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ABSTRACT: Quantitative and qualitative studies have been made on mature pine forests of selected areas on Minnesota Point and Wisconsin Point in the Duluth-Superior Harbor area. The forests were sampled by the point quarters method. The leading dominant in the Minnesota forest was *Pinus resinosa*, while the leading dominant in the Wisconsin forest was *Pinus strobus*. Trees up to 173 years of age were found on Minnesota Point, while the maximum age of the trees sampled on Wisconsin Point was 142 years. A total of 87 species of vascular plants were identified in the two areas.

This study was initiated during the summer of 1966 to investigate features of the vegetation of the Duluth-Superior Harbor area, and particularly on Minnesota Point and Wisconsin Point.

The pine forest on Minnesota Point represents the last basically undisturbed remnant of the natural vegetation which was formerly present on the Point. Wisconsin Point, while disturbed, has been less so than the Minnesota Point forests.

The well-protected Duluth-Superior Harbor is formed by the two points of land, and the St. Louis River flowing into the harbor had been "drowned" by the post-glacial tilting toward the south of Lake Superior (Schwartz and Thiel, 1954). Minnesota and Wisconsin Points combine to form the longest sand bar in the world in fresh water, stretching more than 9 miles.

About 3,200 years ago, the lake level (Lake Superior) dropped to 596 feet. In response to this lower level, two inner harbor points (Rices and Connors), were abandoned and a new profile of equilibrium was established in the sand of the south shore six miles to the east. From this point a spit built across the head of the lake parallel to the storm wave crestline at a rate of 15 to 20 feet per year and reached the Minnesota shore a few hundred years ago (Loy, 1963a). Natural accretion from the south shore is more than 22,000 cubic yards per year (Loy, 1963a). This is the only available evidence as to how long the two points have been exposed for plant colonization.

Pinus resinosa and *Pinus strobus* trees still living and standing on the points are for the most part scattered, and in many cases isolated, except for two main bodies of trees.

References to pine forest vegetation in the harbor area are found in the writings of Alfred Merritt (Van Brunt, 1921, p. 2), discussing red pine on Connors Point, and Laurence Oliphant (Van Brunt, 1921) of pine trees in general. Charles F. Johnson in his diary of 1886 discussed the "scrub pine" on the sand dunes of Minnesota Point. In Woodbridge and Pardee (1910), reference is made to the fact (p. 218, vol. 1) that "Minnesota Point was covered from its base with a heavy growth of pine through which ran a narrow road for a mile or two, . . ."

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Conjecture on Origins

Just when the *Pinus resinosa* and *Pinus strobus* forests became established can only be conjectured—but there are no visible remains of decaying trees (logs) on the two points. However, there are a number of standing dead trees, some of which have been aged. Both forests, small in area which could be sampled systematically by modern techniques, have been much disturbed. On Minnesota Point a road cuts through a side of the forest for most of its length, and there are at the present a number of rubble remains of dwellings. Recently fires have further disrupted the forest ecosystem. On Wisconsin Point there is also a road through much of the forest, leaving a tract with trees of greater maximum diameter than that of the Minnesota Point forest. There also has been some selective cutting of pine on Wisconsin Point.

The beach strand communities of the Great Lakes (of which these two points are examples) have received considerable attention from plant ecologists, Curtis (1959), but the most complete account was made by Cowles (1899) for the sand dunes of Lake Michigan. Beals & Cottam (1960) reported on pine forests of the sand bars of the Apostle Islands on Lake Superior. Curtis (1959) illustrated the evergreen. heathlike mat of *Hudsonia, Juniperus* and *Arctostaphylos* on the dunes of Wisconsin Point, but did not give attention to the mature pine forests. The studies of Lakela, unpublished and her paper of 1939, and Johnson (1963) represent the work in Minnesota on Lake Superior beaches. Many of Lakela's extensive collections of Minnesota Point plants are recorded in her monumental work on the Flora of Northeastern Minnesota (1965).

Nomenclature follows Fernald (1950). Dr. John W. Moore, Department of Botany, University of Minnesota, made some determinations and verified or corrected all others.

Field and Laboratory Methods

Trees and saplings were sampled by the point-centered quarters method (Cottam and Curtis, 1956). On Minne-

sota Point, only trees were sampled (15 points), as the sapling layer was too sparse to warrant sampling. On Wisconsin Point, both trees and saplings were sampled (13 points). In the laboratory, data on basal area and density were converted to values of relative dominance and relative density. A table was then computed showing the values of relative density and relative dominance for each species. From the values of relative density and relative dominance, an importance value (total for each stand, 200) was then computed. Soil samples were collected from two points in each stand at a depth of four inches. The samples from the two points were then pooled for analysis from each stand. Analysis for pH, total P, Ca, Mg, K and organic matter were made by the University of Wisconsin Extension Soil Laboratory, courtesy of Mr. Conrad C. Olsen and Mr. Raymond E. Polzin. A complete floristic survey for each of the two stands was made. Increment borings were made on each stand as a means of attempting to determine the age of the forests.

Results

Importance values for the 4 species of trees on Minnesota Point and the 5 species on Wisconsin Point are shown in Table 1. The leading dominant on Minnesota Point was *Pinus resinosa* (107.8) with *P. strobus* number 2 (86.5). The other species found on Minnesota Point are shown in Table 1. The leading dominant on Wisconsin Point was *P. strobus* (112.7). *Betula papyrifera* was number 2 dominant (41.4) and number 3 dominant was *P. resinosa* (33.9). In the sapling layer of Wisconsin Point the principal species were *P. strobus* (87.7), *Acer rubrum* (47.8), and *Thuja occidentalis* (29.5). Although no sampling was done on the saplings of Minnesota Point, there is some reproduction of *P. strobus* in the interior of the forest and more abundant reproduction of *P. resinosa* on the lakeshore side of the forest.

Results of the soil analyses are shown in Table 2 and results of the increment corings are shown in Table 3.

Concerning the floristics of the two pine areas, there were 39 species common to both areas, as shown in Table 4. There were 21 species found only in the forest on Minnesota Point, and 27 species found only in the forest on Wisconsin Point (Tables 5 and 6). In all, 87 different species were identified in the two forested areas.

TABLE 1. Importance Value of Trees and Saplings

SPECIES	Minnesota Point (Trees only)	Wisconsin Point Trees	Wisconsin Point Saplings
Pinus resinosa	107.8	33.9	16.5
Pinus strobus	86.5	112.7	87.8
Betula papyrifera	2.0	41.4	13.4
Betula cordifolia	3.7	..	..
Acer rubrum	..	10.2	47.9
Thuja occidentalis	..	1.9	29.5
Prunus pensylvanica	..	..	4.8

TABLE 2. Soil Analysis

	pH	Organic Matter	P	K	Ca	Mg
Minnesota Point	5.1	2.0%	9 ppm	20 ppm	150 ppm	50 ppm
Wisconsin Point	5.0	1.5%	9 ppm	20 ppm	100 ppm	40 ppm

TABLE 3. Increment Borings

SPECIES	Minnesota Point DBH	Minnesota Point Growth Rings	Wisconsin Point DBH	Wisconsin Point Growth Rings
Pinus resinosa	16.6	95	19.9	135
Pinus resinosa	19.6	173	20.9	131
Pinus resinosa	19.3	148	..	..
Pinus resinosa	20.1	169	..	..
Pinus strobus	21.4	91	19.7	142
Pinus strobus	..	..	22.4	122
Thuja occidentalis	..	..	3.9	68

Discussion of Differences

Although similar in gross appearance when passing through them. the natural pine forests of Minnesota Point and Wisconsin Point are somewhat different in composition. The leading dominant in the Minnesota pine forest (*P. resinosa*, 107.7), is only one-third as important in the Wisconsin pine forest (33.9). There has been some selective cutting of pine in the Wisconsin pine forest, and this would affect the result somewhat. The leading dominant in the Wisconsin pine forest (*P. strobus*, 112.7) is represented in the Minnesota pine forest at 86.5. The importance of *Betula papyrifera* is vastly different in the two forests, being much more important in the Wisconsin forest (41 versus 5.7 on Minnesota Point). Two species, *Acer rubrum* and *Thuja occidentalis*, were found in the Wisconsin forest, but not in the Minnesota forest. This can probably be explained by the fact that on Wisconsin Point, the sampling touched several low areas.

Reproduction was inadequate for sampling purposes in the Minnesota forest, so no quantitative data are available. However, in the interior of the Minnesota forest the pine reproduction is *P. strobus*, while on the lakeshore side the dominant reproduction is *P. resinosa.* On Wisconsin Point, it can be said that in general all canopy species are represented in the sapling layer, and in addition *Prunus pensylvanica* is present. *P. strobus* was more important in the sapling layer in the interior of the Wisconsin forest, just as in the Minnesota forest.

To determine the ages of trees, cores were taken from the largest individuals of each species which could be located. The ages of the larger trees of *Pinus resinosa* (up to 169 and 173 years) indicate that this species has been on Minnesota Point for at least 200 years and probably longer. The maximum age of the trees sampled on Wisconsin Point was 142 years (*Pinus strobus*).

Beals and Cottam (1960) in their studies on the Apostle Islands, found pine forests typically located on sand bars on the shores of some islands. Three such stands were studied, with *P. resinosa* as the dominant and *P. strobus* as the second dominant. *Pinus banksiana* and *Betula papyrifera* also were present in small numbers. No naturally-occurring *P. banksiana* was found in either the Minnesota or Wisconsin Point forests.

The pH of the soils on both Minnesota and Wisconsin

Points ranges from strong to moderately acid (Buckman and Brady, 1960). With the exception of calcium and organic matter, the chemical analysis of the two soils differs little.

The total of 87 species in the two areas is not large. Nearly half (39) of the species were found in both areas. The areas cannot be said to be rich floristically, and would not be presumed to be so with the poor nutrient status of stabilized sand dunes. As Olson (1958) points out, "Even after plants have overcome the instability of the dune sand, this infertile medium for plant growth must be sufficiently poor to exclude all but a few typical sand plants—." In the present study there were more than a few typical sand plants present, but the environmental conditions no doubt restrict the floristic diversity.

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TABLE 4. Plants Found in Both Minnesota Point and Wisconsin Point Sample Areas

Acer rubrum L.
Achillea millefolium L.
Amelanchier intermedia Spach
Aralia nudicaulis L.
Betula cordifolia Regal
Betula papyrifera Marsh.
Calamagrostis canadensis (Michx.) Beauv.
Clintonia borealis (Ait.) Raf.
Cornus canadensis L.
Cornus stolonifera Michx.
Diervilla lonicera Mill.
Dryopteris spinulosa (O. F. Mueller) Watt.
Epilobium angustifolium L.
Fragaria virginiana Duchesne
Galium triflorum Michx.
Juniperus communis L. var. *depressa* Pursh
Linaria vulgaris Hill
Linnaea borealis L. var. *americana* (Forbes) Rehder
Lonicera dioica L. var. *glaucescens* (Rydb.) Butters
Maianthemum canadense Desf.
Maianthemum canadense Desf. var. *canadense*
Melampyrum lineare Desr.
Pinus resinosa Ait.
Pinus strobus L.
Poa interior Rydb.
Poa palustris L.
Prenanthes alba L.
Prunus pensylvanica L. f.
Prunus virginiana L.
Pyrola asarifolia Michx.
Ribes glandulosum Grauer
Rosa blanda Ait.
Rubus idaeus L. var. *strigosus* (Michx.) *Maxim.*
Sambucus pubens Michx.
Taraxacum officinale Weber
Sorbus decora (Sarg.) Schneid.
Trientalis borealis Raf.
Vaccinium angustifolium Ait.
Vaccinium myrtilloides Michx.

(Total Species, 39)

TABLE 5. Plants Found Only in Minnesota Point Sample Areas

Agropyron repens (L.) Beauv.
Amelanchier humilis Wieg.
Amelanchier interior Nielsen
Amelanchier sanguinea (Pursh) DC.
Arabis divaricarpa A. Nelson
Aralia hispida Vent.
Artemisia caudata Michx.
Campanula rotundifolia L.
Poa pratensis L.
Potentilla tridentata Ait.
Rosa arkansana Porter var. *suffulta* (Greene) Cockerell
Schizachne purpurescens (Torr.) Swallen
Silene cserie Baumg.
Smilacina stellata (L) Desf.
Solidago gigantea Ait. var. *leiophylla* Fern.
Syringa vulgaris L.
Trientalis borealis Raf.
Urtica gracilis Ait.
Viola adunca Sm.
Viola incognita Brainerd
Viola conspersa Reichenb.

(Total Species, 21)

TABLE 6. Plants Found Only in Wisconsin Point Sample Areas

Abies balsamea (L.) Mill.
Acer spicatum Lam.
Actaea rubra (Ait.) Willd.
Amelanchier laevis Wieg.
Aster ciliolatus Lindl. forma *comatus* Fern.
Bromus ciliatus L.
Carex brunnescens (Pers.) Poir.
Carex deweyana Schwein.
Coptis groenlandica (Oeder) Fern.
Corylus americana Walt.
Corylus cornuta Marsh.
Fragaria virginiana Duchesne var. *illinoensis* (Prince) A. Gray
Iris versicolor L.
Ledum groenlandicum Oeder
Lonicera canadensis Marsh.
Lonicera tatarica L.
Lycopodium annotinum L.
Lycopodium lucidulum Michx.
Lycopodium obscurum L. var. *dendroideum* (Michx.) D. C. Eaton
Oryzopsis asperifolia Michx.
Ribes triste Pall.
Rosa acicularis Lindl.
Solidago hispida Muhl.
Solidago nemoralis Ait.
Thalictrum confine Fern.
Thuja occidentalis L.
Viola renifolia A. Gray

(Total Species, 27)

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