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How old are white spruce trees in the Mackenzie Delta really?

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Introduction

Soils in the Mackenzie Delta are characterised by fluvial deposits along the channels of the Mackenzie River. Alluvial deposits are very fine particles and produce fine textured soils. In contrast to upland sites, these fluvial soils can support a productive forest cover of white spruce (*Picea glauca* (Moench) Voss) and balsam poplar (*Populus balsamifera* L.). This is largely due to generally warmer soil temperatures during the growing season, which results in deeper active layers. Forests of the delta are mostly dominated by riverine disturbances, such as flooding, erosion, and fluvial deposits. In addition, these sites have longer fire return intervals than upland sites, which allows trees to become very old. In the southern part of the delta, forests can produce impressive trees >40 cm diameter at breast height (1.3m). In some instances coring or cutting these trees (30 cm above ground) revealed that the trees were only about 100 to 200 years old (pers. observation, Mackenzie Delta Forest Inventory 1997). Therefore the productivity and growth of these trees should be comparable with sites in the more southern regions of the boreal forest.

Since white spruce in the Mackenzie Delta establish under the flooding regime of the Mackenzie River, stems of seedlings and saplings get partially buried by silt deposits after each flooding event. Gill (1975) found that silt deposits are larger close to the stems of existing trees due to the obstruction of flow and the formation of eddies. The increased deposits will not only lead to a burial of the stem but also to lower soil temperatures and soil oxygen concentrations surrounding the tree. Decreased soil temperature and oxygen level lead to less root growth and reduced root activity resulting in decreased water and nutrient uptake (Grossnickle 1987). To counteract the negative effects of silt deposits, white spruce is able to produce adventitious roots further up the buried stem, creating multi-layered root systems (Jeffrey 1959). The ability to grow roots, helps to avoid the less optimal condition in the deeper portions of the soil by replacing the dying or only partially functioning elements of the roots system in the deeper soil layers (Strong and La Roi 1983, Gill 1975). Therefore the buried stem of these trees can easily be mistaken as a tap root; however, tap rooted white spruce has only been reported for sandy soils in northern Ontario (Jeffrey 1959; Wagg 1967).

In the case of a stem buried by fluvial deposits, the evidence of the true age of a tree is also buried with the stem under ground; therefore, age measurements taken above-ground or at ground level are potentially incorrect and could let us believe that the trees are significantly younger than they really are (DesRochers and Gagnon 1997). It is thought that even-aged stands on fluvial deposit landtypes are generally the result of a catastrophic event such as fire (Jeffrey 1961). Many of the white spruce stands in the Mackenzie Delta appear to be even-aged due to similar heights and diameters; however, especially stem diameter is not a good indicator of tree age (Smith et al. 1997).

The objective of this study was to determine the true age of buried white spruce trees excavated near the arctic tree by Inuvik and to determine radial growth rates over the last two centuries.

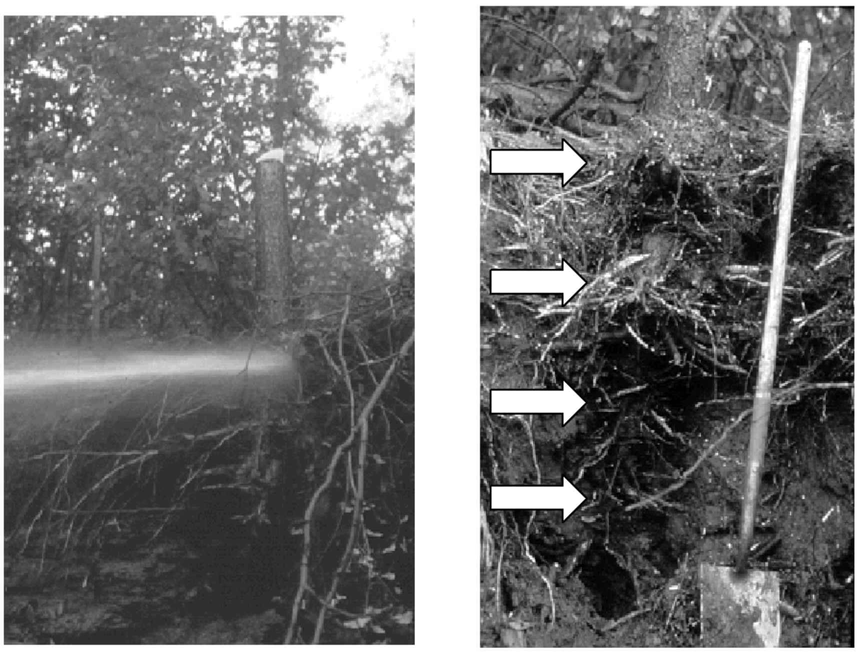

Figure 1a and b: a) Water excavation of trees and **b)** the stump after excavation showing several layers of major adventitious roots (arrows)

Methods

In the summer of 1999, 5 white spruce trees were selected along a cutbank on the east channel about 2 km north of the town site of Inuvik. Trees were excavated using a portable high-pressure WAJAX fire pump (Figure 1a). Stem discs were also taken at breast height (BH) and at ground level. The stumps and discs were transported to Edmonton for further examination. Three of the excavated tree stems were up to one meter buried in the ground, while the other two were buried to about 0.5m (Figure 1b).

The stumps were cut into 2.5 cm thick discs and sanded up to 400 grit (Figure 2 and 3). Rings were counted under a stereo dissecting scope. Using a sharp razor blade and chalk for increased contrast of the vascular cells, the tight tree rings were highlighted and counted (Figure 3 and 4). If possible, the root collar was determined by the transition from the pith to a central vascular cylinder (Esau 1960). The radial sections were then cross-dated using the skeleton plot method

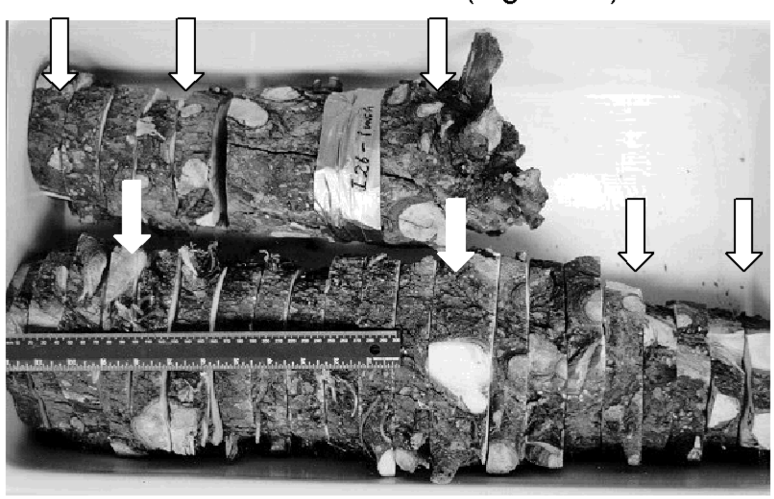

Figure 2: Tree #3 total length 79cm. Arrows indicate the establishment (layers) of major adventitious roots.

(Schweingruber 1989). Relative ring width, compression wood, false rings and other specific characteristics were used in the crossdating.

Ring width measurements were also taken on discs cut at ground level to describe the radial growth rates during that period of growth.

Figure 3: Discs of tree #3

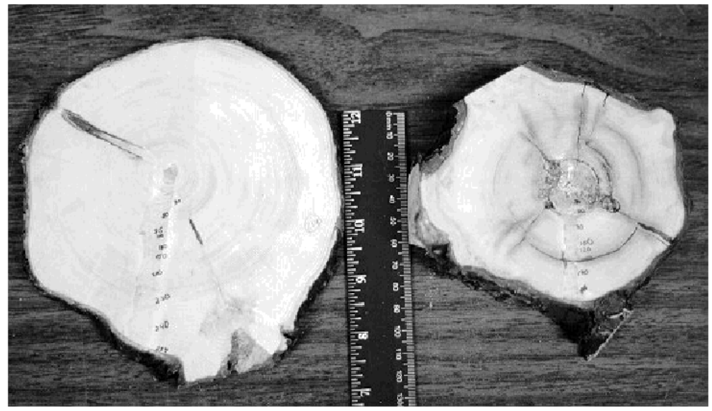

Figure 4: Discs of tree #3 from base and last measurable disc of buried stem at 64 cm.

Results

The 5 selected trees had an average age at breast height (BH) of 213 years. The ages ranged from 176 to 245 years (Table 1). The age at current ground level was between 209 and 317 years, which resulted in an average difference of 44 years between BH age and ground level age. All of the tree stumps had a rotten or missing central part of the stem therefore the transition from pith to central vascular cylinder could not be determined. As a result the precise total age of the tree could not be determined. The portions, which could be crossdated, added an average of 36 years to the age of the tree at ground level (Table 1).

Table 1: Dendrochronological analyses of 5 white spruce trees collected near Inuvik in 1999.

Tree	Age at BH (1.3m) (years)	Age at base (years)	Cross-dated Age (years)	Remaining stump length (cm)	Conservative estimate of total age (years)
1	176	209	236	65	261
2	224	262	300	6	303
3	224	254	278	15	286
4	198	242	258	20	268
5	245	317	391	6	400
AVG	213	257	293		304

There were, however, remaining lower portions of the stems, which could not be crossdated (Table 1). Conservative estimates of the age of the remaining portions were made and added to the total age of the tree. The age was estimated by assuming an average height growth of 3 cm. The average height growth was derived from the age difference between the breast height age (1.3m) and the ground level age. Therefore the estimated total age of these three trees was determined to be between 261 and 400 years (Table 1).

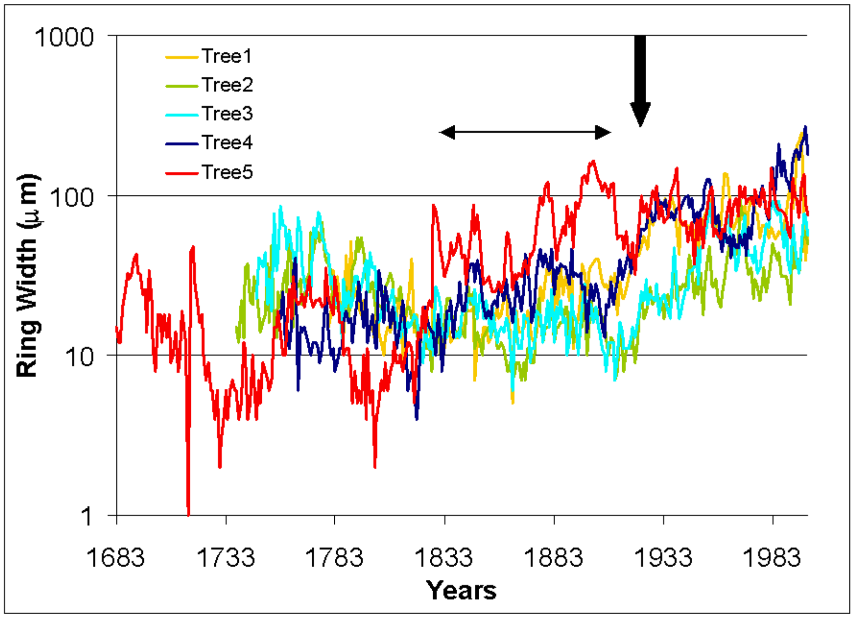

Figure 5: Tree ring width at ground level of five trees collected near Inuvik in 1999.

On average there were 47 years buried with the stem in the fluvial deposits. However, the number of years ranged from a minimum of 26 years to a maximum of 83 years. It is very likely that these numbers are still an underestimation of the true age, since all trees were missing stem sections below the excavated stem (see blunt end of stem in Figure 2).

Measuring the ring width at ground level of all five trees revealed that ring width has been increasing by ten fold from 10μm to 100μm (notice logarithmic scale of y-axis) since the turn of the century (vertical arrow) (Figure 5). Only tree number 5 showed an earlier increase in ring width (horizontal arrow). This increase is largely due to the presence of reaction wood. Reaction wood is the preferential allocation of wood towards parts of the stem or branches to compensate for stresses such as leaning or bending. In the case of conifers, compression wood is put down on that side the tree is leaning towards. This results in the production of larger rings in that particular region to support the leaning trunk. Due to difficulties (rot) on the opposite side of the stem, the tree ring widths in the compression wood had to be used for the measurements, artificially increasing the ring width.

Discussion

A significant amount of growth of the white spruce tree in the Mackenzie Delta is concealed due to past and present flooding events depositing substrate around the stems of the trees. This study determined that an average of 47 years of growth was hidden under ground. The length of the buried stem did not appear to be a good indicator of the number of years, which need to be added to the tree age. For instance, tree number 5 had about 50cm of its stem buried, this length represented about 83 years of growth. This stays in contrast to tree number 3, where 76 cm of the stem was buried. This represented 32 years of growth. Generally these results have to be carefully interpreted. This study looked only at a limited number of stems and can be seen as an exploratory study producing more questions than answers. The determination of the true age of these trees and the amount of stem buried in the fluvial deposits are likely an underestimation. Even the careful excavation of the trees from the cutbanks of the river did not allow for a full recovery of the stems. Therefore it is not known, how much of the bottom end of the stems is actually missing. To avoid these problems it would be probably better to extract trees further away from the edge of the river, since the bottom parts of the stems might be preserved in the higher permafrost table (Gill 1975).

The establishment of white spruce in this selected stand north of Inuvik, as determined by the five trees, did not to occur at the same time, resulting in an uneven-aged stand structure. This suggests that white spruce establishment in the delta probably occurs in waves, which coincide with major flooding events rather than catastrophic events such as fires (Jeffrey 1961). However this line of inquiry needs further testing. These fluvial deposits create favourable seedbeds and when coincide with good seed crops in nearby mature stands they will result in periods of spruce establishment (Jeffrey 1961; Wagg 1964). Once the seedlings have established, major flooding events, which deposits large amounts of silt will be detrimental to the growth and survival of these newly established seedlings. The establishing seedlings must have sufficient height growth to be able to out-grow subsequent silt deposits from the succeeding flooding events.

Tree discs at ground level of all five trees showed a substantial increase in ring width of about 10 fold from 10μm to 100μm since the turn of the last century. It can, however, only be speculated whether the response is due to climatic or flooding factors or both. However, data like these could give the opportunity to correlate radial growth with existing climatic and flooding data over the last fifty or so years which might be available for the region. Additionally, the small size of rings during earlier growth raises another important issue. During various periods, the five trees in this study showed remarkable narrow growth rings therefore accurate age determination in the field seems impossible. The chronological data clearly show that in the case of these five collected trees, up to 200 years are represented in rings, which are between 10 and 50μm wide. This could lead to gross mistakes in determining ages at either breast height or ground level.

As indicated earlier, this study presents the opportunity to use the buried stems as an indicator for past and present climate or flooding regimes. If it was possible to find deeply buried stems of earlier white spruce stands preserved in the permafrost, ring width data could be crossdated with current tree data and extended into the past over longer time periods. These growth data could then be correlated to past and present climate and/or flooding regimes.

The pattern of adventitious root development is an interesting area in the autecology of flood plain white spruce (Jeffrey 1959; Wagg 1964) which has not been addressed in detail. The pattern of rooting is most likely the response to soil temperature and soil oxygen minima. As the thickness of the fluvial deposit layer increases new adventitious roots are produced to keep the tree alive. By crossdating the initiation of the roots in each layer with the main stem, fluvial deposit patterns could be determined and projected into the future. Research in this area could lead to a better understanding of white spruce autecology in response to flooding and soil temperature regimes. This information is pertinent for the prediction of establishment and growth of white spruce in flood plains and will assist in the future regeneration and maintenance of northern riparian forest stands.

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