Succession: A Comparative Study in the
Revegetation of Three Abandonded Building Sites

very good
- and interesting!

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Introduction

Succession and patterns of revegetation have long been accepted almost as axiomatic by ecologists though the evidence for support has been largely circumstantial and based on casual observation. The types of evidence available have been reviewed (McCormick 1968) and include casual observation, historical records, age series, and direct study and experimentation. Of these the most valuable evidence on which to base successional theory is the direct, long term studies of vegetation on specific sites. Such studies have seldom been preformed and thus this study provides an almost unique longterm succession study with abundant data, though unfortunately a twenty-eight gap exists in the data.

Classically succession is thought of as the orderly, gradual change in vegetation types (Clements 1916) eventually leading to a climax community which will be stable to perturbation. These patterns of change have been noted in an old field situation (Evans and Dahl 1955), and in an abandoned building site (Duncan 1973). This study was conducted to update the revegetation-succession study started by F.C. Gates in 1930, to note the pattern in changing vegetation over times as well as to compare the changes in the three sites which were first studies by Gates, and which have now all been resurveyed.

History of the Sites

The site of study is on the southeast shore of Douglas Lake which was the original site of the University of Michigan Biological Station. When Camp Davis, an engineering camp, vacated the adjacent site, the south shore of South Fishtail Bay , the Biological Station relocated there and moved several buildings in the winter of 1929-30. Three abandoned building sites were chosen for study and fenced off. They were sites that had been covered for short, medium, and long periods of time: the Research laboratory, three years; the Botany laboratory, six years; and the Houghton laboratory, sixteen years (Gates 1952). These sites (Figure V) were studied by Frank C. Gates from 1930 through 1950 at which time he concluded that those sites that had been covered longest were the slowest to revegetate (Gates 1952).

None of the sites were resurveyed until 1971 when Duncan (Duncan 1973) relocated and resurveyed the Botany laboratory site. He found only a small increase in the number of vascular plants, but noted the changing composition from annuals to perennials. He also predicted an increase in trees and herbs common to the adjacent forest, such as _Poa compressa_, _Melampyrum lineare_, and _Pinus strobus_ and a decrease in mosses and lichens. The site was heavily disturbed by construction after his study and is unfortunately lost for future study.

The Research laboratory was restudied in 1977 by Kachman (Kachman 1977) who found a decrease in the number of species, but an increase in the number of forest individuals, both trees, _Pinus strobus_, _Quercus rubra_, and _Acer rubrum_, and forest understory species, _Vaccinium angustifolium_ and _Arctostaphylos uva-ursi_.

The Research laboratory site is closest to the adjacent forest and the best protected from human disturbance, being furthest removed from any paths or housing.

The Houghton site is closest to the shore of Douglas Lake and the northern section of the site was disturbed in 1974 when a small building was dragged across it (D. Gates,pers. comm.). This obviously damaged the site, but its impact is unknown. This site is in a precarious position and susceptible to disturbance, being surrounded by housing, the beaches of Douglas Lake, and a foot path regularly used by humans.

Methods and Materials

The Houghton laboratory site was relocated in July 1978, and the original creosoted stakes placed in the ground by F.C. Gates in 1930 defining the perimeter of the plot relocated. Gates ~~(Gates~~ (1952) mentions the area of the plot as being "about 90 square meters", but the area delimited by the original stakes was measured to be 104 square meters in 1978. Almost all of the original stakes were found, which had been placed at one meter intervals, so it appeared that the original plot had been accurately relocated and the discrepency of 14 square meters seemed unusual. Because Houghton lab still stands at the site to which it was moved in 1929 it was possible to measure its basal area. The basal area is 99 square meters, so it seems likely that that is the approximate area marked off and studied by Gates. Although the area studied in 1978 was five square meters larger, no corrections were made in the numbers of species or individuals counted counted in that year.

The plot was divided into fifteen east-west transects and each individual of vascular plant was mapped (Figure I). Each transect measured one meter by about 6.75 meters except the first and fifteenth which were larger. The area of each transect is noted on Figure I. The maps from 1931, 1940, and 1950 were redrawn (from Gates 1952) and are included for comparison (Figures II, III, and IV). The map of the site in 1978 shows every vascular plant except for the numerous individuals of Poa compressa; these numbers are noted at the side of each transect in Figure I.

Although many of the species are rhizomatous, an individual was defined as a stem coming from the soil. Thus very large numbers of several species, Poa compressa (8638) and Pteridium aquilinum (221) do not reflect the number of genetically different individuals, but was the only quick method of determining the abundance of a species in the plot.

Discussion: Changes in the Houghton laboratory site over time

In the first growing season after the move (1930), 12 species were recorded, with six of them non-native species, and only five or six being perennials (Figure VIII). The species that did arrive, either native or introduced, were those characteristic of sandy areas and dunes, such as Cirsium pitcheri, Elymus canadensis, Chenopodium capitatum and Poa pratensis. Populus tremuloides was the only tree species reported in the first year.

From 1931 to 1939 the number of species in the plot dropped and stayed below ten. This decrease is probably due both to the changing flora of the plot and also to the severe drought conditions (Gates 1938) that existed in the 1930's. The flora composition also changed greatly during this time, though the number of species in the plot did not. By 1933 eight species were recorded, but only four had persisted from the twelve recoded in 1930. The eight species of 1933 included four introduced species, and seven or eight of them were pernnials. Thus the first wave of invaders, plants which preffered the open sand, began to disappear. About half of the species were introduced species, and half were annuals throughout the 1930's. Both classes of plants continued to decrease over time, and by 1950, of the 16 species recorded, only three were introduced, and 13 or14 were perennials. The 1978 survey found 27 species of vascular plants, with only four of them being introduced species, while 22-24 were perennials. These trends support the observations (Evans and Dahl 1955) that introduced annuals are the first colonizers in secondary succession, but are unable to compete with the native species and are not able to persist.

None of the annuals or biennials have survived for more than three years, though they have always been present. This is probably due to slight microhabitat changes and chance which allows the species to continually be introduced into the plot, only to die out in several years.

A strong correlation also exists between the origin of the species and their persistence. Only several grasses, Poa compressa, Poa pratensis, and Agropyron repens have been successful (i.e. persistent) introduced species. The last two have virtually disappeared, there being but one individual of Poa pratensis, and no Agropyron in the plot in 1978. Poa compressa however is a well established and persistent grass throughout North America, and will probably persist in the plot. It is the most successful species in the plot, based on number of shoots, though not on biomass.

Species which have become of greater importance since 1950 include Danthonia spicata, which is characteristic of dry sandy areas and found only in the north end of the plot, and Pteridium aquilinum, which has greatly increased in numbers. This increase is probably time dependant, for it spreads via rhizomes, and its great increase may be due to the arrival of a single rhizome into the plot. Several introduced species have also invaded the sandy area, Centaurea maculosa and Hieracium florentinum, both rather recently arrived to the area. These species probably will not persist for long, but may be replaced by other weedy annuals.

The Houghton site has been slower to revegetate with forest species than have the other plots, and part of the plot may never be covered with those species. The site shows an obvious gradient from a sandy open area near Douglas Lake, the north edge of the plot, towards an area dominated by forest species at the southern end of the plot, the area furthest from the lake. This gradient is demonstrated by the changing, vegetation, ground cover, and the number of trees (Figures VI and VII)

The dominant species in the open sandy site are Smilacina stellata, Arabis lyrata, and Asclepias syriaca, while the southern end of the plot is dominated by Pteridium aquilinum, Quercus rubra, Melampyrum lineare, and Vaccinium angustifolium, all absent from the north end.

This gradient has a very strong correlation with substrate, and distance from the lake (or distance towards the woods). The ground cover changes from about 30% bare sand to no bare sand along a line moving away from the lake. The cause of the persistence of this gradient is unknown. The northern edge of the plot does not form a continuous sand cover to the lake, grading into the beach, but rather is interupted about three meters from the north edge by a dense growth of Amelanchier sp., Pinus strobus, Toxicodendron radicans and several large individuals of <u>Populus tremuloides</u>. This growth forms the edge of the level plateau which the Houghton site is on, and north of this growth the sand slopes down to the lake edge. The site has never developed a thick ground cover, (Figures II, III and IV) and the number of trees in the area has always been low. Certainly human disturbance has played a role in slowing the revegetation, and a small building was moved across the site in 1974. But there are similar areas along the lake, to the east of the Houghton site, however, which show the same pattern, and have probably suffered much less human disturbance and have also remained open and unvegetated. Shifting and blowing sand may play an important role, continually burying vegetation. This is a possibility though the area is protected by the buffer of vegetation from the direct winds and blowing sand from the lake, which are never very strong in the protected bay where the site is located.

Moss cover has always been low in this area and has not developed to bind the sand. Gates ~~(Gates~~ (1946) showed that moss, especially <u>Ceratodon</u>, may play an important role in revegetation of sandy sites by both binding the sand and humifying it. Perhaps it has been human disturbance which has slowed the spread of the moss which is neccessary for revegetation to occur on this exposed dry sand.

The tree species play an important role both as indicators of revegetation and in influencing changing floristic composition. The first species of tree to move into the plot (1930) was <u>Populus tremuloides</u> which probably moved in as root suckers from trees outside of the plot. The number of individuals of <u>Populus tremuloides</u> has remained high though most of the trees do not survive more than a few years. (figure XII) Of the 43 individuals in the plot in 1978, 35 were less than one meter tall, two were between one and two meters, and only six were above two meters. Of these six however, three were very sick and had very few leaves. There were also two dead standing individuals of about ten meters in the site. The reason for the state of these trees is unknown. They contain very few lower branches, and the upper branches are usually short and the leaves small. The trunk is very gnarled with many scars. Browsing may be a cause of this though no other species of tree in the plot show this condition, and other individuals of Populus tremuloides in the woods ten meters away appear healthy without these characteristic signs.

Quercus rubra did not appear in the plot until 1936 and has been present in stable numbers for the four points measured since 1945. Several large oaks are just outside the plot and provide ample nut shower onto the plot. Most of the seedlings do not survive past seedling stage; of the 52 present in 1978, only four were between one and two meters, and seven over two meters. All individuals however appear very healthy and vigorous.

The small understory tree, Amelanchier sp., appeared in 1940 and has increased to 23 individuals by 1978. This tree usually gets no more than a few meters high and is characteristic of the nearby forest understory. Its increase is an indication of the increasingly forest revegetated aspect of the plot.

Two tree species found for the first time in the plot were two seedlings of Pinus strobus and a single seedling of Fagus grandifolia. All three individuals were found in the southern edge of the plot, nearest the woods. All three were first year seedlings, and it is doubtful if they will all survive, or that they can be used as indicators for the future of the plot. It is significant however in that they have never been reported from the plot, and that they have been able to at least germinate in the site. *Pinus strobus* is quite common of the area and the species may well move into and persist in at least the southern half of the plot. *Fagus grandifolia* however is not common of the nearby woods and its survival or the future for any individuals of the species on the site is doubtful.

Altough the number of species has not increased in the other sites (Figure IX), there has been a large increase in the Houghton site. The increased diversity in the Houghton plot may be attributed to both the environmental gradient that exists, providing more niches in a varying environment, and also due simply to the larger area of the site. Although these two factors are difficult to separate, by using only 38 square meters of the Houghton plot, from the south edge, a total of 14 species were found, comparable to the number found in 38 square meters of the other two plots. This indicates that it is probably the gradient providing greater diversity and not simply the larger area sampled.

The Houghton laboratory site provides a rare opportunity for conducting an accurate long-term revegetation study and should be permanently fenced off to prevent further human disturbance, and be resurveyed as often as possible to provide an accurate picture of the revegetation of the site. Two important questions could be answered from such measures: if the gradient existing in the plot is caused by disturbance or if there are natural climatic, or substrate influences, and if the site will ever return to a forest community, or remain an open, dry sand community.

Comparison of the Sites

During the period that Gates studied the plots (1930-50) the number of species in each plot did not change significantly (Figure IX) and the relative number of species between the plots remained constant. Gates noted (Gates 1952) that there was a strong positive correlation between the length of time that a site was covered and the time that the sites took to revegetate. This trend held well, especially through the 1930's drought when the Houghton site, covered 16 years, had far fewer species than the other sites, and the Botany site, covered for six years, had fewer that the Research plot which had been covered three years. When compensating for the larger area of Houghton site, this trend still holds, though the correlation between length of covering and slowness in revegetation is probably an artifact produced by the location of the sites. As seen in Figure I the Houghton location is very close to the lake (covered 16 years); while Research is at the edge of the neighboring woods (covered three years; and intermediate between the lake and the woods, adjacent to a road, and traversed by a foot path, is Botany (covered six years). The Research site showed the most rapid gain in the number of species, and has always maintained this higher number. The site is the most removed from the exposed open sandy area immediately adjacent to the lake, is the most set back in the woods, and the site most removed from human disturbance. The only disturbance that the site has suffered has been the cutting of two aspens when a power line was run through the plot in 1971 (Kachman 1977). Few people traverse the plot as it is well marked and is covered by a dense growth of low trees and shrubs. The substrate is a humus layer covering the sand, mostly of decaying Quercus rubra leaves and Pinus strobus needles. This site is now nearly surrounded by the woods and its vegetation reflects this in its compostition. Dominant species in 1977 (Kachman 1977) included Pinus strobus, Quercus rubra, Vaccinium angustifolium, Melampyrum lineare and Maianthemum canadense, all typical of the adjacent woods.

The Botany laboratory site is located next to a road, a concrete slab, and has only one side adjacent to the woods (Figure V). It is thus less available to seed and fruit infusion from the forest species, and is removed from the sandy beech of DouglasLake and its flora. The substrate contains a thick layer of organic matter, mostly Quercus rubra leaves, and would appear to be prime for colonization from forest species. Disturbance has probably played a major role in this site in keeping diversity low. It has always been adjacent to the road and cement slab and is at present traversed by a foot path, though it is not known how long it has been crossing the plot. Duncan ~~(Duncan~~ (1973) makes no mention of it, so it probably was not created until 1973, alter the last survey, with the building of the Gates' home.

The Houghton laboratory site is nearest the beach, and extends back to near a foot path. The site is removed from the neighboring forest and its composition is much more influenced by plants typical of Douglas Lake shore than the other sites. The site contains Arabis lyrata and Elymus canadensis, both typical of the shore, and Asclepias syriaca, Panicum xanthophysum, and Danthonia spicata, all more widespread, but typical of drier sandy locations. The substrate is largely bare sand with some area being covered by a thin layer of organic matter. This sand is classified as Eastport sand (Gates 1952) and is rather sterile. It has a high porosity and drainage through it is quick. This provides a drier site than the other two which have a well developed humus layer to retain the moisture. The site is elevated enough from the lake level so that the water table is greater than a meter below the surface of the site. The effects of soil moisture can be readily seen by the much greater drop in species per area in the Houghton site during the 1930's drought than in the other sites (Figure IX). This area is probably somewhat disturbed by humans passing through the area. In 1974 a small building was dragged over the north edge of the site, though no signs of that are evident today, and that portion of the site has always been at least partially bare sand (Figure I).

The three sites have revegetated at different rates, and these rates have remained approximately constant until the most recent surveys. The differential rates of revegetaion between the sites is probably due to the amount of disturbance, especially human, their proximity to seed, propagule, and rhizome source, and to the substrate of each site.

Comparative Floristics

Although the relative number of species in each plot has been different over time in the three plots, the floristic composition has been very similar in all three. All three have followed a general pattern of first being invaded by weedy annuals, which after a few years gave way to native species characteristic of open, sandy sites, and then replaced by tree species and shade tolerant herbs characteristic of forests adjacent to the sites. During the first few summers (1930-32) after removal of the buildings, most of the species in the plots were weedy introduced annuals or biennials, such as Chrysanthemum leucanthemum, Verbascum thapsus, and Lepidium virginicum. By 1940, most of the plants were native perennials characteristic of the sands of Douglas Lake, such as Arctostaphylos uva-ursi, Oenothera parviflora, Rhus xborealis, and Solidago hispida. Many tree seedlings of Quercus rubra and Acer rubrum moved into the plots also. At this time (1940) the differential revegetation of the sites can be seen, especially the Houghton lab site in respect to the other two sites. The Houghton site contained several species characteristic of the open sands which were not found on the other sites, including Elymus canadensis, Oenothera parviflora, and Asclepias syriaca. The Houghton site did however contain several of the species mentioned above, including Rhus xborealis, Quercus rubra, and Acer rubrum, suggesting that the site was not revegetating equally over the site, and that a gradient of revegetation existed on the site which did not exist on the other sites. This differentiation becomes even more pronounced by 1950. All sites showed an increase in the number of individuals of Quercus rubra and Acer rubrum, and the presence of Pinus strobus was reported for the first time in the Research lab site, indicative of its location near the woods. When the plots were resurveyed in the 1970's, all sites reported Quercus rubra, Acer rubrum, Pinus strobus, Vaccinium angustifolium, Pteidium aquilinum, and Melampyrum lineare, all found in the nearby woods. The Houghton lab site contained but two seedlings of Pinus strobus, which may or may not become establised. The revegetational gradient of the Houghton site was even more pronounced at this time, a phenomenon not observed in the other plots.

Figure XI shows an intra-site comparison of the sites in terms of the species present. The total number of species present has increased from 22 a few years after the removal of the buildings, to 28 in 1940, and to 40 in the 1970's when the sites were resurveyed. Because data do not exist for all sites in one year, it was neccessary to lump data taken in 1931 and 1932, and to lump the three dates of 1971,1977, and 1978 into one time period. Obviously some error may occur by doing this, as species may come and go over a seven year period, but the times are close enough in comparison to different periods to make at least general observations of change.

The percentage of plants found only in one area has increased from 1931-32 (59%) to 1971-78 (70%) indicating that the areas are changing in vegetation, but not converging on a similar "set" of species. As the number of species found in all plots has increased, so has the number of species found in only one of the sites. Each plot seems to be following its own path in revegetation, although there has been a slight increase (14 to23%) in the percentage of species found in all three plots. Only 8% of all plants were found in any two plots, suggesting that there are a few species that are ubiquitous, found nearly everywhere, including all three study sites, but that the rest of the species are not widespread and each site is accumulating its own "set" of plants, unique from the other sites. The sites indeed are not converging on one climax vegetation, and most of this divergence is due to the Houghton site, which contains 61% of all of the species unique to one site.

Summary

The study of abandonded building sites initiated in 1930 has shown that although the total number of species in each plot has changed little over time, the composition has changed dramatically, with strong correlations existing between the persistence of a species in a plot, and its native origin, and to perennial life morphology. This change has been an orderly process of community change which is time-dependant. Revegetation depends heavily on the proximity to seed, propagule, and rhizome source, as seen by the correlation between proximity to the woods and the rate of vegetation by those species. Disturbance, mostly human, has slowed the rate of revegetation and may play both a direct and indirect role. Revegetation can vary over space as well as over time, with small changes in microclimate, disturbance and substrate greatly affecting the rate of revegetation of a site.

The two sites left intact, the Research and Houghton sites, provide an almost unique situation to study revegetation and succession, and their value must not be underrated. These sites should be well marked and protected from any disturbance. Each site should be resurveyed as often as possible so that an accurate picture may be obtained on the process of succession.

Acknowledgments

Thanks are extended to Dr. E.G.Voss for aid in identification of certain taxa, and to Dr. D.M.Gates for showing me the location of the site, and for providing its history. Acknowledgment is made to F.C.Gates, T.Duncan, and R.Kachman from whose previous work on the sites I have borrowed heavily. Appreciation is expressed to the University of Michigan Biological Station for financial support while conducting this study.

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List of Figures

Figure 0: Key to Symbols used in Figures I-IX[a]

AA-Aster laevis

AC-Acer rubrum (in Figure IX)

AC-Agrostis gigantea
(A. alba) (in FigureI)

AR-Acer rubrum (Figure I)

AR-Agrostis repens (Figures II-IX)

AM-Amelanchier sp.

AL-Arabis lyrata

AS-Asclepias syriaca

CA-Chenopodium album

CM-Centaurea maculosa

CP-Cirsium pitcheri

DS-Danthonia spicata

EC-Elymus canadensis

FG-unknown grass

FGr-Fagus grandifolia

HF-Hieracium florentinum

HV-Hieracium venosum

ML-Melampyrum lineare

OP-Oenothera parviflora
(O. muricata)

PA-Pteridium aquilinum
(P. latiusculum)

OC-Poa compressa

PP-Poa pratensis

PS-Pinus strobus

PT-Populus tremuloides

PR-Prunus virginiana

PX-Panicum xanthophysum

QR-Quercus rubra (Q. borealis)

RB-Rhus xborealis (R. glabra borealis)

RO- Rosa sp.

SC-Solidago canadensis

SS-Smilacina stellata

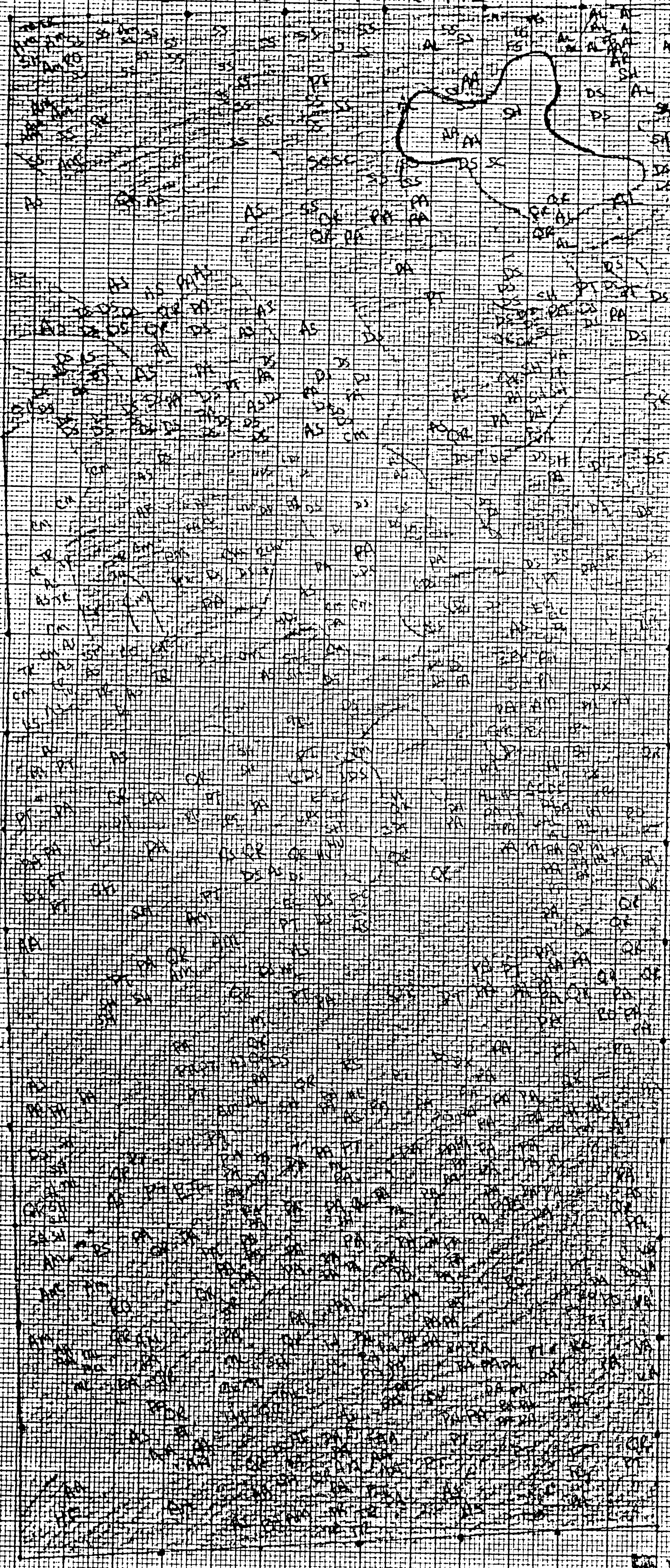
TR-Toxicodendron radicans

VA-Vaccinium angustifolium
(including V.Brittonii)

[a]Names in parenthesis are those used by Gates (Gates 1952).

Figure I Houghton laboratory site in 1978

N.B.: All original maps are on file in EGVoss' office in Bound Flora File



Poa compressa (PC) = 741
Area = 9.69 m²

PC = 498
Area = 6.8 m²

PC = 308
Area = 6.8 m²

PC = 717
Area = 6.8 m²

PC = 544
Area = 6.775 m²

PC = 502
Area = 6.735 m²

PC = 808
Area = 6.72 m²

PC = 722
Area = 6.72 m²

PC = 823
Area = 6.71 m²

PC = 842
Area = 6.675 m²

PC = 694
Area = 6.635 m²

PC = 640
Area = 6.585 m²

PC = 576
Area = 6.525 m²

PC = 606
Area = 6.64 m²

PC = 617
Area = 7.095 m²

• = original stake placed by F.C.Gates

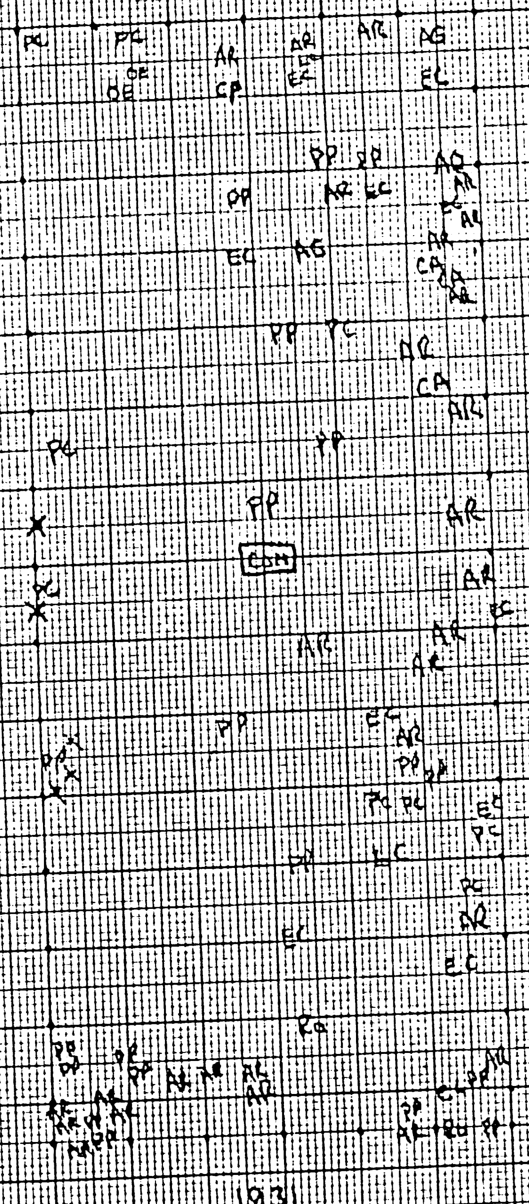


Figure II: Houghton laboratory site in 1931 (after Gates 1952)

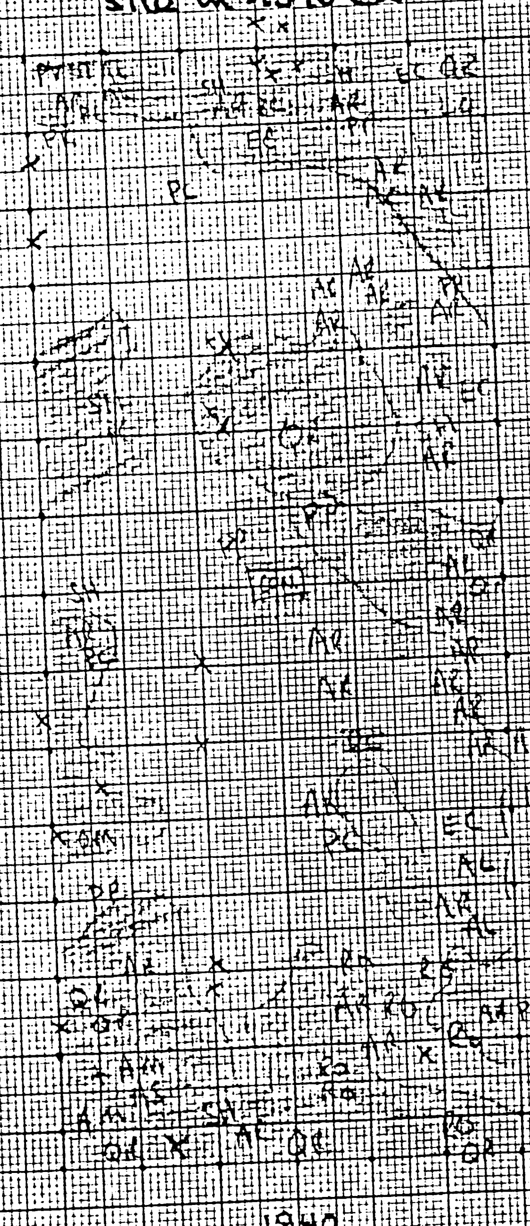


Figure III: Houghton laboratory site in 1940 (after Gates 1952)

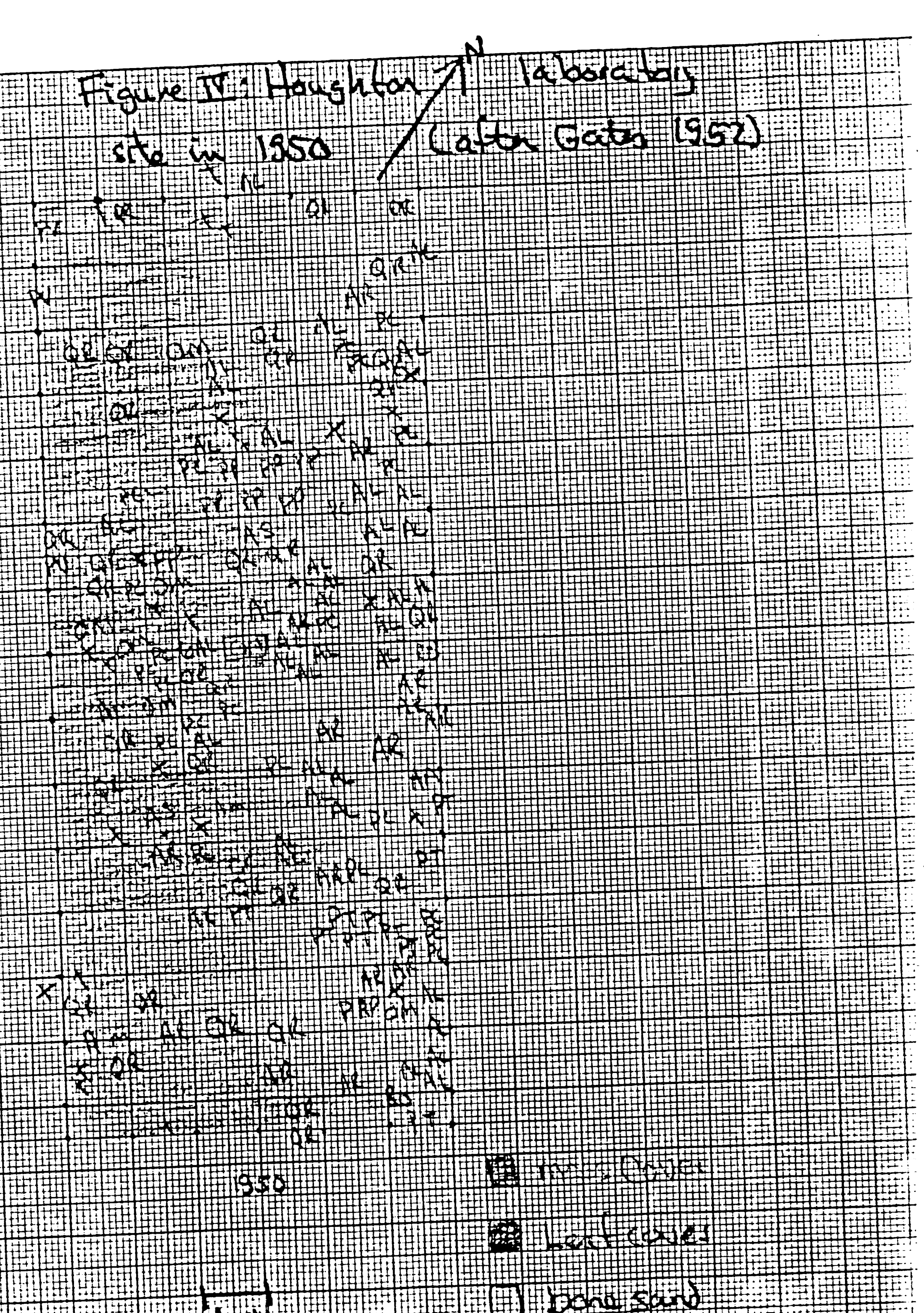


Figure IV: Houghton laboratory site in 1950 (after Gates 1952)

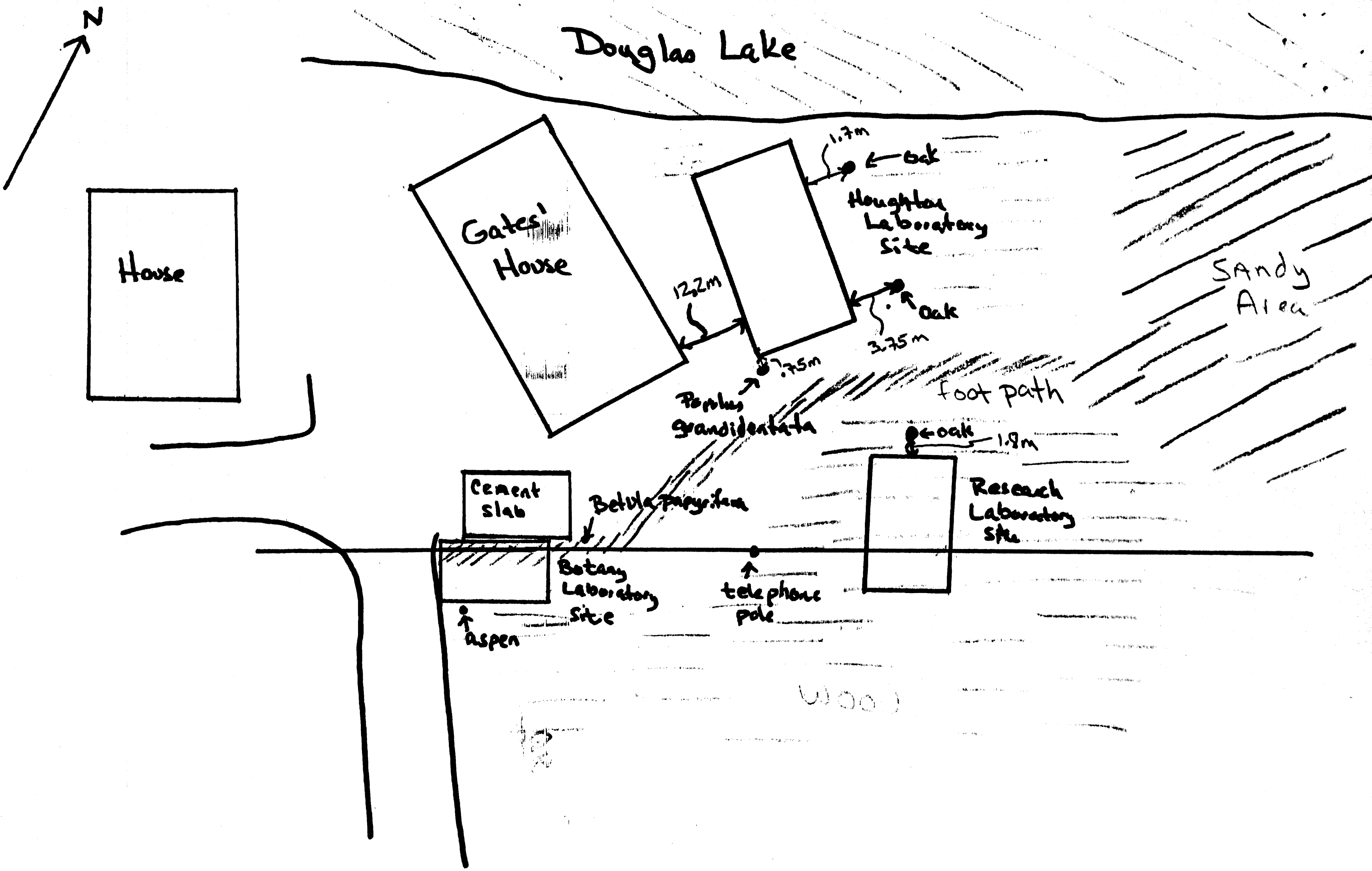


Figure II Location of the three study Sites (after Kachman 1977)

N.B. This map is to show relative location of the three study sites, and does not accurately reflect the actual size of all landmarks, or the distances between them (unless noted).

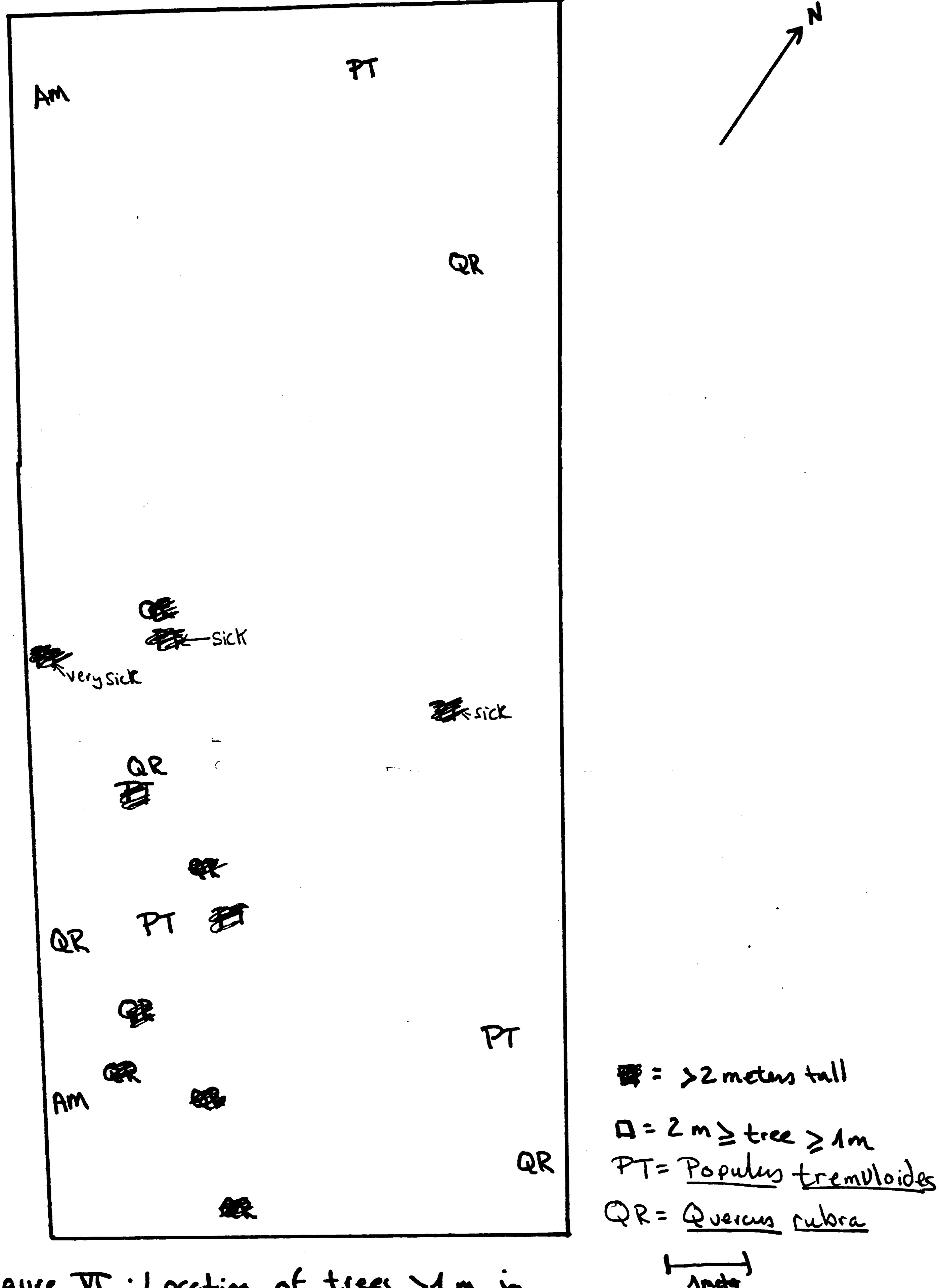


Figure VI : Location of trees >1 m in height in Houghton laboratory site 1978.

Figure VII. Changing vegetation over distance in Houghton laboratory site.

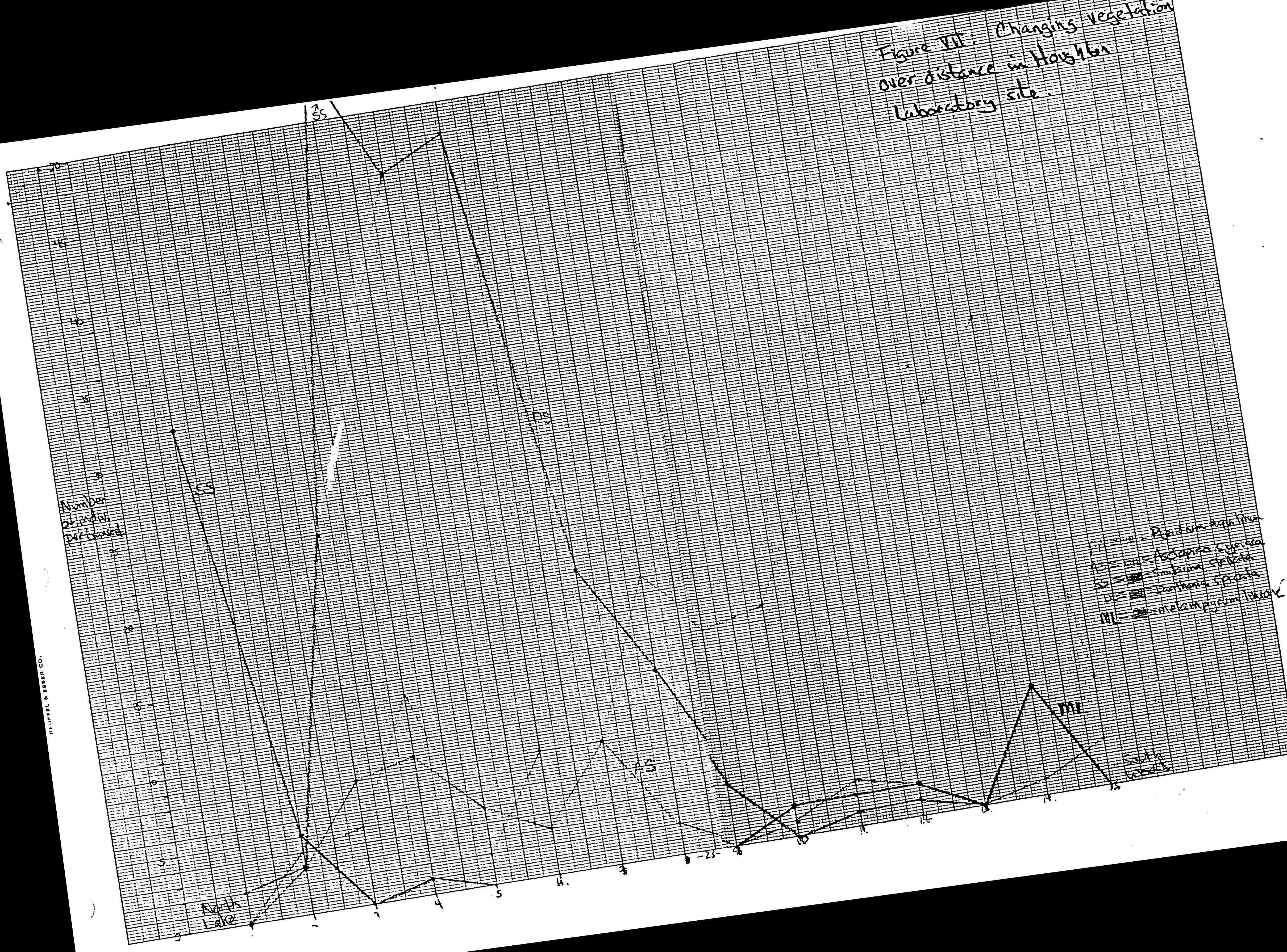


Figure VIII: Changes in the Floristic Composition of the Botany Laborstory Site

Species[a]	Duration[b]	Origin[d]	1930	'31	'32	'33	'34	'35	'36	'37	'38	'39	'40	'42	'45	'49	'50	'78
			Year Present[c]															
Chenopodium capitatum (Blitum capitatum)	A	N	2															
Cirsium pitcheri	B	N	1	1	1													
Chenopodium album	A	I	3	3	1													
Elymus canadensis	P	N	2	+	+	+	5	9	8	5	7	6	8		3	2		6
Galeopsis tetrahit	P	N	1															
Lepidium densiflorum (L. virginicum)	A or B	N	1															
Oenothera parviflora (O. muricata)	B	N	3										1	5	12	10	5	
Poa compressa	P	I	+	+	*	+	+	+	*	+	+	+	+	+	*	*	*	8638
Poa pratensis	P	I	+	+	*	*	+	+	*	*	*	*	*	*	*	*	*	1
Populus tremuloides	P	N	+	+	*	*	*	*	*	*	*	*	*	*	29	25	26	43
Rumex acetosella	A or P	I	1											4				
Trifolium pratense	P	I	1															
Agropyron repens	P	I		*	*	*	*	*	*	*	*	+	+	+	+	+	+	
Agrostis gigantea (A. alba)	P	I		1	1	3												
Rhus xborealis (R. glabra borealis)	P	N		1	1	1	2	7	14	9	6	6	9	9	4	1	1	1
Rosa sp.	P	N		4			1	1	1	2	2	1	2	2	2	2	3	11
Arabis lyrata	B or P	N			1	1							3	3	30	4	66	29
Arabis hirsuta (A. glabra)	B or P	N					1											
Prunus virginiana	P	N						2	2	2	2	2	2	3	4	3	4	
Quercus rubra (Q. borealis)	P	N							2	1	8	7	11	74	52	45	47	52
Agropyrum dasystachyrm	P	N									3				(also 1948)			
Amelanchier sp.	P	N											3	5	6	4	6	23
Asclepias syriaca	P	N											1	5	8	5	10	48
Acer rubrum	P	N												1	2	2	1	1
Conyza canadensis (Erigeron canadensis)	A	N												4				
Ceratodon purpureus														+	+	+	+	+
Asclepias exaltata (A. phytolaccoides)	P	N													2			
Rorippa sp.															1			
Pteridium aquilinum (P. latiusculum)	P	N													5	14	8	221

Figure VIII continued

Species	Duration	Origin	1930	'31	'32	'33	'34	'35	'36	'37	'38	'39	'40	'42	'45	'49	'50	'78
Solidago hispida	P	N														(1948,1)1	1	39
Prunus pennsylvanica	P	N														(1948,1)	4	
Polytrichum juniperinum																	+	+
Smilacina stellata	P	N																38
Danthonia spicata	P	N																215
Centaurea maculosa	B or P	I																22
Hieracium florentinum	P	I																4
Panicum xanthophysum	P	I																22
Toxicodendron radicans	P	N																18
Melampyrum lineare	A	N																13
Pinus strobus	P	N																2
Hieracium venosum	P	N																2
Solidago canadensis	P	N																5
Fagus grandifolia	P	N																1
Vaccinium angustifolium	P	N																5
Aster laevis	P	N																17
unknown grass																		12
Total number of vascular species per year			12	10	10	8	8	8	9	9	10	9	13	15	17	16	16	27

[a] Names applied by Gates in parentheses when different.

[b] A-Annual, B-Biennial, P-Perennial.

[c] The plus sign indicates "several"; the asterisk, "many".

[d] N-Native, I-Introduced.

Figure IX: Number of Vascular Species in Revegetation

Years covered	Laboratory site	Area (m^2)	1930	'31	'32	'33	'34	'35	'36	'37	'38	'39	'40	'42	'45	'48	'49	'50	'71	'77	'78
3	Research	38	24	22	14	16	17	18	18	19	18	23	22	20	24	20	22	28		17	
6	Botany	38	18	14	14	14	12	13	14	12	10	12	12	16	16	17	14	18	17		
16	Houghton	90	12	10	10	8	8	8	9	9	10	9	13	15	17	16	16	16			27

Figure X: Number of Individuals per Species per Transect

Species	North 1	2	3	4	5	6	Transect Number 7	8	9	10	11	12	13	14	South 15	Total
Poa compressa	741	498	308	717	544	502	808	722	823	842	694	640	576	606	617	8638
Solidago hispida	5		2	2	1		4	5	2	3	3	6	3	2	1	39
Arabis lyrata	13	4				2		10								29
Acer rubrum	1															1
Populus tremuloides	3		2			2		8	7	4		6	3	1	7	43
Quercus rubra	1	6	4	4			1	3	8	7	4	3	3	6	2	52
Rosa sp.	1						1	1		1	1		5	1		11
Pteridium aquilinum		4	5	13	2	8	8	18	14	15	23	47	26	31	7	221
Asclepias syriaca		3	8	9	5	3	8	2		1	3	2		1	3	48
Smilacina stellata	32	5		1												38
Amelanchier sp.	8	2				1			1	2	1	1	3	2	2	23
Danthonia spicata	2	3	24	55	46	48	19	12	4		1	1				215
Centaurea maculosa					3	13	6									22
Hieracium florentinum					1									1	2	4
Panicum xanthophysum							12	8			2					22
Toxicodendron radicans						8	5								5	18
Elymus canadensis						2	2		2							6
Poa pratensis								1								1
Melampyrum lineare										2	2	2		7		13
Pinus strobus													1	1		2
Rhus xborealis											1					1
Hieracium venosum									2							2
Solidago canadensis		3					2									5
Fagus grandifolia															1	1
Vaccinium angustifolium													3	2		5
Aster laevis	6													2	9	17
unknown grass	10					2										12
Total Number of Individuals per Transect	86	27	21	29	12	41	49	56	36	36	40	67	47	56	39	9488

Figure XI: Distribution of Species by Area

	Species in only one area: Research	Botany	Houghton	Only one area (total)	Species in two areas: Research Botany	Research Houghton	Houghton Botany	Two areas (total)	Species in all three areas: Research Botany Houghton	All three areas (total)	Total
1931-32	6 (46%)	3 (23%)	4 (31%)	13 (59%)	3 (50%)	1 (17%)	2 (33%)	6 (27%)	3 (100%)	3 (14%)	22
1940	3 (19%)	8 (50%)	5 (31%)	16 (57%)	6 (67%)	2 (22%)	1 (11%)	9 (32%)	3 (100%)	3 (14%)	28
1971-78	6 (21%)	5 (18%)	17 (61%)	28 (70%)	2 (67%)	0 (0%)	1 (33%)	3 (8%)	9 (100%)	9 (23%)	40

Figure XII: Trees in Houghton Site in 1978

Species	Total number	No. less than one meter tall	No. between one and two meters	No. greater than two meters tall
Quercus rubra	52	41	4	7
Populus tremuloides	43	35	2	6
Amelanchier sp.	23	21	2	
Acer rubrum	1	1		
Pinus strobus	2	2		
Fagus grandifolia	1	1		