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miles wide on the north shore of Lake Minnetonka were to the west of Minneapolis.

Men were assigned to definite sections of these areas and made regular collections of larvae and, to a less extent, of adult mosquitoes. Chief reliance for the latter was placed on three electrically controlled mosquito traps.

In all 337,960 adult mosquitoes were taken in the traps and identified during the summer of 1938. In addition, there were 4,166 in the hand catch. In the trap catch there were 27 species represented. Of these 98.28 per cent were *Aedes vexans,* a marsh-breeding species which is able to migrate for fifteen miles, or more, from its birth place.

A surprising fact was that there was a total of only 82 specimens or one out of 4,127 of the supposedly common *Culex pipiens.* The significance of this is apparent when one considers that the control measures most commonly urged are those directed towards this species and the few others with similar breeding habits. It must not be assumed that these data would be valid for different climatic conditions or, necessarily, for different parts of the state.

It is not necessary to present further details of this survey in order to emphasize the point that surveys in different parts of the state would be not only of great biologic interest, but would be indispensable from the viewpoint of practical control.

Whenever control measures are undertaken, it should be with accurate knowledge of the nature of the problem and with due consideration of the other problems involved, such as those of conservation of wildlife and of maintenance of the water levels essential to agricultural as well as to aquacultural enterprises.

THE ROLE OF FOREST FIRES IN THE REPRODUCTION OF BLACK SPRUCE

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Black spruce[3] timber, with its dark foliage and slender irregular crowns, forms one of the most striking features of the northern Minnesota landscape. It is, by far, the most extensive of the remaining virgin forest types of this state, and were it not for the fact that much of it is held in public ownership, it would be depleted rapidly since spruce is the most valuable of any wood for the manufacture of paper.

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[2] Maintained in cooperation with University of Minnesota, University Farm, St. Paul, Minnesota.

[3] *Picea mariana* (Mill.) BSP.

Although the majority of the stands produce timber of sufficient size to be usable for pulpwood, there are some forests growing on bogs which are so wet that the trees never attain the size necessary for this purpose. However, even these stands are of some economic importance as a source of Christmas trees. Altogether, the black spruce forests of northern Minnesota are a valuable natural resource that deserves thorough investigation and wise administration.

For several years the Lake States Forest Experiment Station has been conducting studies in the black spruce type. The object of these investigations is to learn ways of cutting and managing the stands that will keep the forests productive. In some cases this objective will be reached by maintaining a good rate of growth on trees left after cutting the merchantable timber. In others it will be necessary to devise means of encouraging prompt natural reproduction or possibly to provide for artificial regeneration by planting. The establishment of the relationship of forest fires to natural reproduction of black spruce, as reported in this paper, is a result of these investigations.

Although typically a "swamp" species, black spruce occurs on a great variety of sites ranging from well-drained upland to very wet bogs. The bogs, of course, vary widely in productivity from the earlier stages of their development, where only scattered dwarf tamarack and spruce trees occur, to the later stages where the peat has so improved in fertility that hardwood trees and shrubs can replace spruce as the dominant vegetation. However, until the bogs reach this latter condition spruce is thoroughly at home and can reproduce for generation after generation without the aid of unnatural disturbances or artificial measures of assistance. Here it forms dense pure stands having the characteristics of a climax forest, which, for all practical purposes, it may be considered. This position as the dominant plant cover is the result of its ability (1) to tolerate wet sites and a peat soil, and (2) to reproduce and grow, although slowly, in shade.

On fertile upland soils, where practically all of the native trees grow well, black spruce is less important than in the bogs. Nevertheless, due to its ability to endure shade, it frequently becomes established under stands composed of species that require more light such as aspen, paper birch, and jack pine, although it is not so well endowed in this respect as balsam fir.

Despite the fact that black spruce grows with its "feet in the water" and can invade and succeed forests made up of less tolerant trees — thus displaying many of the characteristics of a true climax species — it has also assumed a role similar to that of jack pine, a pioneer tree, in reseeding after fires. It has been generally accepted by foresters for a good many years that numerous even-aged stands of black spruce originated on burned-over land. Recent studies have not only confirmed this observation but also have shown that a far

greater proportion of the spruce forests arose after fires than was previously supposed.

In relatively young and dense stands, proof that fires occurred immediately before the establishment of the existing forests is easily obtained. Charred stumps, bits of charcoal under the litter, the even-aged condition of the stands, historical records and the recollection of settlers are all sources of evidence upon which strong cases can be constructed. In older stands, or more open stands, the even-aged character of the overstory is often obscured by reproduction that has seeded in and filled the openings with trees of various sizes and ages. Such stands often appear to be "all-aged" like a climax forest. However, these apparently "all-aged" stands are usually found to have an even-aged overstory, indicating that the oldest members of the present forest came in after some major catastrophe — presumably fire.

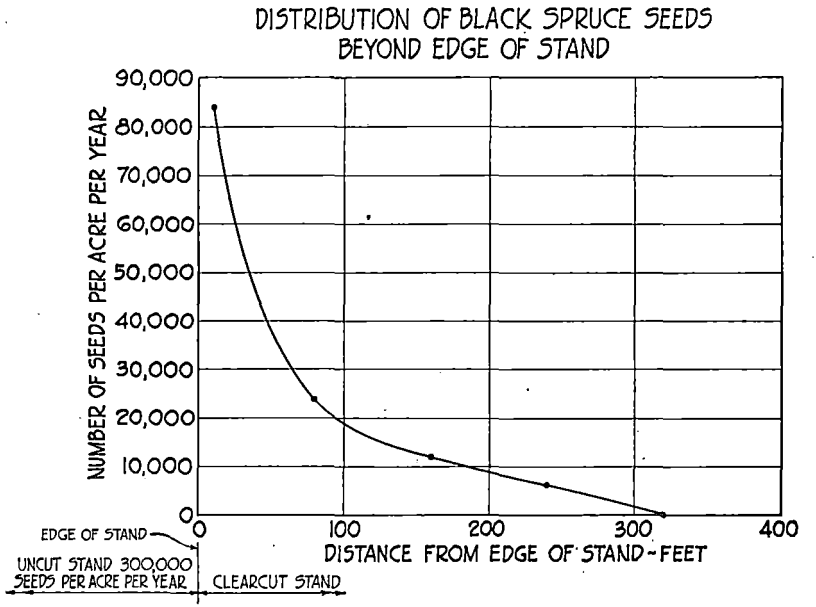
Furthermore, peat samples taken under spruce stands in Koochiching, St. Louis, Lake, and Cook counties contained charcoal, in some cases at several different levels. This proves that fires occurred in swamps long before this territory was settled by white men. During periods of drought when water levels are low, swamps can burn very fiercely and, when they do, spruce timber is killed almost entirely.

Earlier observers assumed that the dense even-aged stands which followed the fires originated from seeds blown in from swamps that for some reason or another were not burned. This was a reasonable assumption, since black spruce seeds are extremely small — one of the smallest of any North American conifer,[4] and possibly the smallest of any conifer in the world. Cleaned seeds average over four hundred thousand to the pound. Moreover, the seed bears a wing that retards the rate of fall materially, so it is likely that when wind and air currents are just right, some of them may travel long distances. Nevertheless, studies of the distribution of seeds from a black spruce stand have shown that the actual distance the great majority of the seeds travel is surprisingly short. In a test made with seed traps near Ely, Minnesota, it was found that the annual fall of seeds within a stand amounted to about 300,000 per acre; at a distance of 100 feet from the edge of the stand it was approximately 18,000; and at 200 feet only 8,000 seeds. (Figure 1). Obviously, at much greater distances the seed fall is likely to be far too small to result in the dense reproduction found in many swamps.

How, then, does spruce reseed after fires? The answer lies in the peculiar seeding habits which enable the trees to conserve seeds and protect them from fires. Black spruce bears some seed practically every year. During the eight seasons 1931 to 1938, in which the annual cone crops were observed near Ely, Minnesota, not a single

[4] Toumey, James W. and Clarence F. Korstian, 1931. Seeding and planting in the practice of forestry. Second edition. John Wiley & Sons, New York, 507 pp. illus.

complete failure occurred. Furthermore, the mature cones remain attached to the trees for many years and the ripe seeds are slowly disseminated over a period of at least 2 or 3 years, unlike most native conifers that scatter their seeds and drop the cones within a few weeks or months after ripening. This characteristic of slow seed



dissemination was brought out by a study which showed that old cones contain many viable seeds.

In September 1936 all the cones, old as well as freshly ripened, were picked from 25 trees which had previously been selected as a representative sample of the seed producing trees in the stand. These were sorted and the seeds were extracted separately from (1) the new cones, (2) cones one year old, and (3) cones more than one year old.

Reduced to a per acre basis, the new cones were found to contain 415,788 seeds, the one-year-old cones 320,713 seeds, and the older cones 428,807 seeds. The same determinations were made for the new and one-year-old cones in 1937 and again in 1938, and as Table 1 shows, the results of the first test were fully corroborated. The testing of old cones was not repeated because it was extremely tedious to separate the seeds from bits of cone scales that broke up and mixed with the seeds during the extraction process. Afterwards, germination tests were made which indicated that there was some lowering in viability of the seeds with increasing age, but a good proportion of the oldest lot was still capable of germination.

The 1936 collections gave germination values of 60, 36, and 30 per cent for the new, one-year-old, and older cones respectively. Both the new and one-year-old cones in the 1937 collections showed the same viability — 76 per cent. Data for the 1938 collections are not yet available. The 1936 and 1937 germination values are not entirely consistent, but these variations do not invalidate the conclusion that large numbers of viable seeds are stored in the cones on the trees for at least two or three years.

The cones are borne in a dense cluster near the tip of the trees

TABLE I. — AMOUNT OF SEEDS IN CONES ON LIVING BLACK SPRUCE TREES

Date of Collection	Number of Seeds per Acre		
	New Cones	Cones 1-Year Old	Cones More Than 1-Year Old
September, 1936	415,788	320,713	428,807
September, 1937	385,401	313,288	No Data
September, 1938	81,884	146,939	No Data

where they are not apt to be injured even by severe crown fires. Hence, after a forest fire, when the trees have all been killed, a large amount of seed is still available.

Fire has another effect which is favorable to the regeneration of spruce; it kills most of the vegetation and destroys much of the layer of dry litter which normally interferes with the germination and early survival of spruce seedlings.

As proof of the ability of black spruce to reseed in the manner just described, the author has observed the process in northeastern Minnesota on lands burned over in the Markham fire of 1936. Shortly after the fire it was found that by striking dead trees with an axe, great numbers of seeds could easily be shaken from the blackened clusters of cones. Two years later, in this same area, a good stocking of two-year-old spruce seedlings was found on the burned surface of the swamps.

Entirely aside from the scientific interest of this finding, it has two decidedly practical aspects: In the first place, because black spruce has been able to take advantage of fires, it has become established in nearly pure stands on sites where it would otherwise occur only in mixture with other species. Consequently, black spruce may occupy land to which other species are equally or better adapted. In management, it is important to recognize such stands for, although they may be valuable, they are likely to be difficult to reproduce and will require different methods than the swamp stands. In the second place, the chain of circumstances which enables black spruce to regenerate so well after fire may provide the clue for obtaining natural reproduction after logging.