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Presettlement Vegetation of the Nemadji River Basin

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ABSTRACT-Features of presettlement vegetation of the Nemadji River watershed were determined from surveying records covering three counties in two states. Data from 3,346 trees indicated major distributional differences in portions of the watershed. White pine (Pinus strobus L.) was the predominant species of the Glacial Lake Duluth Basin, while Tamarack (Larix laricina (Du Roi, K. Koch) characterized the surrounding area of glacial till. In addition, forests occupying ravines were, in general, composed of larger individuals and exhibted less evidence of reproduction than trees in adjacent uplands, which might suggest less erosional disturbance than is evident today.

Because vegetative cover, in conjunction with soil organic content and slope, is important in reducing erosion rates (Meeuwig; 1970, 1971), a definition of vegetative cover types can serve as an initial means of assessing erosion control measures. On Lake Superior's south shore red clay soils have presented serious erosion problems. Recently, research projects were initiated to demonstrate various approaches to reducing erosion of the red clay soils (Andrews, Christensen and Wilson, 1976). This paper reports on the preliminary findings of one aspect of the overall study--the interpretation of the presettlement vegetation from surveying records in order to understand better the role of the natural vegetation in red clay stability.

The Nemadji River drains an area of some 460 square miles in Douglas county of northwestern Wisconsin and Carlton and Pine counties in northeastern Minnesota Of the 294,400 acres in the basin, about 117,800 acres represent clay soils derived principally from the lacustrine deposition of glacial Lake Duluth. The remaining portion, sandy soils of glacial till, tends to be poorly drained. The Nemadji River carries a heavy burden of eroding clay soil from this relatively young landscape and is a major contributor of red clay in Lake Superior, into which the river empties at Superior, Wisconsin.

Most of the Nemadji watershed is underlaid by the Hinckley and Fond du Lac formations of upper Precambrian age and is composed of quartzose and arkosic sandstone with interbedded shales. The southwest area of the basin is underlain by basalts and andensites of middle Keweenawan volcanic formations with interbedded sandstones, shales and conglomerates. Over these are found glacial till and/or lake sediments. The glacial drift material is composed of unsorted sand, silt and clay. It occurs in strata from somewhat less than 100 feet to more than 200 feet, in depth. Perhaps as recently as 10,000 years ago the last massive blanket of ice covered the Lake Superior area. As the ice retreated, Glacial Lake Duluth was formed, and the fine particles from glacier ice and water action were deposited in the basin. As lake levels receded to the present level of Lake Superior, an area of deep clay soils was left behind.

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These clays, largely of the montmorillonite type, comprise particles around two microns or smaller in size and form an almost level plain bounded to the west and northwest by sand and gravel hills and to the south and southwest by till. Between the glacial drift and the central clayey zone is the beach area developed through wave action from Glacial Lake Duluth. This beach zone (near the 330 m contour line on topographic maps of the area) is often observable in the field and delimits major vegetational zones (Mengel, 1973; Andrews, Christensen and Wilson, 1976).

Climate is typical of the western Great Lakes area. Weather Bureau Summaries indicate that precipitation averages 685-735 mm per year, depending upon location within the basin. About 90 mm of precipitation per month falls from May to August and 30 mm or less per month from December through February. The average daily maximum temperature is just over 10 C and average daily minimum is near -10 C. Day - to - day temperature is quite variable, however, with recorded extremes of 40 C (Superior, Wisconsin) and -45 C (Moose Lake, Minnesota). The growing season is relatively short, about 170 frost free days.

Human impact on the region's vegetation has been significant, since the logging activities of the last century. After the forest cover had been removed, much of the area was converted to agricultural use. During this century, agricultural interest in these lands has decreased, and much of the area has reverted back to forest cover. Presently, the clay soils support some agricultural lands and forest cover, with aspen the domininant tree species. A mixed northern hardwood forest (birch-oak-maple) characterized the sandy soils, which tend to be less heavily utilized for agriculture. The composition and extent of the vegetative cover now present in parts of the basin comprise a second part of this study to be reported later.

Information from field records

Survey records used as a source of information about early vegetation were written in the field and followed a previously determined plan, thus constituting a well defined sample of the vegetation that can serve as the basis for quantitative and qualitative analysis. Most survey data available today originated with the General Land Office surveys, and these are the basis for the work described here. Tans (1976) in his review of presettlement vegetation of Columbia county, Wisconsin, reviews the use of such records in that state. Similar uses have been made of surveying records in Minnesota. Bourdo (1956) discusses the use of these records

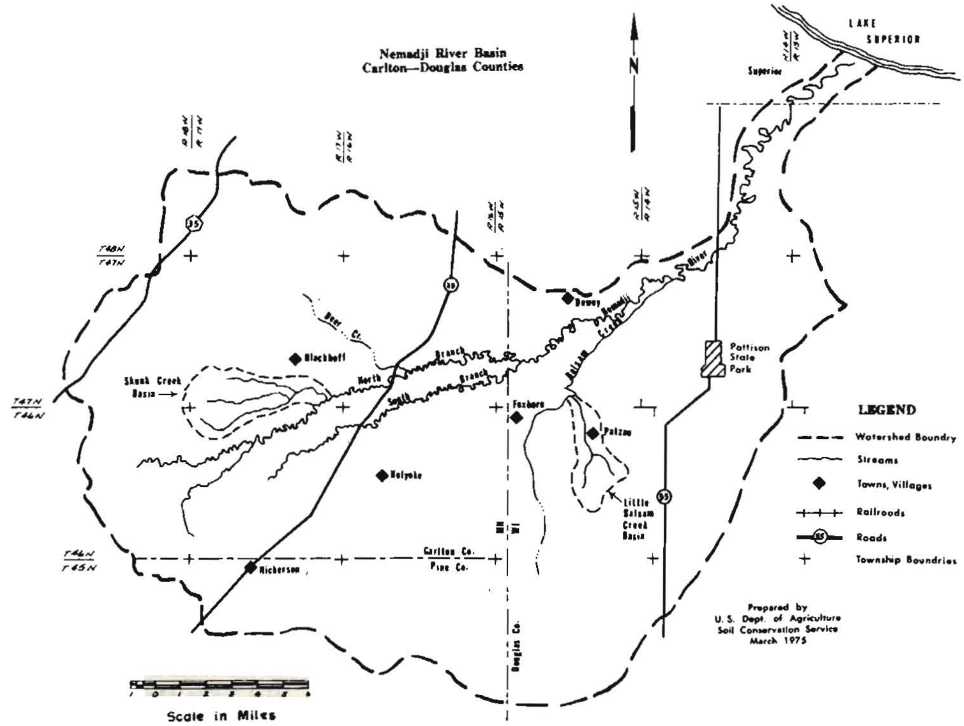

Fig. 1: Outline map of the Nemadji River Basin showing principal towns, highways and landmarks of present time.

in vegetational analysis and provides a good review of problems that may be encountered. Difficulties encountered in this study stemmed from several factors.

The correlation of surveyor's tree names with those in use today was usually not a significant problem since most names were readily recognizable. However, a few were encountered which were initially puzzling. As an example, an entry "Lynn" appeared. Similar to "Lind" and "Linde," this name must be a reference to Linden (Tilia americana L.), more familiar now as basswood.

More troublesome, however, was the usage of different names between surveyors. Probably the most obvious example was encountered with the birches. The Douglas County (Wisconsin) records typically recognized only Birch, rarely distinguishing between the yellow birch (Betula lutea Michx. f.) and the paper birch (B. papryifera Marsh.). In the Minnesota records nearly all birches were recorded as either yellow birch or paper birch. Because of the uneven treatment, it was not possible to distinguish between the birches in the analytical work. Similarly, available records did not always distinguish species of pines, spruces or oaks. The identity of a few names, such as "spruce pine" was not established with certainty. Names of uncertain identity were uncommon, however, and these taxa contributed little to the composition of the basin vegetation.

Another problem encountered was the lack of certain information in the records available. In 1785 congress authorized the rectangular system of surveying public lands, a significant change from the metes and bounds customs used in the British colonies. A good review of surveying legislation is provided by Stewart, (1935). All instructions specified four bearing trees in township corners and at section corners on township and range lines. Frequently, only two or three of these were recorded. In 1850, four trees were required at interior section corners as well, but it is not clear whether these were to be bearing trees. Quarter section corners required only two bearing trees. In theory the data reported by the surveyors should have been equivalent in all townships, and should include records of four trees for all interior section corners since all surveys were made after 1850. For some reason, however, Douglas county records list only two trees for interior section corners.

In addition to the above problems, bias in the record is possible. Although outright fraud was known to occur in some surveying, particularly before 1881 when effective field examination of survey work was initiated. Unintentional bias was a more common source of error. The instructions stressed the necessity for "bearing trees... which are the soundest and most thrifty in appearance ... (which) will be the most permanent and lasting." These instructions suggest that the tree data recorded probably reflected a tendency to select trees of lasting quality. Another source of bias undoubtedly crept in when bearing trees were selected for the iron marks. Since (with the exception of beech which was not reported in our area), the surveyors had to remove the bark to mark the bole with a timber scriber, it is likely that trees with loose bark were included more frequently. The relocation of corners would be easier for the field crews if uncommon species were identified, and it is likely that many surveyors tended to do this. Diameters, especially of large trees, were likely to be estimated, as were distances between the trees selected and the corner, particularly when this distance was great. These estimated diameters and distances tend to show up in the data as rounded numbers, such as 20, 25 or 30 inches, or 40, 50 or 60 links.

Records of the surveying work were obtained from a variety of sources, including copies of the original records and blueprints of various plat books. Where secondary sources (such as plat books) were used, data were verified by comparing part of the record with the original.

Point-centered quadrats of the plotless methods now commonly used by many plant ecologists were originally derived from procedures used by the early surveyors. As a result, the data contained in the surveying records can be analyzed by standard plotless procedures. Since the points recorded by the surveyors were not restricted to discrete stands, however, caution is necessary in making interpretations.

Corners at which four trees were recorded provide better data than those at which only two trees were recorded.

Because of the limitation inherent in using data from two-tree corners, it was necessary to separate two-tree (2 point) and four-tree (4-point) data. The latter provided estimates of density which are unavailable with 2-point data.

Tree species, diameter and distance from the corner (for 4-point corners) as well as the location of the corner were recorded from the surveying records. Summary calculations of density, frequency, dominance, the respective relative values and importance percentage (Grieg-Smith, 1964) were performed. Importance percentage in this paper is the mean of the three relative measures.

Computer-assisted species distribution maps for the Nemadji Basin area were prepared, and the presence of a given species at each survey point was printed on corresponding x, y, coordinate loci.

Several ordinations of the summarized data were constructed in an attempt to illuminate possible relationships that exist between species, populations or community structure and environmental factors. Among the various techniques of ordination (Orloci, 1972) are those which compare communities on the basis of (1) similarity of species presence and (2) percentage composition of species in the respective communities. When dealing with extremely diverse habitats, species presence is preferred because it is less subject to sampling error (Gauch and Whittaker, 1972). However, in less diverse habitats such as the Nemadji study, we found percentage composition provided better discrimination. In this study the survey data of the vegetation of the Nemadji River Basin (Townships, including both 2-point and 4-point data, are considered as communities.) were used to calculate the Bray-Curtis (1957) ordination as modified by Gauch and Whittaker (1972). The end points selected were chosen to reflect the geographical distribution of species.

Forest patterns from broad categories

From this summary of vegetation as recorded by surveyors it was not possible to determine, a priori, discrete vegetative stands for analysis. The end result is a synthetic picture of the forest without regard to local variation patterns that must have been present. Interpretations must therefore be tempered by the realization that the summaries are based on broad, inclusive categories.

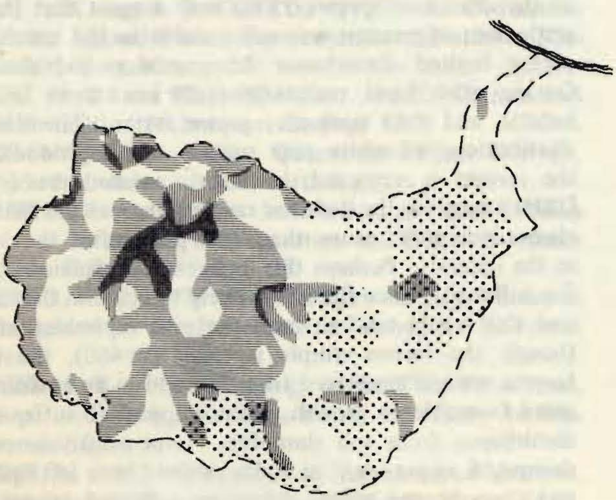

Fig. 2: Species distribution map for birch (Betula spp.) in the Nemadji River Basin.

Computer plotted maps of species distribution provided considerable information about the early vegetation. The distribution of the birches (Fig. 2) reflects the nomenclatural problem discussed earlier. Other maps indicated that species distribution is more or less random, i.e., no clear patterns are discernable. One exception to this was noted for the ashes (Fraxinus sp.). This taxon appears to be distributed along stream courses, but the small number of individuals reported is limiting. The maps for white pine and tamarack (Fig. 3), however, show them to occupy separate areas of the basin. The line of separation tends to be coincident with the 330 m contour line which is an approximation of the bed of old glacial Lake Duluth. This boundary tends to separate sandy, poorly drained soils outside of the former lake bed from the clayey, better drained soils of lacustrine origin. No other discernable patterns relating tree species to soil, slope or other characteristics of the basin were noted.

In the Nemadji Basin as a whole (table 1), white pine (Pinus strobus L.) has the highest I.P. (Importance Percentage) value. Almost one-fourth of the white pines were 60 cm DBH or larger, a size practically unmatched by any other tree in the forest. However, spruce (Picea spp.) occurred with near or greater frequency. Next in significance was tamarack (Larix laricina Du Roi) and birch, if the birch species were grouped (Betula spp.). The forest was dense, with 187 trees per ha, with an average point-to - tree distance of 2.2 m. The average diameter of the trees was near 28 cm.

Nemadji Basin maps indicate that many corners fell into the deeper ravines eroded by small streams. When all corners thus identified (by comparison with current topographic maps) were examined as a group in comparison with the corners on the more level lake plain (table 2), it was apparent that the two areas differed in vegetation. The original hypothesis was that the steep slopes of the ravines would generally be less stable. Disturbance from slumping would occur, resulting in data which would indicate a somewhat younger, smaller forest than the adjacent uplands. Just the opposite was observed, however. The ravine stands apparently consist of somewhat larger trees and appear to be slightly more dense.

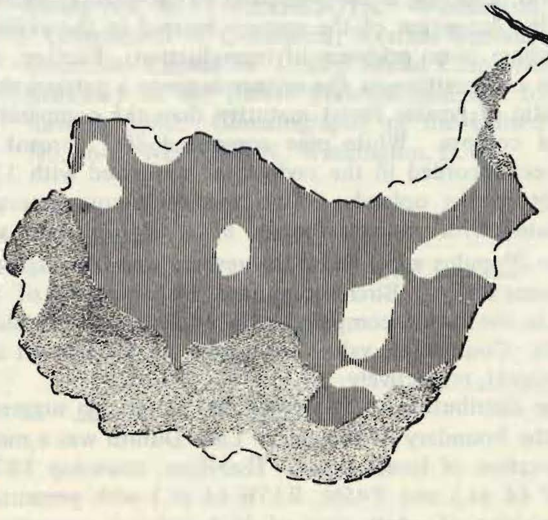

Fig. 3: Species distribution map for tamarack and white pine in the Nemadji River Basin.

SPECIES	2 pt.		4 pt.	
	F	I.P.	F	I.P.
Abies balsamifera (L.) Mill				
Abies balsamifera (L.) Mill.	35.4	9.5	16.4	4.9
Betula papyrifera Marsh.	20.1	6.1	24.4	9.4
Betula spp.	28.5	8.7	10.5	4.1
Larix laricina (Du Roi) K. Koch	41.4	12.7	24.7	11.0
Picea spp.	50.2	14.4	35.2	13.9
Pinus resinosa Ait.	8.2	3.3	9.9	6.3
Pinus strobus L.	41.4	22.3	38.0	27.2
Populus spp.	17.2	5.6	17.3	6.5
n =		2050		1296
x dbh (cm)		27.2		29.2
x point-to-tree distance (m)		n.d.		2.2
x density (trees/ha)		n.d.		187.3

TABLE 1-Summary of presettlement vegetation of the Nemadji Basin. F = % frequency of points at which species are present; I.P. = Importance Percentage = Sigma (relative density + relative dominance + relative frequency)/3. (Only species with I.P. greater than 5 reported.)

SPECIES	RAVINE				UPLAND			
	2 pt.		4 pt.		2 pt.		4 pt.	
	F	I.P.	F	I.P.	F	I.P.	F	I.P.
Abies balsamifera (L.) Mill.	59.1	16.5	20.4	6.3	31.8	8.4	15.6	4.6
Betula papyrifera Marsh.	25.8	8.0	20.4	6.1	19.3	5.8	25.1	10.2
Betula spp.	16.7	4.7	10.2	3.6	30.3	9.4	10.5	4.3
Larix laricina (Du Roi) K. Koch	10.6	2.9	12.2	4.8	46.0	14.2	27.0	12.2
Picea spp.	50.0	14.8	34.7	12.1	50.2	14.3	35.3	14.3
Pinus resinosa Ait.	3.0	0.7	4.1	3.1	9.0	3.8	10.9	7.0
Pinus strobus L.	59.1	28.9	69.4	47.5	38.8	21.3	32.4	22.9
Populus spp.	12.1	4.2	4.1	1.3	17.9	5.8	19.7	7.6
n =		264		196		1786	1100	
x dbh (cm)		30.2		35.6		26.9	27.9	
x point-to-tree distance (m)		n.d.		2.1		n.d.	2.2	
x density (trees/ha)		n.d.		196.3		n.d.	185.8	

TABLE 2- Comparison of presettlement vegetation between ravine and upland corners of the Nemadji Basin. F = % frequency of points at which species are present; I.P. = Importance Percentage = Sigma (relative density + relative dominance + relative frequency)/3. (Only species with I.P. greater than 5 reported.)

A final comparison (table 3) was undertaken to examine the nature of the vegetation within and without the boundary of the former glacial Lake Duluth. From ordination patterns and species distribution maps, there was a strong indication that the 330 m contour line formed an approximate boundary between two major vegetational types. Since this same contour line generally marks the uppermost zone of influence of the old lake, corners were separated on the basis of their location in reference to th 330 m contour line. Vegetation in the two areas differs with tamarack the dominant species (but nearly equaled in I. P. by spruce and white pine) outside of the old lake bed. Inside, white pine is the major dominant with no near challengers. In addition, the corners outside of the old lake bed influence tended to be smaller and denser, consistent with a tamarack-dominated forest type.

When the size class frequency distributions of various species are tabulated, some interesting comparisons are possible. Probably most interesting are those of white pine (Fig. 4). This tree, the major dominant in the basin, is represented with individuals in every size class, but tending to have many individuals 60 cm or larger DBH. The number of smaller sized trees suggest some reproduction was occurring in the basin and all sub-parts examined, with the exception of the corners located in the ravines. Here there is no evidence of reproduction. Further, the species composition in the ravines suggests a pattern characteristic of greater forest maturity than the comparative upland corners. White pine comprised 30.7 percent of the trees recorded in the ravines, as compared with 13.9 percent in the uplands. Two species groups generally associated with younger forests, birch (Betula spp.) and poplar (Populus spp.) show the reverse trend, though not as dramatically. Birch comprised 14.6 percent of the trees in the ravine compared with 18.8 percent in upland forests. Comparable values for poplar are 4.1 percent and 6.7 percent, respectively.

The distribution of P. strobus and L. laricina suggested that the boundary of the glacial Lake Duluth was a major demarcation of forest types. Therefore, township T47N, R16W (4 pt.) and T45N, R15W (4 pt.) with percentage composition of white pine of 56.5 and 0.0, respectively and tamarack 1.0 and 18.8, respectively were chosed as end points for the ordination. An attempt to interpret the resulting ordination based on the alignment of communities in and out of the former lake basin proved fruitless. However, the percentage of wetlands of each township appears to be correlated with community (township) position on the ordination as determined by percentage similarity. Pinus strobus and Larix laricina dominate opposite extremes and spruce (Picea spp.) tends to be generally distributed. Taxonomic confusion and low sample size of the other species preclude additional interpretations.

Species, slope and size variations

Surveying records data suggest that the presettlement forest of the Nemadji Basin was essentially of two types. One, located on the clay soils of the old glacial Lake Duluth bed, was dominated by white pine. The other associated with the poorly drained soils to the south and west of the old lake bed, was dominated by tamarack. Within the basin, moisture relationships appear to exert more control over vegetation than other factors.

The forest of the ravines appears to be different from the associated uplands in that it is more mature, whether measured by species composition or size class distribution of the dominant species. This may suggest that the presettlement vegetation was more stable in the ravines, implying limited disturbance from erosion and slumping. On the other hand, ravines generally are a more favorable habitat, and their trees may grown faster. The size class distributions of white pine suggest that reproduction in the ravines is restricted, in that no smaller trees (12cm DBH) appear in the data for ravines whereas the same size classes comprise more than five percent of the sample in the uplands. Perhaps this difference is explained by less fire influence, since fire is less likely to occur in the ravines, and this would tend to limit the pine reproduction. Although the ravine sample is small (n=460), the ravine forests, even if protected from fire and in an environment more favorable to growth, did not appear to suffer undue disturbance from soil slumping. Over a 50 year period, slumps, if as prevalent as today, should have left openings and disturbances which would be reflected in size class distribution data and species composition. This finding, however, must remain tentative.

SPECIES	Inside (less) 330 m Contour				Outside 330 m Contour			
	2 pt.		4 pt.		2 pt.		4 pt.	
	F	I.D.	F	I.D.	F	I.D.	F	I.D.
Abies balsamifera (L.) Mill.	42.8	11.6	21.8	6.6	27.4	7.2	10.0	2.9
Betula papyrifera Marsh	16.7	4.8	21.8	8.5	23.8	7.6	27.3	10.7
Betula spp.	23.1	6.7	8.6	3.1	34.3	11.0	12.7	5.7
Larix laricina (du Roi) K. Koch	30.3	8.9	19.0	8.2	53.3	16.9	31.3	14.8
Picea spp.	56.1	15.6	35.6	13.8	44.0	13.0	34.7	14.1
Pinus resinosa Ait.	8.3	3.0	8.0	4.6	8.1	3.8	12.0	9.2
Pinus strobus L.	56.4	27.8	49.4	36.4	25.4	13.0	24.7	13.4
Populus spp.	15.2	4.9	11.5	4.3	19.4	6.3	24.0	9.6
n =		1058		696		992	600	
x dbh (cm)		28.4		32.3		25.9	25.4	
x point-to-tree distance (m)		n.d.		2.3		n.d.	2.1	
x density (trees/ha)		n.d.		167.7		n.d.	214.7	

TABLE 3- Comparison of presettlement vegetation between corners located inside the 1,100-ft. contour line (approximate outer boundary of Glacial Lake Duluth) and outside. F = % frequency of points at which species are present; I.P. = Importance Percentage = Sigma (relative density + relative dominance + relative frequency)/3. (Only species with I.P. greater than 5 reported.)

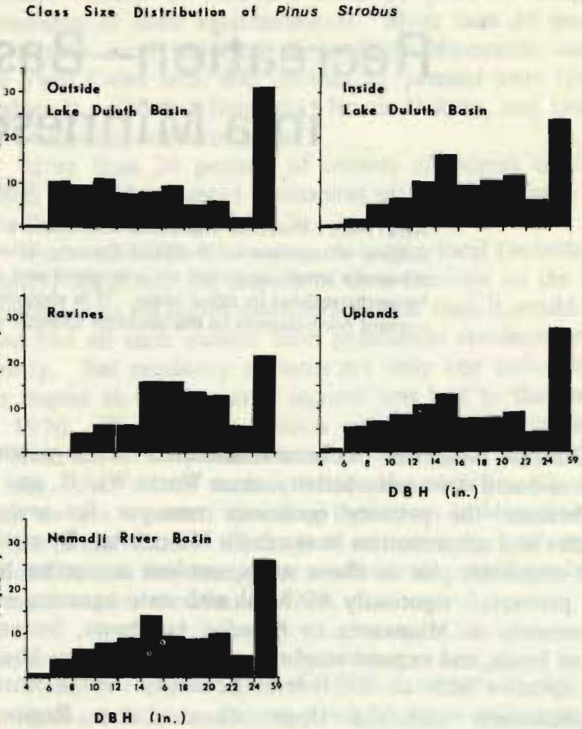

Fig. 4: Class size distribution of Pinus strobus.

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