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THE VEGETATION HISTORY OF THE
PAMET CRANBERRY BOG, NORTH TRURO, MASSACHUSETTS

by

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January 1980

ACKNOWLEDGEMENTS

We would like to acknowledge the assistance of those who made this study possible. Richard Bradshaw, Sheldon Nelson and Katie McGown helped in the coring of the Pamet Cranberry Bog. Thompson Webb III of Brown University graciously loaned coring equipment. Anne Hine analyzed the charcoal content of selected samples and Marjorie Hicks provided maps and information on the use of the Pamet Bog by early European settlers. Funding for the project was made available by Glen Kaye of the Cape Cod National Seashore.

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INTRODUCTION

Our understanding and appreciation of modern environments is almost invariably enhanced by a knowledge of how those environments developed, both through natural processes and as a result of man's activities. Because modern man is increasingly developing the ability to significantly alter the landscape in short periods of time, it is becoming increasingly important that we study the nature and extent of the changes that occur. National Parks are excellent areas in which to do this, both because they are established to preserve unique environments and because developments that are undertaken are done so only after careful consideration of the possible outcome.

Changes are inherent in all environments (or ecosystems) and are best understood by direct observation. We are often unable to do this, however, either because the developmental processes we are interested in occur over long periods of time, or because current conditions are the result of past changes, examples of which are no longer available. In the first category are succession, long term climatic changes and evolution. In the second are such things as sea level rise, post glacial species migrations and extinctions that result in unique plant and animal communities, and the effects of native peoples on the landscape. Where these situations occur it is the task of paleoecologists to reconstruct, through indirect observations, changes that have taken place.

It is the objective of this study to accomplish such a reconstruction. We have examined the sediments of a bog in the Cape Cod National Seashore, Massachusetts in an attempt to understand how the bog has developed since its earliest formation and to learn how European man altered natural processes in the bog as he converted it to the production of a commercial cranberry crop. The results of the study will assist park personnel in interpreting environmental change for bog visitors and will provide data upon which future developments can be based.

STUDY AREA

The study site -- the Pamet Cranberry Bog -- is located in North Truro, Barnstable County, Massachusetts ($42^{\circ}00'$ N. Lat., $70^{\circ}02'$ W. Long). The bog is approximately 27 acres in size and lies within the Cape Cod National Seashore. It is on the outer arm of Cape Cod approximately one-half mile west of the Atlantic Ocean and 6 miles ESE of Provincetown (see Figure 1). The surface of the bog is presently 8 feet above mean sea level and the surrounding sand hills and dunes rise to an elevation of 100 to 120 feet.

SETTING

Cape Cod is geologically quite young, having been formed 10-20,000 years ago at the close of the Wisconsin Glacial Stage. The material from which the Cape was formed is entirely of glacial origin. Till of the Sandwich Moraine makes up the northern half of the Cape's inner, east-west arm. Extending south from this is the Mashpee Outwash Plain which is comprised of coarse-textured sands. The north-south forearm of Cape Cod is a pitted sand plain formed from material deposited by water melting from the South Channel Ice Lobe to the east. The South Channel Lobe apparently left a moraine that has, in the 12,000 years since glacial retreat, been eroded by the sea. As much as two miles of land may have eroded from the Cape's eastern shore with some of this material forming the Provincelands near Provincetown. The outwash plain slopes westward and, in the Truro area, is dissected by hanging valleys truncated by westward moving dunes. Both the Pamet and Little Pamet Rivers occupy such valleys, which give further evidence of a former moraine to the east. The outwash plain itself is dotted with small ponds and bogs occupying kettle holes formed when slowly melting blocks of ice left by the glacier were buried by outwash deposits. These ice block depressions may have taken up to 2,000 years to form

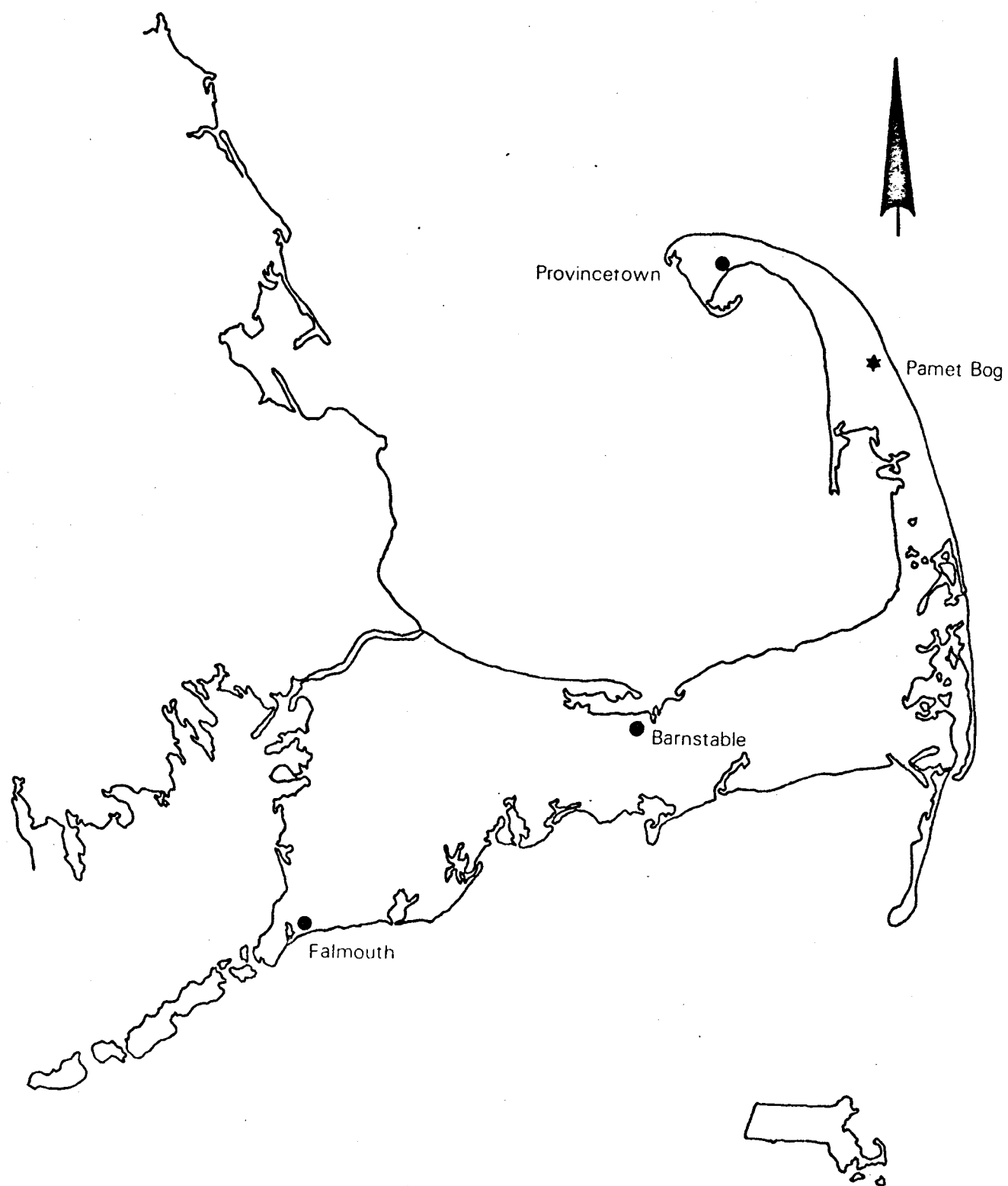


Figure 1. Map of Cape Cod showing the location of the Pamet Cranberry Bog.

following the retreat of the ice. The Pamet Cranberry Bog occupies one or more of these depressions and lies just north of the Pamet River.

When glaciers covered southern New England sea level was 300-500 feet lower than it is today (Strahler 1966). As the ice sheets melted they released vast quantities of water and sea levels rose rapidly. Twelve thousand years ago, when revegetation of southern New England first began, sea levels stood 120 feet lower than today (Upson, Leopold and Rubin 1964). During the Holocene (the last ~10,000 years) sea levels continued to rise so that they stood ~35 feet below current levels 6000 years ago and at -6 feet at 2000 B.P. (Redfield 1965). Rising sea levels forced the water table on Cape Cod to rise and kettle holes that were originally dry began to fill with water. Depending upon their depth and elevation above sea level kettles filled either with peat and became bogs or with water and became ponds. The actual date for the initiation of sediment filling varies from one kettle to the next, but those that we have visited appear to have been dry through most of the first half of the Holocene.

In addition to raising ground water levels, the rising sea covered land that formerly was dry. Erosion of the coast resulted, but even if this had not occurred the coast would have been one to two miles further east when the Pamet Cranberry Bog began to form 6-7,000 years ago.

Post glacial vegetation changes in southern New England have been the subject of many studies. These have been reviewed by Davis (1965) and, more recently, by Whitehead (1979). Several trends are recognized throughout the region. During late-glacial time a treeless tundra-like vegetation prevailed. This Herb Pollen Zone (T) was followed about 11,500-12000 BP first by an open spruce woodland and then by a closed spruce forest (Spruce Pollen Zone A). During the post glacial period (10,000 BP to the present) four vegetation zones are commonly recognized. A forest dominated by white

pine (Zone B) prevailed until 7500 BP. This was replaced by oak - hemlock (Zone C1) forests, which persisted until 5000 BP when hickory replaced hemlock (Zone C2). About 1800 BP chestnut migrated into southern New England. Oak-chestnut (Zone C3) forests were the dominant vegetation type at the time of settlement.

The vegetation changes outlined above are generally interpreted as indicating a warming of climate through 1800 BP and since that time a slight cooling.

The general patterns outlined above must be modified somewhat in coastal areas. Deevey (1948) examined the sediments of Oyster Pond at Falmouth and found that although oak was the dominant pollen type during pollen Zone C, pine and birch were next in abundance. Hickory was always less abundant than pine and birch and chestnut was present in only very small amounts.

Pine and birch cycled in reciprocal abundance throughout pollen zones C2 and C3. Deevey recognized four discrete cycles in which pine first declined rapidly and was replaced by birch and then gradually increased in importance at the expense of birch. Deevey speculated that these cyclical changes in the abundance of pine and birch were related to fluctuating ground water levels, presumably resulting from fluctuations in sea level. These changes could not have been great however, for more recent studies show a steady rise in sea level throughout the period.

No comprehensive descriptions of the forest of Cape Cod at the time of European settlement exist, but it is possible to estimate their composition and extent using a collection of early diaries and descriptions of the area in conjunction with records of population, land use and material production. Altpeter (1937) has provided such an estimate, a summary of which is as follows. Upland areas above 100 feet mean sea level probably were occupied by a fairly open forest containing large expanses of nearly pure pitch pine

or oak (scarlet, black and white) with scattered red maple, gray birch and white pine. These forests were maintained in a fairly open state by semi-annual burning by Indians. At somewhat lower elevations, where more moisture was present and fires were less intense a great variety of hardwood species, including red oak and beech were common. The frequency of white and chestnut oak, red maple and white pine also increased. Trees at these elevations were generally taller and of better form than those at the higher elevations, and the understory contained more shrubs and vines. At elevations below about 75 feet the presence of even more water produced a more mesophytic forest consisting of white pine, pitch pine, hemlock, beech, yellow birch, ash, hickory, red maple, white pine, red oak, black gum and holly. Many of the bogs contained nearly pure stands of Atlantic white cedar. Other low areas were dominated by shrubs.

The results of our study suggest that the above descriptions are applicable only in a general way and probably are more accurate for the Sandwich Moraine than for the drier outwash plains of the outer Cape.

The earliest records specific to the Pamet Cranberry Bog include a map of the area drawn in 1848. The basic outline of the bog appears much as it does today with the open pond evident in the southeast corner. The 1848 map indicates that the bog and surrounding hills were treeless. The nearest stand of trees was ~2000 feet to the northwest. The bog was first cultivated for cranberries in 1888 by James F. Howe. During cultivation it was standard practice to add a layer of sand to the bog surface each year. The sand was brought from the surrounding hills, which were also used for grazing until 20 years ago (Marjorie Hicks, personal communication).

Cranberry cultivation ceased at the Pamet Bog in 1961, and the property was sold to the Cape Cod National Seashore in 1963. A dense stand of Myrica, poison ivy, scattered cranberry plants and other shrubs occupied the site in 1978. In some parts of the bog pitch pines invaded the peaty soil 15 to

18 years ago and have attained heights of 10 to 15 feet. It is unlikely that these trees were old enough to produce abundant pollen, but 8 to 12 year old pitch pine saplings that are open grown are capable of flowering (Fowells 1965), and some locally produced pine pollen was probably incorporated in the peat in the last 5 years.

During the summer of 1978 the southern half of the east bog was cleared, and the area is presently being replanted for cranberry production. Cores 1 and 2 were taken from this cleared area.

METHODS

Three sediment cores were recovered from the Pamet Bog on June 7, 1979. Coring locations are shown in Figure 2. At each site the uppermost 20-40 cm were predominantly sand (presumably from previous sanding of the cranberry plants). Surface material was, therefore, removed with a shovel. Below the sand, sediments were composed of humified peat. These were sampled either with a 5 cm - diameter modified Livingston piston corer or, near the surface a 25 cm long, 2 cm diameter Davis corer. Sediment depths at the three locations were: core 1 - 7.68 m, core 2 - 3.01 m, core 3 - 3.12 m. In each instance peat graded directly into coarse-textured sand and pebbles at the base. No limnic sediments were encountered in any of the cores. Chunks of wood were encountered at several points in core 1, especially at a depth of approximately 1 m where large fragments made recovery of a complete core difficult. We were unable to recover sediments from the 2 - 3 m interval at site 1. The high water content and unconsolidated nature of the peat made recovery impossible with the available equipment. Compaction of the peat during coring occasionally resulted in our recovering a core that was shorter than the distance driven with the tube. Discrepancies of this nature were accounted for in later sub-sampling.

After the cores were recovered they were carefully wrapped in cellophane and aluminum foil and returned to Amherst for processing. Sub-samples for pollen and charcoal determinations were removed at approximately 25 cm intervals from core 1 and at the surface of cores 2 and 3. Sub-samples were of either 1 or .5 cc depending upon their presumed pollen content. Preparation for pollen analysis followed the procedure of Faegri and Iversen (1964) and included treatment with 10 percent KOH, 10 percent HCl, 48 percent HF and acetolysis solution. Subsamples containing large plant fragments were sieved through 250 μ mesh nylon screening prior to chemical treatment.

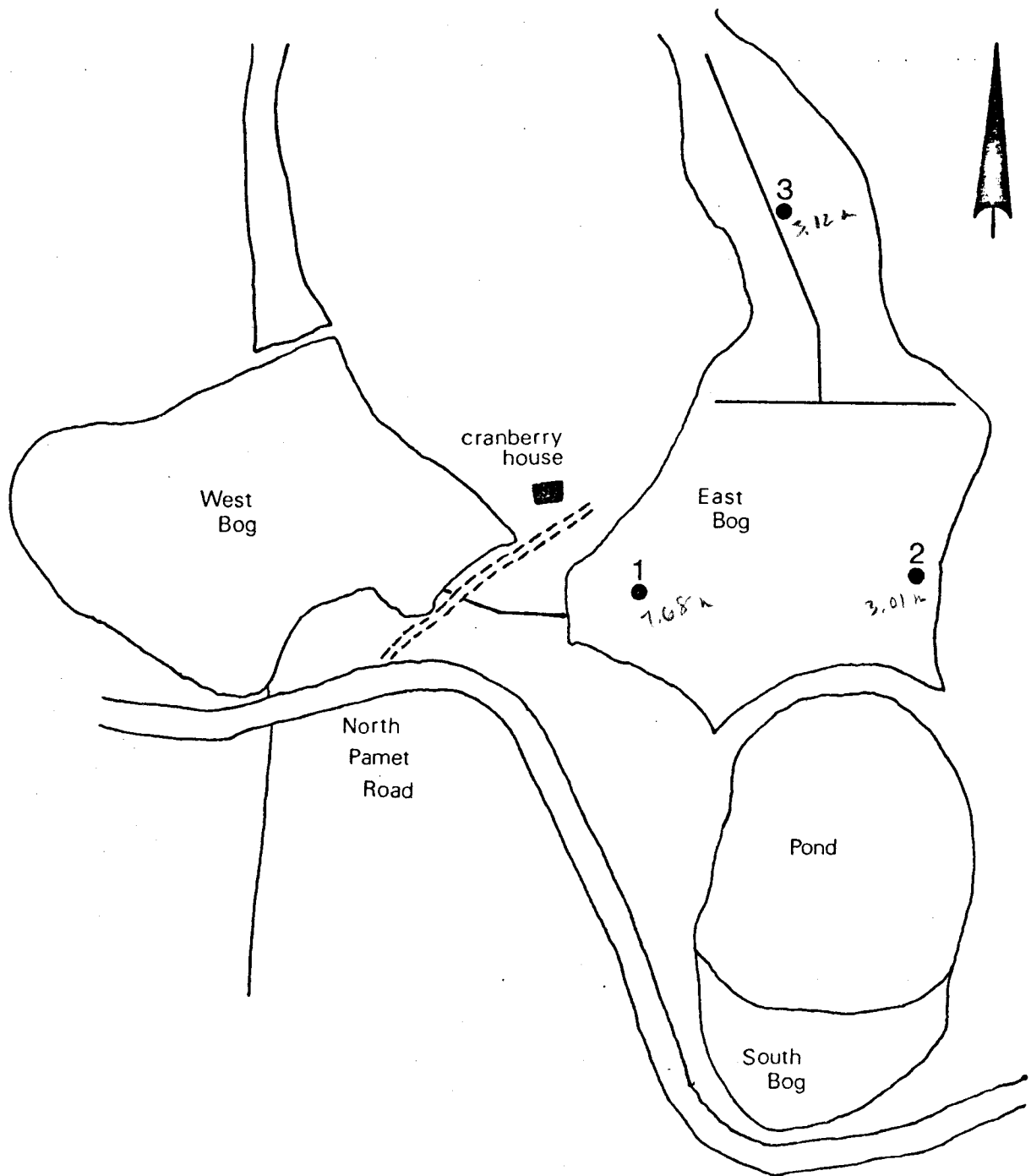


Figure 2. Map of the Pamet Cranberry Bog showing core sites 1, 2 and 3.

A known quantity of reference pollen (Eucalyptus in glycerin at 158,750 grains per cc) was added to each sub-sample prior to preparation. This procedure allowed the calculation of pollen concentrations and facilitated the comparison of pollen and charcoal data. After processing, residues were mounted in silicone oil.

Thin slides (20-30 μ) of the prepared sediment were made, and we attempted to count at least 150 fossil pollen and spores per sample. In some instances the peat was so badly humified that the preparation procedures inadequately concentrated the pollen, and it was impossible to count more than 75-100 grains. In these samples fossil pollen was often highly degraded, and this further complicated counting and identification.

Routine counting was done on a standard light microscope equipped with a 10X eyepiece and a 40X objective (n.a. = .65). Difficult grains were viewed with an oil-immersion objective (90X, n.a. = 1.25). Pine pollen was identified as being Diploxylon (jack, red, or pitch pine), Haploxylon (white pine) or undifferentiated. An attempt was made to identify unknown grains by comparing them with known reference material and through the use of keys (McAndrews et al. 1973, Kapp 1969).

Charcoal determinations were made from the pollen slides using the method first described by Waddington (1969) and later modified by Swain (1974). Briefly, the area of individual charcoal fragments is measured with an eyepiece graticule. Fragments are tabulated by size classes, and the sum of the area in the individual size classes is expressed relative to the number of fossil pollen grains. A graticule 16.7 square microns was used, and sample-to-sample standardization was accomplished by counting Eucalyptus grains along with charcoal fragments. Fragments were tallied in 7 size classes; 0.25-.5, .5-1.0, 1.0-2.0, 2.0-4.0, 4.0-8.0, 8.0-16.0, and 16.0-32.0 squares. Particles smaller than .25 square were ignored, whereas those

larger than 32.0 squares were tabulated individually. Swain (1974) demonstrated that the above technique yields reproducible results level-by-level.

Dating of the sediments was accomplished by radiocarbon (C-14) analysis. Five centimeter intervals of the 5 cm-diameter core from site 1 were removed for dating. Samples of the 105-110 cm and 400-405 cm intervals were sent to the Radiocarbon Dating Laboratory, University of Miami. An additional sample from 738-743.5cm was sent to the Radiocarbon Laboratory, University of Wisconsin. In each instance one-half of the indicated interval was used for dating. The remainder was saved for possible future analysis.

RESULTS

Pollen and charcoal data for core 1 are presented in Figure 3. At the left of the diagram is a depth scale with the series of horizontal bars at each depth representing the percentage of fossil pollen grains in the indicated type. Percentages for each depth were calculated on the basis of all pollen and spores counted in the sample from that depth. Although only those taxa that occur in fairly high frequencies or show important fluctuations are included in Figure 3, the percentages for the summary categories (trees, shrubs, herbs and spores) were arrived at by summing all grains in the respective groups. When added to the percentages of unidentifiable grains, the sum of these four categories equals 100 percent. Percentages for pollen and spore types that are not individually represented in Figure 3 are included in Appendix B.

At the right hand side of the pollen diagram are two distinctive profiles. One labelled "Pollen Sum" shows the total number of fossil grains counted at the indicated depth. The second shows the ratio of charcoal area to fossil grains. Note that charcoal determinations were not made at several depths (195, 315, 375, 400, 475, 525, 550, 625, and 650).

Radiocarbon dates are available for three depths in core 1. These are 1910 ± 100 BP for the 105-110 cm interval, 3695 ± 105 BP for the 400-405 cm interval and 6980 ± 85 BP for the 738 - 743.5 cm interval. Peat accumulation rates are as follows: 0-107.5 cm, .056 cm/yr; 107.5-402.5 cm, .165 cm/yr; and 402.5-741 cm, .10 cm/yr. An overall rate (0-741 cm) is .11 cm/yr. Possible reasons for this disparity between the first two dates will be discussed later. Using the last rate, an extrapolation to the base of the core (768 cm) yields an estimated age of 7235 BP. This is about 1500 years older than the date that Butler (1959) gives for the initiation of peat formation at Barnstable Marsh and is the oldest date available for Cape Cod sediments.

PAMET CRANSBERRY BOG

BARNSTABLE CO., MASSACHUSETTS

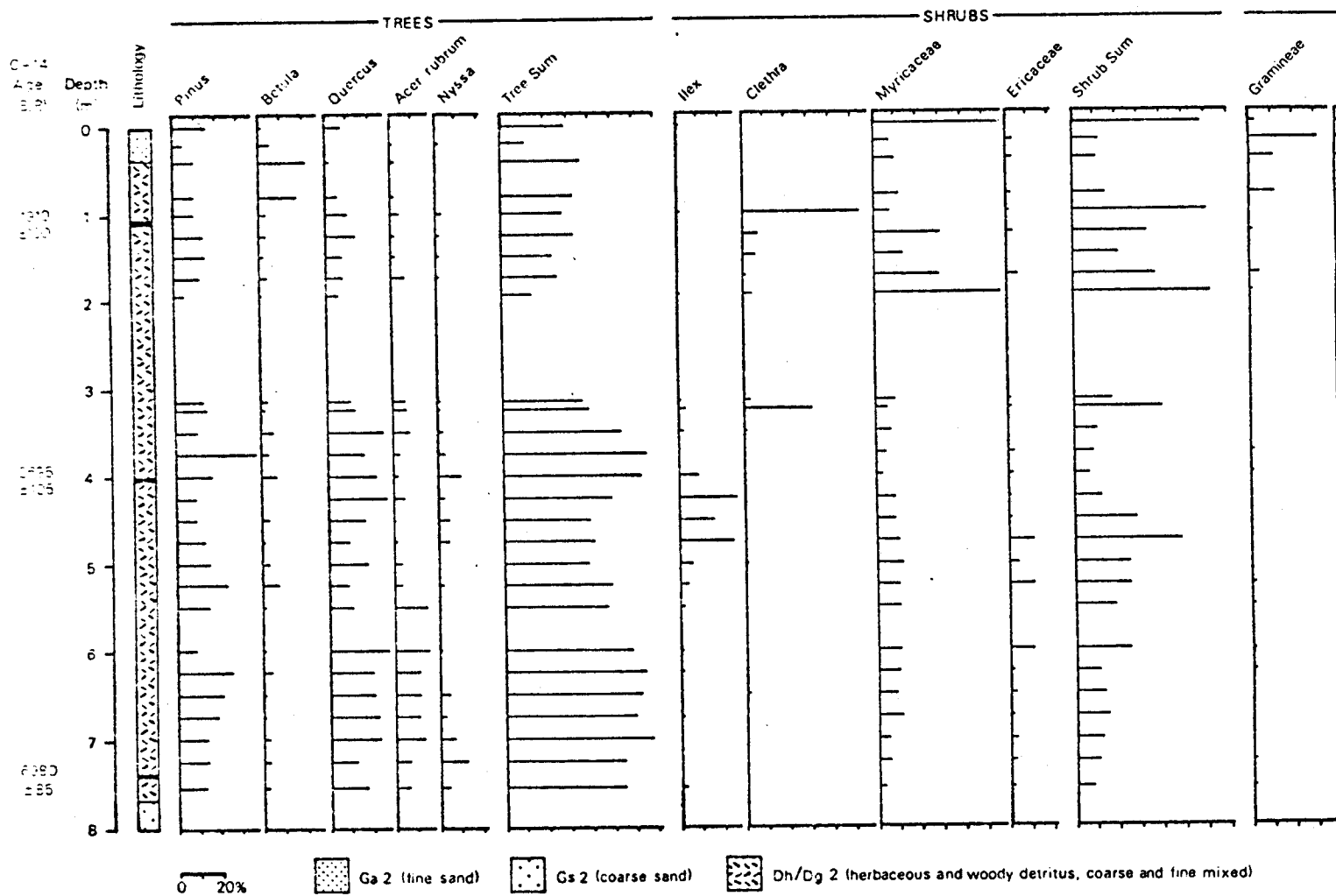


Figure 3. Percentage pollen diagram and charcoal profile for the Pamet Cranberry Bog

Of the tree species represented in Figure 3, pine and oak show the highest percentages overall. Both taxa show somewhat higher values in the lower half of the core. Examination of the relative abundance of Diploxylon and Haploxylon pine pollen shows that white pine is abundant only at 375 cm (see Appendix B). Although we did not try to differentiate the Diploxylon grains, most appeared to be larger than the Haploxylon grains, and this suggests that pitch pine was the dominant species (Whitehead 1979). As mentioned earlier, pitch pine dominates the present pine forests of Cape Cod.

Differentiation of oak pollen is not possible at the species level, but any of several species could have contributed pollen to the Quercus sum. Although percentages of both oak and pine appear to fluctuate in a cyclical manner, the pattern is not as observed by Deevey (1948) at Oyster Pond. Birch pollen percentages are low at all levels except 40 and 80 cm. Fluctuations in tree pollen appear to be more directly related to reciprocal variations in shrub percentages. Because almost all taxa included in the shrub sum are lowland species, it is possible that changes in the upland vegetation are masked by changes in the lowland vegetation. To circumvent this problem we recalculated percentages for pine, oak and birch based upon the sum of upland tree species (not red maple and black gum). The results are presented in Table 1. Few systematic trends are evident, perhaps in part because the sum of upland tree pollen is frequently quite low (30 grains or less). Percentages based upon low sums are inherently quite variable. It is, never-the-less, of considerable interest that the ratio of pine to oak is consistently high at the surface. By contrast, oak values are higher throughout much of the lower half of the core. These data suggest that the present pine-dominated vegetation may be an artifact of European man's activities. Oak is entirely absent at 20 cm, and this

Table 1. Pollen percentages for pine, birch and oak based upon Upland Tree Sum only.

Depth (cm)	Pinus	Betula	Quercus
0-1	74.0	1.6	21.1
0-2	59.3	5.6	28.2
0-3	67.2	11.9	17.9
20	26.8	23.9	0
40	29.2	60.7	4.5
80	27.4	51.3	14.2
100	42.4	12.1	42.4
125	45.9	8.2	42.6
150	64.3	7.1	28.6
175	50.9	10.5	31.6
195	31.6	2.5	40.5
315	42.0	8.7	34.8
325	43.4	3.8	37.7
350	24.6	11.6	55.1
375	63.4	5.2	27.5
400	34.8	12.8	45.4
425	25.4	0	68.7
450	30.7	10.3	51.3
475	55.6	2.5	39.5
500	43.5	7.1	49.4
525	54.5	18.2	22.7
550	47.6	3.9	33.0
600	21.8	3.1	65.6
625	49.0	7.6	38.2
650	45.7	2.9	45.7
675	40.7	2.8	48.3
700	29.8	5.2	50.3
725	42.3	6.4	38.3
755	31.8	5.2	39.5

could reflect selective cutting for fuelwood in the late 19th and early 20th Centuries.

The effects on pollen percentages of plants rooted in the bog can be seen by examining values for some of the shrub species. The two very high values for Clethra at 325 and 100 cm are typical. Rather than indicating that the entire bog was covered with white alder, these values probably reflect the presence of an individual plant or group of plants growing directly at the core site. Other shrubs show a more systematic pattern of increasing and decreasing percentages and these may reflect more wide spread populations. Ilex, for example, is quite rare throughout most of the core but shows consistently high values between 475 and 525 cm. MYRICACEAE (sweet gale) pollen percentages are consistently low (5-10 percent) but increase substantially at 195 cm, fall again at 125 cm and rise, once more, at the surface.

The highest values for all of these shrub taxa probably reflect plants growing directly on the core site. A low shrub that produces much pollen would be more effective in concentrating pollen in a small area than would a tree, whose pollen would have to fall farther to the ground and hence be subject to increased dissipation by wind.

Pollen of the ERICACEAE family, which includes cranberry, is found throughout the profile with the highest values (~10 percent) between 4.5 and 6 m. The ERICACEAE are insect polinated and values in excess of 3-5 percent would represent a substantial population. Unfortunately we can not differentiate the pollen of the many genera and species of Ericads, but it is quite possible that cranberry plants grew in the Pamet Bog throughout the last ~7,000 years.

The herb sum is relatively stable and quite low in the bottom seven meters of the core. At 80 cm, however, values increase dramatically and remain high, until they again decline at the surface. At their peak, the

herb sums are comprised chiefly of grasses, ragweed and Rumex pollen. All of these are plants commonly associated with agricultural activities.

Spore percentages fluctuate at levels <10 percent from the bottom of the core through 375 cm. At 350 cm values begin to rise, peak at 315 cm and remain high through 150 cm. Spores of Sphagnum moss are most abundant in these levels.

Percentages of unidentifiable grains vary widely but generally are quite high. This category includes only those grains that are hidden, crushed, degraded or otherwise unrecognizable and does not include grains that are in good condition but simply unknown. The large amount of extraneous material on the slides and the "caramelized" nature of the peat contributed to the high percentages of undifferentiated grains. The problem of "caramelization" was particularly troublesome. Throughout much of the middle portion of the core the peat has been altered in some as-yet-unexplained manner. Fragments of peat have an amorphous appearance and are "caramel-colored" In this state the peat appears quite resistant to acetolysis, which normally removes much of the organic matter in sediments. The abundance of non-pollen organic matter complicated the counting of slides for pollen analysis and contributed to the low pollen sums shown at the right of Figure 3. Although the counting of 300-500 grains per level is preferred, we frequently had to dilute preparations to such an extent that pollen was extremely sparse. In some instances we counted two entire slides and still encountered only 100-150 grains.

Percentages for the three surface samples are compared separately in Table 2. Values for sites 1 and 3, which are well out on the surface of the bog, are quite similar, although site 3 has substantially higher percentages of grass and heath pollen. MYRICACEAE pollen dominates both assemblages.

Table 2. Percentages of selected pollen types for three surface samples from the Pamet Cranberry Bog.

Pollen Type	Sample		
	1	2	3
<u>Total Pinus</u>	20.5	26.0	14.0
<u>Betula</u>	0.5	2.5	2.5
<u>Quercus</u>	5.9	12.4	3.8
<u>Acer rubrum</u>	0	0	0
<u>Nyssa</u>	0	0	0
Total Tree Pollen	28.2	40.0	21.1
<u>Ilex</u>	1.4	0	0
<u>Clethra</u>	0	13.4	3.2
<u>MYRICACEAE</u>	56.4	8.9	42.9
<u>ERICACEAE</u>	0	4.0	9.5
Shrub Pollen	58.2	26.8	55.5
<u>GRAMINEAE</u>	2.7	2.5	10.7
<u>Ambrosia</u>	0.5	0.5	1.3
<u>Rumex</u>	0	1.0	0
<u>CYPERACEAE</u>	0	0.5	0.6
Herb Pollen	5.4	15.9	15.8
<u>Osmunda</u>	0	0.5	0.6
<u>Sphagnum</u>	0.5	0	0
Total Spores	2.7	2.0	1.9
Unidentified	3.6	7.9	5.7

Site 2, which is close to the eastern edge of the bog, shows markedly different values for several pollen types. Percentages of oak and pine are higher and MYRICACEAE values are <10 percent. By contrast, Clethra and Tubuliflorae pollen are more abundant, perhaps reflecting the presence of these plants in the transition zone between the upland and lowland vegetation. Although these data illustrate the problems associated with drawing inferences from single samples, variations are explainable if consideration is given to the environments surrounding the individual sampling sites.

The results of the charcoal analysis are summarized in the right-most profile of Figure 3. The data represent the ratio of charcoal area to reference pollen divided by the ratio of fossil pollen to reference pollen. A recent analysis of data from a lake in Minnesota suggests this ratio is the best means of expressing sedimentary charcoal data (Patterson and Nordheim in preparation).

Much charcoal was deposited in the bottom-most samples from core 1 (755 and 725). Little charcoal was encountered throughout much of the remainder of the core. Only at 175 cm were fragments abundant. Minor increases in the amount of charcoal occurred at the time of settlement. These results give a general idea of the occurrence of fire near the bog, but sampling intervals were too great to give a concise picture of the fire history of the outer cape. Charcoal values are, however, surprisingly low throughout much of the core. The data suggest that much work needs to be done to identify natural fire-vegetation interactions on Cape Cod. Early accounts of the precolonial forest (Altpeter 1937, Day 1953, and others) indicate that fire was more prevalent than do the sedimentary data we present.

DISCUSSION

The pollen sequence presented here represents the vegetational history of the Pamet Cranberry Bog over the last 7,000 years. It apparently took nearly 5000 years for water tables on Cape Cod to rise sufficiently to allow the accumulation of organic sediments in the bog. When peat began to form sea levels were ~40 feet lower than today and the coast may have been several hundred yards farther away.

Red maple pollen comprises 7-15 percent of the total fossil pollen in the lower portion of the core. Maples are pollinated by insects and their pollen is rarely abundant in sediments. The values noted above are thus very high and suggest that red maple dominated the vegetation of the bog. Wood fragments tentatively identified as red maple were found at 475 and 563 cm and these further substantiate the presence of red maples in the bog. Nyssa pollen is also abundant in the lower portion of the core, and this assemblage of red maple and tupelo pollen resembles the red maple - tupelo community that Godfrey (1978) describes in the present vegetation of the Cape Cod National Seashore. The paucity of Chamaecyparis pollen throughout the core makes it unlikely that the bog ever supported an extensive stand of Atlantic white cedar.

The decline in red maple, tupelo and total tree pollen above 600 cm corresponds with a rise in MYRICACEAE, ERICACEAE and later Ilex pollen. The increasing importance of shrub species suggests that nutrients may have become less readily available as the peat grew deeper. Many shrubs are able to grow on sites of low nutrient status and Myrica, in particular, has recently been shown to be able to fix atmospheric nitrogen (Sprent 1978). The general trend of increased poludification seems to be somewhat reversed between 3 and 4 meters, and this could indicate a slightly drier climate. If water levels

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fell, decomposition of the peat could have occurred and nutrients could have become more readily available. Butler (1959) suggests that the cape's environment was somewhat milder during this period.

Above 3.5 m tree pollen percentages fall, shrub percentages rise and Sphagnum spores increase in abundance. These changes suggest a return to a moister, more nutrient deficient environment. Percentages for red maple remain at about 5 percent, however, and red maples must have continued to grow either on the bog or at its fringes.

It is unfortunate that the 2-3 m portion of the core was not recovered. Although no major hiatus occurs during the interval, total shrub pollen increases dramatically at the expense of the tree pollen. MYRICACEAE pollen, in particular, becomes much more abundant. The pollen of shrubs have dominated the pollen assemblages of the last 2500 years. Increases in the abundance of fern and moss spores are also apparent, and, together, these trends indicate that trees have become a less important component of the bog's vegetation.

A major change in upland pollen assemblages is evident above 100 cm. Birch pollen increases in importance at the expense of oak and pine, and indicators of agriculture such as grass, ragweed and sorrel become much more abundant. These changes are indicative of the land clearing and settlement activities of European man. The precise chronology of the upper meter of sediment is somewhat confused. The C-14 date of 1910 BP for the 105-110 cm interval seems rather old if the 60-80 cm interval represents initial settlement (mid 1600's). We have no reason to suspect the accuracy of the C-14 date, however, and instead hypothesize that some peat in the uppermost portion of the bog has been removed. It seems quite likely that peat could have been harvested from the bog for fuel during the 18th and 19th Centuries. Both Altpeter (1937) and Strahler (1966) note that this was a common practice on Cape Cod. Some surface peat may have wasted away when the bog was initially

drained for cranberry production. The initial rise in grass pollen at 80 cm may indicate that the bog was cultivated for hay prior to its conversion to commercial cranberry production. Haying could also have resulted in disturbance of the surface peat.

There is little doubt that the uppermost 36 cm represents the last 90 years. Cranberry cultivation began in 1888, and a 2 to 4 inch layer of sand was spread over the bog at that time (Marjorie Hicks, personal communication). A thin layer of sand was spread over the bog in each of the succeeding 70 years, and this accounts for the sand at the top of the core we analyzed.

The presence of this sand could also account for the slow rate of peat accumulation observed in the upper one meter, for the weight of a thick layer of sand could compact the underlying peat.

All of these factors (peat harvesting, cultivation and drainage, and compaction) are reasonable explanations for the apparent truncation of the surface peat of the Pamet Cranberry Bog. A similar truncation was observed by Ogden (1959) who examined the sediments of Duarte's Cranberry Bog on Martha's Vineyard. He cited many of the factors mentioned above as possible reasons for the disturbance of surface sediments.

The sample from 20 cm indicates that upland tree pollen inputs were very low during this period, with the bulk of the upland pollen being that of grasses and ragweed. On the bog itself heath and MYRICACEAE were abundant but Sphagnum was absent.

At the bog's surface pine and oak again increase in abundance at the expense of birch and agricultural herbs. This reflects the reversion of the surrounding uplands to scrubby pitch pine and oak forests during the 20th Century. The fact that the bog is presently covered with Myrica is reflected in the high percentage of MYRICACEAE pollen.

SUMMARY

The pollen sequences presented here represent changes, over the past 7000 years, in the vegetation of the Pamet Cranberry Bog, North Truro, Massachusetts and its surrounding upland. Changes are, for the most part, gradual compared to those that presumably occurred during the late and early post glacial period when many species migrated to southern New England. On the bog itself, vegetation changes seem to reflect a gradual pooludification of the environment. As peat accumulated, nutrients became scarce and a red maple - tupelo forest gave way to shrubs and Sphagnum moss. Heath plants such as cranberry and blueberry have, however, been present in the bog since peat began to form.

On the upland, oak apparently was more important in the pre-colonial forest than it is today. Pitch pine, by contrast, is more abundant relative to oak now than in the past. In general, vegetation changes on Cape Cod have not been as distinct as those observed elsewhere in New England during the last half of the Holocene period. Specifically, there is little evidence that mesic forest species (beech, maple, hickory, birch and chestnut) have been an important vegetation component during the past 7000 years. The upland pollen assemblages we observed are those that one would expect to find on the dry, sandy soils typical of outer Cape Cod. The proximity of the ocean may also have tempered vegetation changes that have been observed elsewhere in New England.

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APPENDIX A
COMMON-SCIENTIFIC NAME
COMPARISONS

1	Ash	<u>Fraxinus</u> genus
2	Atlantic white cedar	<u>Chamaecyparis thyoides</u>
3	Beech	<u>Fagus grandifolia</u>
4	Birch	<u>Betula</u> genus
	Gray birch	<u>B. populifolia</u>
	Yellow birch	<u>B. alleghaniensis</u>
5	Chestnut	<u>Castanea dentata</u>
6	Ericads	<u>ERICACEAE</u> family
	Heath	" "
	Blueberry	<u>Vaccinium</u> genus
	Cranberry	" "
7	Grass	<u>GRAMINEAE</u> family
8	Hemlock	<u>Tsuga canadensis</u>
9	Hickory	<u>Carya</u> genus
10	Holly	<u>Ilex</u> genus
11	Maple	<u>Acer</u> genus
	Red Maple	<u>A. rubrum</u>
12	Oak	<u>Quercus</u> genus
	Black Oak	<u>Q. velutina</u>
	Chestnut Oak	<u>Q. prinus</u>
	Red Oak	<u>Q. rubra</u>
	Scarlet Oak	<u>Q. coccinea</u>
	White Oak	<u>Q. alba</u>
13	Pine	<u>Pinus</u> genus
	White Pine	<u>P. strobus</u> (Haploxylon pine)
	Red Pine	<u>P. resinosa</u>
	Jack Pine	<u>P. banksiana</u> } (Diploxylon pine)
	Pitch Pine	<u>P. rigida</u>
14	Poison ivy	<u>Rhus radicans</u>
15	Ragweed	<u>Ambrosia</u> genus
16	Sedge	<u>CYPERACEAE</u>
17	Sorrel	<u>Rumex</u> genus
18	Spruce	<u>Picea</u> genus

- | | | |
|----|---------------------|--|
| 19 | Sweet gale | <u>MYRICACEAE</u> family
<u>Myrica gale</u> |
| 20 | Tubuliflorae | a type of pollen characteristic of
certain members of the <u>COMPOSITAE</u>
family |
| 21 | Tupelo
Black gum | <u>Nyssa sylvatica</u> |
| 22 | White alder | <u>Clethra alnifolia</u> |

APPENDIX B

POLLEN PERCENTAGES FOR TYPES
NOT PRESENTED IN FIGURE 3

Core- Depth(cm)	Picea	Cupressaceae	Pinus Undiff.	Pinus Haploxylon	Pinus Diploxylon	Populus	Fraxinus spp.	Ulmus	Ostrya- Carpinus
1-0		0.5	15.1	0.90	4.5				
2-0			22.3	0.5	3.2				0.5
3-0			12.0		2.0				
1-20			4.3		.5			0.5	
1-40		0.8	6.5	1.1	2.3				1.1
1-80			5.2	2.7	.5			0.5	
1-100			8.9						
1-125	0.5		10.6	1.2	2.0				
1-150			12.4		1.6				
1-175			8.6		3.3	0.8			
1-195									
1-315			7.9	0.8	3.3				0.8
1-325		1.2	12.0	1.2	0.6	1.2	1.6		
1-350			4.5	2.6	2.6				
1-375			24.1	7.4	6.2	0.8			
1-400	0.7		10.6	1.4	4.8		0.7		
1-425		1.2	8.7		1.2		2.3		
1-450	0.8		8.1	0.8	0.8			0.8	0.8
1-475			7.6	1.7	3.4				
1-500			12.1		3.3				
1-525			16.7		6.9				
1-550			12.5		3.2			0.6	
1-600			5.9	2.6	0.7				0.7
1-625			23.9	0.7	1.0			0.7	
1-650			16.4	0.7	3.9		0.7		
1-675	0.6		11.0	1.3	6.3		1.2		
1-700			11.5		2.5	0.5		0.5	2.0
1-725	0.7		8.9	2.2	3.7	0.7			0.7
1-755	3.0		7.9		6.0	3.0	0.8		

Salix	Acer saccharum	Tilia	Juglans nigra	Juglans cinerea	Carya	Tsuga	Platanus	Fagus	Castanea	Ceano- thus	Alnus
0.5							0.5			0.5	
0.5		0.5				1.0	0.6	0.5			0.4
						0.8					0.5
0.5								0.5 0.6	0.5		1.1
	0.8								1.0		0.5 2.3 1.6
						2.5 0.6		0.8 1.6 2.6			0.8 1.2
0.8 1.4	0.7		0.7			0.8					0.8 0.7 1.2 0.8
	0.8 0.6					0.8					1.7
	0.6				1.2			3.2 0.7			0.7
0.7				0.7		1.3 1.3 1.3 0.6 2.0 0.7 0.8		0.7 1.3 1.0	0.7		0.6 0.7 0.8
0.7 0.8	0.6 1.0 0.7 1.5									0.8	
		0.8									

Viburnum	Corylus	Vitis- Rhamnus	Tubul- iflorae	Ranuncul- aceae	Urtica	Rosaceae	Spargan- ium	Lycopodium	Equisetum
			6.0	.5		2.5 2.5	2.3 2.5 0.6	.5 0.6	
	0.5	1.0	1.6 0.8 2.2		.4				.4
0.5			2.9 0.8 0.8						1.6
1.6 0.3			1.7				0.3		
	0.8 0.7 1.2 0.8		1.6 3.3						
	1.9		0.7 2.0					.7	
	0.7 0.8								