moss
<i>Marchantia polymorpha</i>	Green-tongue liverwort