FACTORS LIMITING THE ADVANCE OF SPRUCE AT GREAT WHALE RIVER, QUEBEC*

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The following notes are derived from observations made at Great Whale River, on the east coast of Hudson Bay, in 1949. Publication was withheld at that time because of an expectation, repeatedly unfulfilled, of making complementary observations at inland sites. The current widespread interest in northern ecology suggests that these admittedly fragmentary observations may be of some value, particularly as they were made before human influences at this site became very serious.

Although black spruce (*Picea mariana*) is predominant a few miles inland, near the coast abundant sand favors white spruce (*P. glauca*), which accordingly supplies most of the seed and is dominant even in the bogs. Larch (*Larix laricina*) is present but not very abundant. These remarks apply chiefly to white spruce.

Some earlier observers were inclined to regard some single factor as all-important in preventing spread of trees into the barrens. Today most students will agree that we must think in terms of a complex of factors. When total attrition due to these factors equals total growth the trees cannot advance. The situation is complicated by the frequent interaction of factors. The effects are accordingly not purely additive.

Great Whale River is on a lee shore. Consequently some factors are more important than they would be inland or on a weather shore. The site is actually subarctic, but, as in many coastal situations, a narrow coastal strip is essentially barren. Large deposits of sand were laid down to depths of up to 200 ft. during emergence of the land at the end of the Pleistocene, and smaller deposits occur for several miles up and down the coast.

(1) Mean summer temperature is, of course, important, because it influences the total possible growth. The prevailing wind off the ice-laden water of Hudson Bay causes a steep upward temperature gradient as one moves inland. As the moist air moves in from the sea it need only be lifted a few feet to form persistent fog or low stratus. Looking under such a deck one may see continuous sunshine a few miles inland and at sea.

(2) Length of growing season. The cold winds off Hudson Bay delay the spring warming and shorten the effective season. Although the effect is slightly reversed in late summer, the water does not warm up enough to be of much value, and by early September all growth has stopped, whether from shortened day length or other factors is not clear.

(3) Lack of soil was emphasized by J. W. Marr (Ecological Monographs 18: 117-144, 1948), who worked mainly at Richmond Gulf, but also at Great Whale River. It is true that many of the glaciated granite hills and ridges have large expanses of bare rock. Yet the smallest pockets of soil often

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support small spruce; and on the raised delta there is unlimited soil that is often devoid of trees.

(4) Low soil fertility is probably of considerable importance, especially on the delta sand. While it does not prevent growth it must sometimes reduce its rate.

(5) Lack of water is probably of minor importance on this coast, but in dry seasons it certainly limits the growth of various plants on the sand deposits. Although large trees can presumably reach the water table at all times, seedlings are probably checked and injured by prolonged dry periods.

(6) Snow abrasion is very important on this coast, owing to the sweep of wind off the sea ice. Its importance is demonstrated by the absence of spruce on areas of level ground with ample soil, and their presence in the smallest pockets of soil on the lee slopes of granite ridges that cause the wind to eddy. The abrasive effect of the hard spicules of winter snow is shown by the well-known broomstick effect. Branches remain alive on the lowest foot or two of the trunk, which is snow-covered from early winter; but the blowing snow generally kills the lateral buds for the next three feet or so of trunk. Only if the leader happens to survive this treatment can branches be produced above this level. Anything that causes eddying reduces the velocity of the abrading snow crystals. If the terrain is unimpeded only the mutual protection of a group of trees can curb abrasion. When only few seedlings can become established, this problem is partly solved in white spruce, and rarely in larch, by the formation of clonal colonies. The lowest branches of a tree, protected by the snow, spread laterally for several feet; each may then send up one or more leaders. Thus we have in effect a small grove whose members afford each other substantial protection. Several of these "groves" occurred near Great Whale River, and in some of them secondary trees were well rooted and becoming independent.

(7) Sand abrasion. Although there can be relatively few days in the year on which the combination of wind, and dry, exposed sand permits drifting, sand abrasion is of striking local importance. Numerous small and a few large blowouts occur on the delta sand, the biggest being about one quarter mile in length. Partly because it operates in summer, the effect of sand abrasion on white spruce differs markedly in appearance from that of snow abrasion. It is too severe to allow the establishment of seedlings. If a blowout forms and moves toward an established spruce grove, all the trees on the side nearest the advancing sand are killed completely before there is any visible accumulation of sand at their bases.

(8) Limited seed dispersal into tundra. On this coast spruce seed must be transported against the prevailing west to northwest wind. The red squirrel and White-Winged Crossbill are unlikely to take seeds beyond the trees except where gulleys filled with willow and alder provide some cover. This factor would be of small importance but for its interaction with snow abrasion. Because snow abrasion increases with decreased density of spruce, any factor that reduces the number of seedlings also endangers the survival of those that do occur.

(9) Human activity. Old tent rings and flint chippings suggest that the river mouth was a native gathering place long before the establishment of the first trading post. The main attraction was presumably the seasonal concentration of white whales in the river mouth, which apparently teemed with fish until some forty years ago. The natives presumably cut some spruce, and their trails may have started some blowouts where they cut across old beach ridges on the raised delta.

(10) Difficulty in establishing seedlings in *Cladonia* ground cover. Although such white spruce as become established on a closed cover of *Cladonia* and other fruiticose lichens grow well, very few seedlings are seen. Consequently we find large expanses of very open spruce-*Cladonia* parkland. This is evidently not a purely climatic limitation, for the same association occurs far inland under more benign conditions. It is not clear whether the failure of seedlings to develop is due to a chemical inhibitor supplied by the lichens, or whether the lichen cover simply supplies a physical barrier through which the spruce seeds cannot easily fall. Various herbs and shrubs with quite small seeds also seem to have difficulty in becoming established in the lichen cover, which suggests a chemical effect. It would be interesting to know whether this extremely simple association was equally abundant in the Ungava Peninsula before decline of the caribou population.

(11) Insect pests and diseases. No insects seem to be an appreciable hazard to spruce at Great Whale River, although *Adelges* galls kill some twig tips. However, several rust fungi of the genus *Chrysomyxa* play a significant part. Three species are abundant enough to be serious at Great Whale River and two others may occur to a limited extent on this coast and elsewhere along treeline. Other species attack spruce further south. *Chrysomyxa ledicola*, whose alternate hosts are *Ledum groenlandicum* and *L. palustre* var. *decumbens*, is common everywhere at and near treeline and is a serious disease of spruce at Great Whale River. Seedlings must often grow up through a mat of *Ledum* and aecia may form on 75% of the new needles. As infected needles are shed late in the first summer instead of a year later, a heavy infection greatly reduces the vigor of the seedlings. *C. empetri*, with *Empetrum hermaphroditum* for its alternate host, occupies essentially the same ecological niche and is only slightly less serious. *C. woronini*, also harbored by the two species of *Ledum*, infects and kills the new growth of spruce branches. It is potentially very destructive, but usually only a few shoots are killed on any one tree. *C. ledi* var. *ledi* and *C. ledi* var. *rhododendri*, with *Ledum palustre* and *Rhododendron lapponicum* for alternate hosts, may also cause minor defoliation of spruce. All but *C. woronini* can persist and spread on their alternate hosts, and are found on them up to 300 miles beyond treeline.

Because alternate host plants harbouring spruce rusts commonly carpet the ground, rust spores are ready to attack seedlings that emerge anywhere beyond the closed forest. These rusts seldom if ever kill seedlings, but they constitute a serious drain on the vitality of the young plants and may so reduce their vigor that they are killed by snow abrasion or crowded out by other plants.

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