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OBJECTIVES AND INTRODUCTION

The objectives of this exploratory pollen analysis of selected samples from a sediment core taken at Hargrove Lake, Davy Crockett National Forest, Houston County, Texas, are to ascertain the quality of pollen preservation in the lake bottom matrix and to evaluate the potential of the pollen spectra deposited in the lake for providing information about former environmental conditions on Davy Crockett National Forest. Hargrove Lake is a natural lake in the floodplain of the Neches River in Houston County, Texas (Figures 1 and 2). The Hargrove Lake site (41HO150) lies a short distance to the west (Jurney 2000). The lake is presently is surrounded by a 10 m wide stand of buttonbush (*Cephalanthus*). These plants are three m tall and have two to ten cm diameter trunks. A woodland dominated by water oaks (*Quercus nigra*) and sweetgum (*Liquidambar styraciflua*) lies beyond the buttonbush. These trees are 30 to 40 m tall, and the woodland canopy is 90 to 98 percent closed. The lake is normally about 50 m wide by 200 m long, giving it a normal surface area of approximately 2.5 hectares. The mean depth of the lake at high water is about 90 cm. Bedrock marl underlies the area, and the lake retains water during even the most severe droughts. It should provide a continuous pollen deposition record.

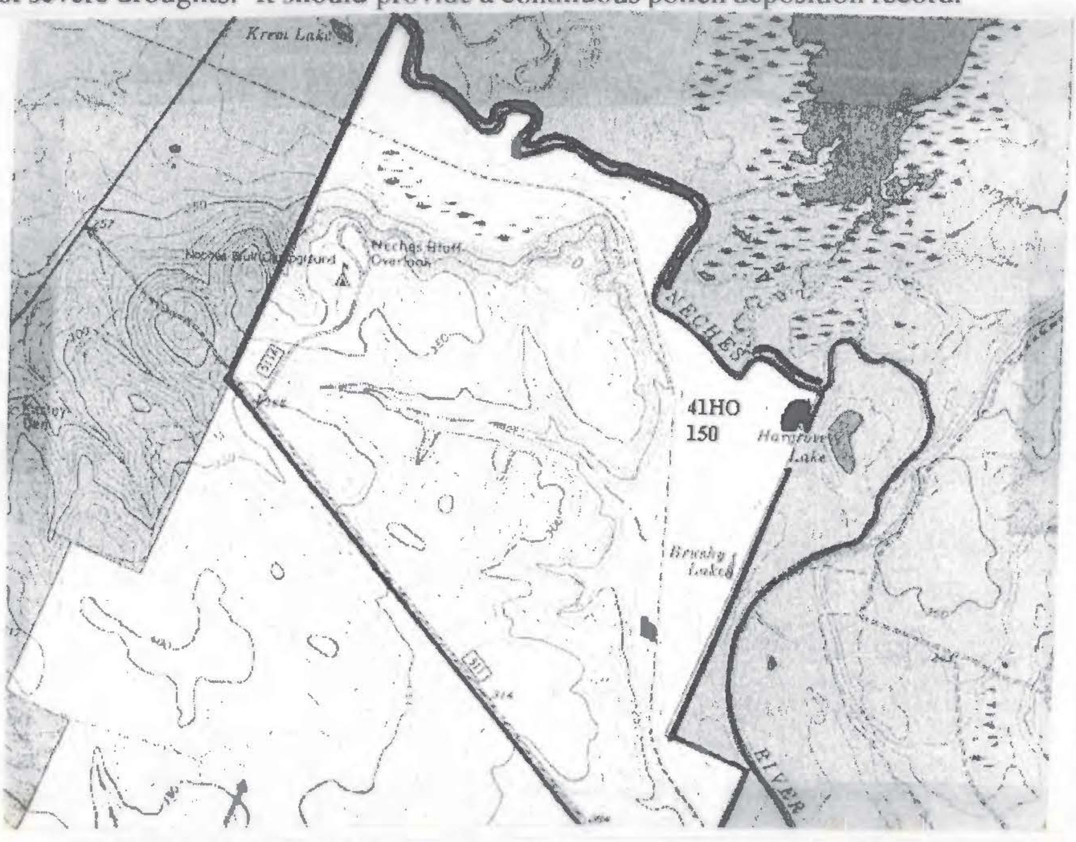

Figure 1. The location of Hargrove Lake adjacent to the Hargrove Lake site (41HO150).

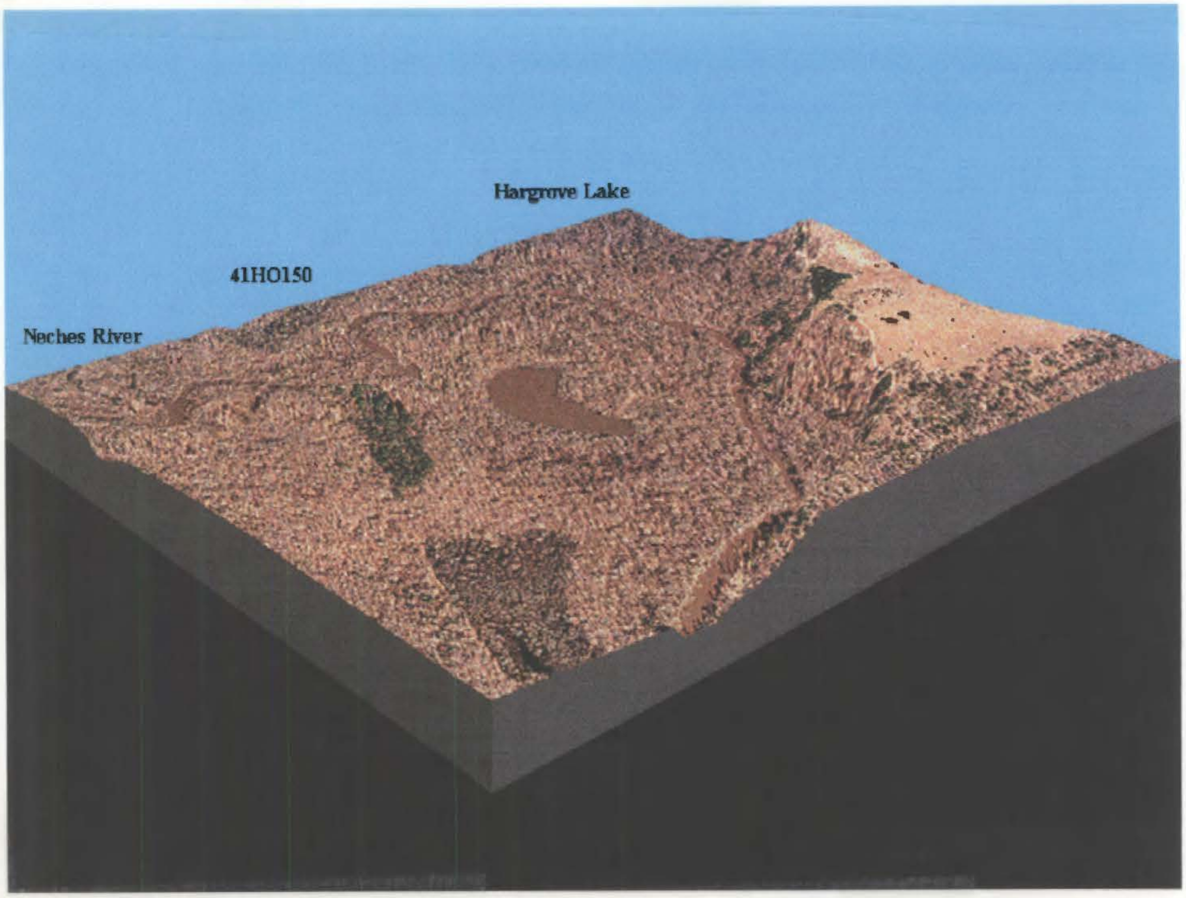

Figure 2. Three-dimensional infrared photograph of the Hargrove Lake area.

The size of the source area for the pollen in Hargrove Lake has yet to be determined. Tauber (1965:32) estimated from his theoretical pollen dispersal data for European forests that the effective source area for pollen deposited in a small lake or bog (100 to 200 m in diameter) should extend 300 to 1,000 m out from the basin. Eighty percent of the pollen grains in such small lakes come from the trunk space, but deposition can be markedly altered by filtration effects in vegetation of different densities (Tauber 1965:32). Such filtration could affect the size of the pollen source area at Hargrove Lake. The dense buttonbush surrounding the lake may capture much of the pollen transported in the trunk space of the woodland. The pollen transported across the top of the woodland canopy, normally only 10 percent of a small lake spectrum (Tauber 1965:32 and Figure 7), may contribute a larger proportion of the spectrum than predicted by Tauber's (1965:32) model. This could extend the effective pollen source area out from the lake a considerable distance.

It may be possible to evaluate the size of the Hargrove Lake pollen source area by comparing the concentrations and species composition of pollen caught in a series of traps. These should be placed above the woodland canopy at several intervals from the shoreline on the side of the lake from which the prevailing winds blow, above the buttonbush, within the buttonbush trunk space at upwind side of the lake, in the woodland trunk space at upwind side of the buttonbush, in the wind shadow at the edge of the lake below the buttonbush, at the center of the lake, and at the downwind edge of the lake.

METHODS

Sampling

Hargrove Lake was cored at its deepest point, where bottom sediments should be thickest, by then Davy Crockett National Forest Archaeologist David Jurney. The core was taken by driving a sharpened segment of 2 inch-inside diameter PVC pipe into the lake bottom sediments with a sledge hammer until movement was stopped by resistant material. The depth of the drive was marked on the outside of the core pipe, and it was manually withdrawn. The core pipe was then sealed at both ends with plastic to prevent contamination.

The core was shipped to the Tombigbee Ranger District, Ackerman, Mississippi, for sampling and analysis. The core pipe was split in the laboratory with a table saw set to cut only the thickness of the PVC. Once cut, half of the split core pipe was removed and the other half used as a sampling tray. The recovered core was measured, and its stratigraphy was noted (Figure 3). Sediment colors were recorded using the Munsell system, and matrix textures were estimated from the feel of the sediment when rubbed between thumb and finger. The core was cut into 2 cm contiguous samples (no space between them), and the outer 0.5 inch around the circumference of each sample was removed to preclude contamination from the core pipe wall.

Laboratory Methods

Four samples spaced through the sediment profile—PS 26 (4/6 cm below the surface), PS 19 (18/20 cm bs), PS 10 (36/38 cm bs), and PS 2 (52-54 cm bs)—were selected for exploratory analysis. Pollen extraction generally followed Mehringer's (1967) mechanical/chemical procedure. His first two HCL washes and HNO^3 step were eliminated, and the strength of the final NaOH wash was reduced to 0.05 percent. The acetolysis process was not employed. Residues were mounted in glycerol for viewing, and all samples were tabulated within five days of extraction to reduce the pollen grain size distortion that sometimes occurs with this mounting medium (Anderson 1960). Standard Southwestern 200 pollen grain tabulations (Martin 1963:31) were employed. The pollen was identified at 430X, and problematical pollen grains were examined under oil immersion at 970X.

Approximately 28,000 *Lycopodium* pollen grains were added to each sample at the start of extraction so that Benninghoff's (1962) exotic pollen addition method could be employed in computing pollen concentrations per gram of sample. Pollen concentration figures were not calculated for individual taxa. These would not be meaningful in the absence of chronological control over sedimentation rates and might be mistaken for pollen influx data. All pollen grains that were too degraded to be identified were tabulated to provide control over corrosion factors. Unidentifiable pollen grains were not incorporated in any sum from which the frequencies of other types were computed; but the data for this pollen group, as a percentage of total identifiable and unidentifiable pollen, are presented for each site sample in Figure 4. The terms "corroded" and "degraded" are used interchangeably and refer to any kind of pollen deterioration other than tearing. They are not intended as references to the specific classes of deterioration defined under these terms by Cushing (1964) and Havinga (1984).

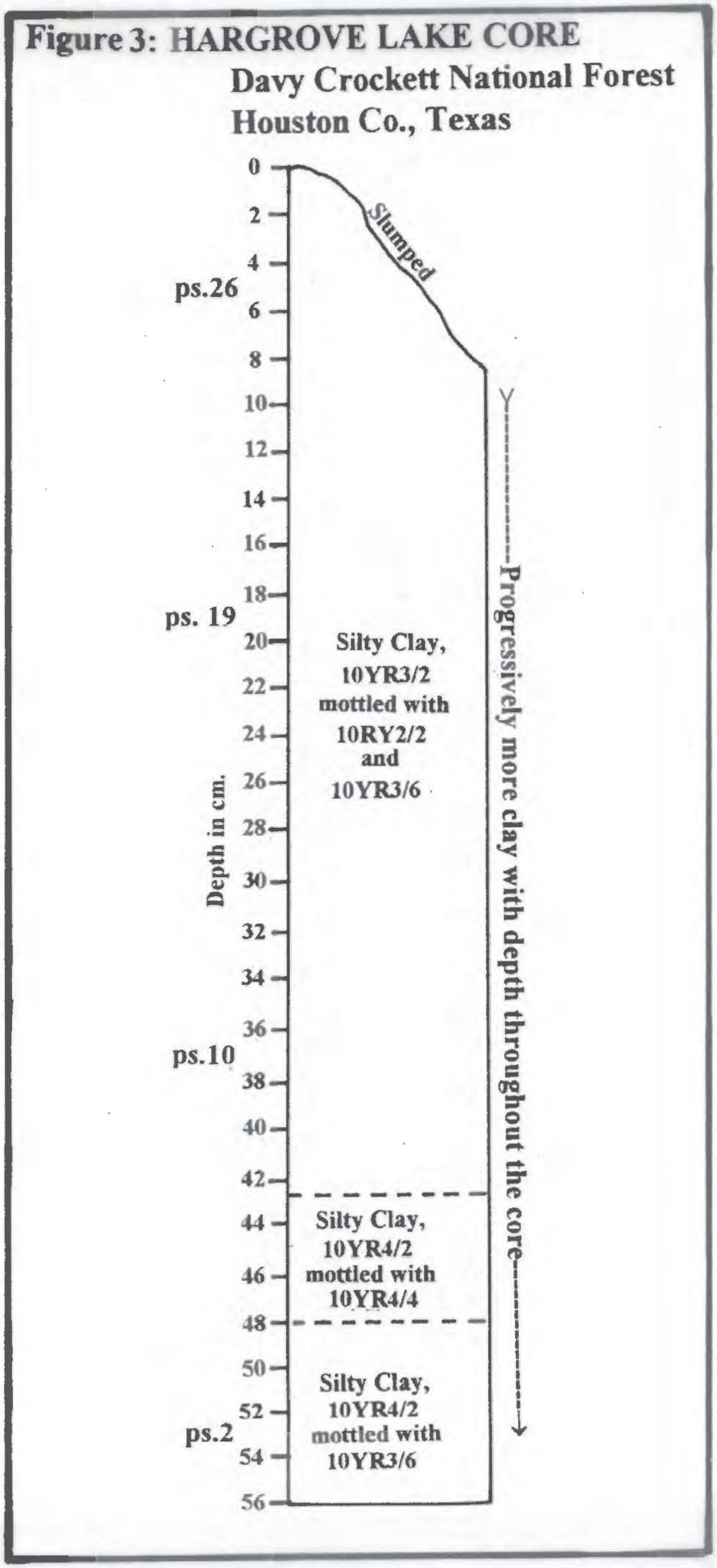

Figure 3. Hargrove Lake Core, Davy Crockett National Forest, Houston County, Texas.

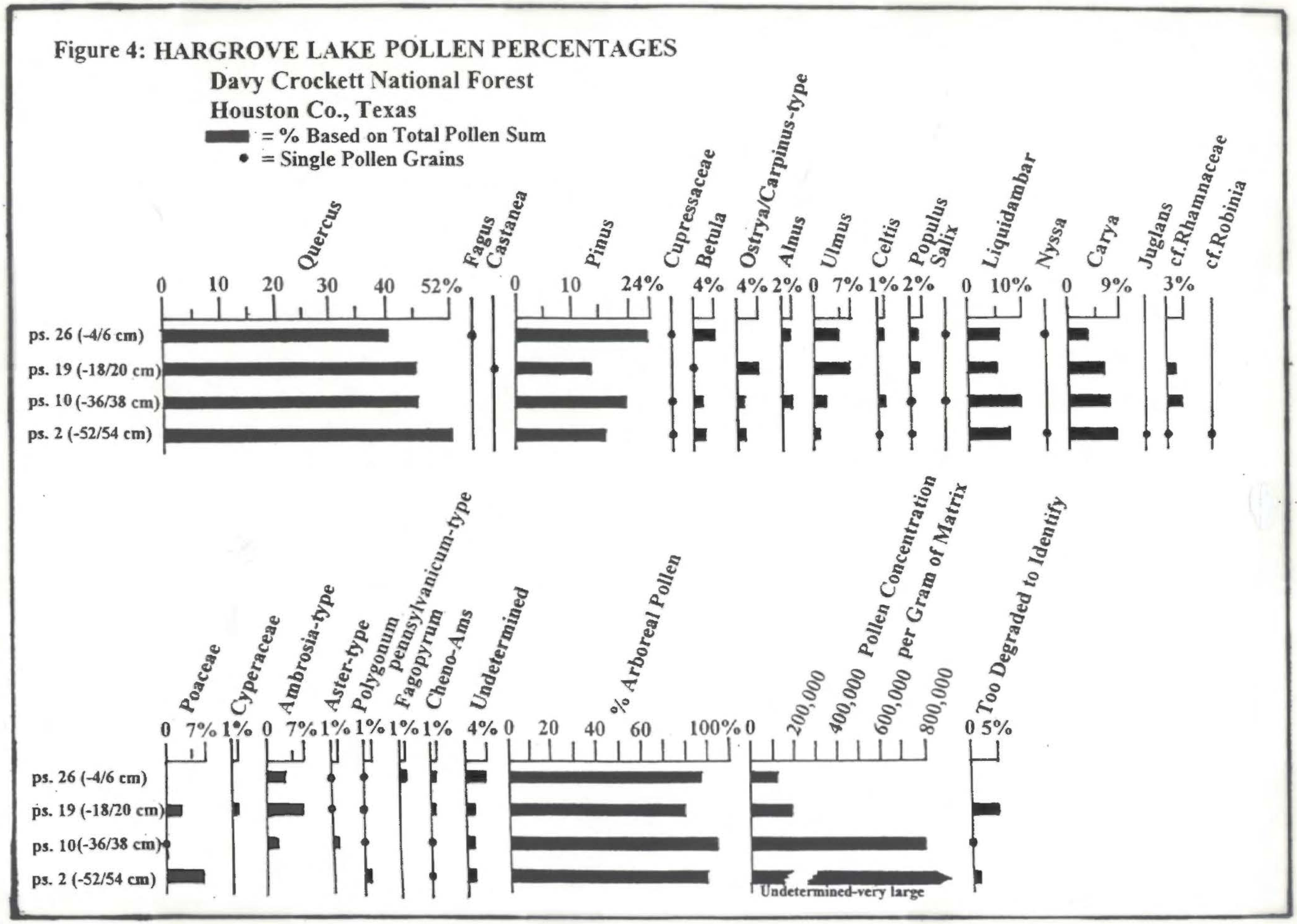

Figure 4. Hargrove Lake Pollen Percentages.

The pollen grains of the goosefoot family (Chenopodiaceae) and the amaranths (*Amaranthus*) cannot be distinguished except by labor intensive statistical means and are conventionally combined under the term "Cheno-Ams" (Martin 1963; McAndrews and Swanson 1967). The pollen from the aster family (Asteraceae) observed in the Hargrove Lake samples is divided into a wind-transported group (*Ambrosia*-type) and an insect-transported group (*Aster*-type) on the basis of the longer spines on the exine surface of insect-pollinated members of this family (Martin 1961:71). Common English names for plants are used in the text. They are followed by Latin names the first time that they are used, and Latin terms followed by common English names are used on the pollen diagram. Latin and common English names are listed in Table 1.

Table 1. Latin and Vernacular Plant Names.

Arboreal	**Non-Arboreal**
Quercus - oak	Poaceae - Grass family
Fagus - beech	Cyperaceae - Sedge family
Castanea - chestnut	*Ambrosia* - ragweed (wind-pollinated Asteraceae)
Pinus - pine	*Aster* - aster (insect-pollinated Asteraceae)
Cupressaceae - cedar family	*Polygonum pennsylvanicum* - Pennsylvania smartweed
Betula - beech	*Fagopyrum*.-. buckwheat
Ostrya/ - hop hornbeam	Cheno-Ams - Chenopodiaceae/*Amaranthus*
Carpinus - blue beech	
Alnus - alder	
Ulmus - elm	
Celtis - hackberry	
Populus - cottonwood	
Salix - willow	
Liquidambar - sweet gum	
Nyssa - Tupelo/black gum	
Carya - hickory	
Juglans - walnut	
Rhamnaceae - buckthorn family	
Robinia - black locust	

Undetermined - well preserved but not identified
Arboreal Pollen - tree pollen
Too-Degraded-to-Identify - recognizable only as degraded pollen

RESULTS

Stratigraphy

The upper 25 cm of the Hargrove Lake bottom sediment profile consisted of brown, watery silt (see Figure 3). This was lost during coring. The remainder of the core profile appears to be silty clay with a progressively larger proportion of clay with increasing depth. A 75 cm drive into this more solid portion of the sediment yielded a 56 cm thick core, indicating 25.4 percent matrix compression during the coring process. Some slumping occurred in the wetter upper 6-8 cm of the core during horizontal transport and storage before extraction (see Figure 3). The core as originally recovered may have been a few cm shorter than when sampled.

The Vegetation Record

All four Hargrove Lake exploratory pollen samples are dominated by tree (arboreal) pollen (85-94.5 percent). Oak (*Quercus*) pollen is the most prominent type, and pine (*Pinus*) is the second most important pollen taxa. Herb (non-arboreal) pollen is not well represented in the series. Only grass family (Poaceae) and ragweed-type (*Ambrosia*-type) pollen exceed one percent in any sample. There are some differences between the older and younger pollen spectra that may prove to register vegetation trends in an expanded sample series. The oak, hickory (*Carya*), sweetgum, and grass family pollen percentages are, for instance, generally higher in the tabulations from the deeper samples, while pine, elm (*Ulmus*), cottonwood (*Populus*), ragweed-type, and the Cheno-Am-type are somewhat better represented toward the top of the profile.

Several interpretations of these data are possible. Environmental conditions, natural or cultural, may have changed from those favoring oak, sweetgum, and hickory to those favoring pine, elm, and cottonwood. Statistical constraint within a fixed numerical sum may also be involved here. It is possible that the parent populations of oak, sweetgum, and hickory declined, and the pollen percentages of pine, elm, and cottonwood simply expanded statistically to fill out 100 percent of the 200 grain tabulations without any increase in the populations of the parent trees. Alternatively, the pine, elm, and cottonwood populations may have actually increased and statistically forced down the percentages of pollen contributed by stable populations of oaks, sweetgum, and hickories. Which tree taxa really increased or decreased in numbers and which pollen types statistically responded in the percentages should be easier to evaluate with an augmented sample series. The best way, however, to resolve this question will be to calculate pollen influx for the expanded profile. This will require generation of sedimentation rates.

The shift from grass family to ragweed-type and Cheno-Ams among the non-arboreal pollen spectra can be more confidently addressed. Soil disturbance destroys the perenniating organs of grasses (Behre 1981:226). Ragweeds, on the other hand, are better adapted to withstand the water and temperature stress of bare, disturbed ground than most other herbs. They are, consequently, the premier agricultural weed of eastern North America (Bazzaz 1974), and increases in ragweed-type pollen percentages in bog and lake deposits are the accepted horizon marker for the advent of Euro-American style agriculture in paleoenvironmental pollen sequences (Davis 1965:395) The apparent replacement of grass by ragweeds in the Hargrove Lake pollen source area suggests an increase in soil disturbance. An expanded sample series may also demonstrate that the addition of aster-type (*Aster*-type) to the spectrum in PS 10 and the slight decline in Pennsylvania smartweed-type (*Polygonum pennsylvanicum*-type) percentages in and above the same sample are also products of change in the soil stability regimen.

The Cheno-Am counts support a soil disturbance interpretation of the grass and ragweed-type percentages. The Cheno-Ams are the primary soil disturbance indicator in prehistoric sites in the southwestern United States: increasing in frequency as sites were established, decreasing again at abandonment, and increasing again at reoccupation (Kelso 1980:350 and Figure 161). The plants producing this pollen type favor fertile soils (Behre 1981:236; Muenscher 1980:180-196), and they proliferate on the flood-renewed soils of Midwestern floodplains as well as in the nutrient-rich soils around stockyards and cattle tanks. The modest increase in Cheno-Am percentages suggests utilization of the lake as a water source by cattle during the historical-era.

Disturbance aerates the soil and provides agents of pollen degradation, primarily free oxygen (Havinga 1969) and aerobic fungi (Goldstein 1960), with access to pollen already in sediments. Quantities of pollen too-degraded-identify, consequently, register relative soil disturbance (Kelso 1993:71 and Figure 1). The peak of pollen too-degraded-to identify in Hargrove Lake sample PS 19 coincides with the largest tabulation of ragweed-type pollen in the sample series and supports the inference that the grass to ragweed shift resulted from increased soil disturbance. Such disturbance is not necessarily of agricultural origin. Natural erosion (Solomon et al. 1983) during a dry interval or simply exposure of the matrix to the atmosphere could also both encourage ragweed and damage pollen.

The only sedge (Cyperaceae) pollen to appear in the Hargrove Lake exploratory samples also occurs in sample PS 19 (see Figure 4). Sedge pollen is very heavy and was undetectable beyond 1 m from the parent plants in an experimental study (Handle 1976). The Hargrove Lake sedge pollen must have come from the immediate vicinity and suggest a period of low water with bottom exposed around the periphery of the lake. Such bottom exposure would also account for the increase in the quantity of degraded pollen in the sample containing the sedge pollen. Alternatively, churning of the soil at the water's edge by cattle could have caused the pollen degradation, and created the habitat for both sedges and ragweed.

It does not automatically follow that these changes in the herb pollen spectra and pollen preservation measure occurred during the Euro-american era. Increases in ragweed pollen in New England have been dated to ca. 7,300 years ago (Sneddon and Kaplan 1987:7; Winkler 1985:8; Davis 1969:419; Kelso 1991) and are considered to record a continental scale mid-Holocene dry period in pollen spectra recovered in the Southwestern United States (Mehringer 1966:97). At Pocksha Marsh, Middleborough, Massachusetts, coincident increases in ragweed and quantities of degraded pollen during the Hypsithermal reflected a combination of climatic change and sheet erosion off of the hillside above the marsh (Kelso 1991). Ragweed-type pollen appears deep in the Hargrove Lake core but not at the bottom, while buckwheat (*Fagopyrum*), the lone Hargrove Lake pollen type from a plant of undoubted Eurasian origin, was noted only in the most shallow of the four exploratory pollen samples. Both historical-era soil disturbance and a prehistoric dry episode could appear in an expanded sample series.

No buttonbush pollen was noted in any of the four exploratory pollen samples. Buttonbush pollen is distinctive (Kapp 1969:145), is produced in abundant quantities (Radforce et al. 1968:979), and does not appear to be coated with the sticky oils and resins characteristic of insect-pollinated taxa (Fagri and van der Pijl 1971). Buttonbush pollen should have been found in at least the most shallow sample of the series. The absence of the type suggests either that the buttonbush fringe around the lake is a very recent development or that the plants on the periphery of the lake have been mis-identified. It will be necessary to develop a vegetation map of the area around the lake. This will facilitate interpretation of the lake pollen spectra and the data from the pollen source area study.

The absence of buttonbush pollen emphasizes the poor representation of all herbaceous pollen in the spectra. The non arboreal sum does not exceed 15 percent in any of the Hargrove Lake samples analyzed to date and pollen sums larger than the standard Southwestern 200 grain tabulations should be employed to improve the representation of herbs and minor tree pollen types (Duffield and King 1980). This will bolster the analyst's confidence in patterns discernible among the herb pollen spectra.

Pollen Concentrations

All four Hargrove Lake exploratory samples contained adequate pollen to permit tabulation of 200 grain counts in a few hours each. Pollen concentrations in the deeper two samples (see Figure 4, lower right) are much larger than those previously recovered by the analyst from lake and marsh sediments in the Northeastern United States. In the deepest sample the quantity of native pollen was so large that that none of the *Lycopodium* pollen added at the beginning of extraction was noted during the tabulation on the 200 native pollen grains. The tracer pollen type was observed in a subsequent scan of the slide. Larger quantities of exotic pollen will have to be added to future extractions to insure that it is recorded during tabulation of the native sum. Adding larger quantities of exotic pollen will also reduce the element of chance in encountering the exotic pollen during tabulations of all samples and, consequently, statistically improve the accuracy of the calculated pollen concentrations and influx data.

The pollen concentrations decrease from the deepest to the most shallow of the Hargrove Lake exploratory samples. No age determinations from which sedimentation rates can be generated for the lake are yet available (see Endnote by David H. Jurney and Timothy K. Perttula), and the pollen concentrations cannot be converted into pollen influx rates at the present time. Lacking such chronometric data, the decline in pollen concentrations can be interpreted in three ways:

1) It may reflect a decrease in the density of the vegetation contributing to the pollen spectrum;

2) It may indicate a changing matrix environment, resulting in progressively greater pollen destruction later in the deposition sequence; and

3) It may register an accelerating sedimentation rate through time.

The first potential explanation appears unlikely because the declines in the oak, sweetgum, and hickory percentages are much less than the amount suggested by the proportions of the decrease in pollen concentrations. In situ pollen destruction also appears improbable because the quantities of pollen too-degraded-to-identify never exceed five percent in any of the four samples, and no degraded pollen was noted where pollen concentrations are lowest at the top of the profile. This leaves an increase in the sedimentation rate as the most probable cause of the progressive decline in pollen concentrations from the bottom to the top of the Hargrove Lake sample series.

Large increases in the sedimentation rate comparable to that suggested by the Hargrove Lake pollen concentrations appear to be historical-era phenomena. At Nauset Marsh, Cape Cod, Massachusetts, the post-settlement rate was 370 percent of the prehistoric rate (Kelso 1994). The rate at Pearson's Pond on the San Francisco Peninsula in California, calculated from dates and historical markers presented by Adam (1975:730 and Table 1), increased by 760 percent with the advent of logging and grazing. The historical-era rate in an estuary on Santa Rosa Island, California, was 1900 percent of the prehistoric rate on the average and rose to 3300 percent of the prehistoric rate between 1874 and 1920 (Cole and Liu 1994:334). It appears probable that the progressive decline in pollen concentrations per gram of matrix in the Hargrove Lake core is also the product of an increase in sedimentation rate resulting from an intensification of human activities in the vicinity of the lake during the historical era. The sedimentation rate will have to be investigated. Radiocarbon dating should be sufficiently precise for the deeper, prehistoric, portion of the core. Sedimentation rates for the Euro-American era can be generated with Pb^{210} dates and pollen horizon markers for dated events that affected the vegetation. Documentary and oral history research will be required to establish pollen horizon markers.

In a series of only four widely spaced samples it is not possible to determine the point in the depositional history of the lake at which the sedimentation rate began to increase. If, however, the advent of ragweed-type pollen in the herb pollen spectrum is a horizon marker for the beginning of the Euro-American-era, the sedimentation rate probably began to accelerate between PS 10 and PS 2. This would mean that only one third, or less, of the profile dates to the prehistoric period. If the range of variation of the pre-European settlement vegetation within the Hargrove Lake pollen source area is to be defined, contiguous pollen samples will have to be analyzed from the deeper portion of the core. The resolution of events in the historical-era vegetation history for the vicinity will also be improved by employing contiguous samples throughout the core.

DISCUSSION AND RECOMMENDATIONS

Abundant pollen was recovered from all four Hargrove Lake exploratory samples, and several probable trends are evident among both the tree and herb pollen spectra of the Hargrove Lake exploratory samples. In an expanded sample series, these will probably register systematic vegetation changes interpretable as the result of changes in environmental and cultural history. Oak, sweetgum, and hickory percentages decline toward the top of the sample series in the tree spectrum, while the pine, elm, and cottonwoods increase. It appears probable that the decreases in the first three types reflect actual events, while the increases in the second three pollen types are statistical responses within a fixed numerical sum. It is possible, however, that there were real increases in the numbers of pine, elm, and cottonwood trees in the pollen source area. This question should be resolved by generating pollen influx data for the core. This will require an accurate history of sedimentation rate changes based on radiocarbon dates, Pb^{210} dates, and pollen horizon markers for dated events spaced through the core.

The grass family is better represented toward the bottom of the herb pollen spectrum, ragweed-type appears in the upper three pollen samples, and goosefoot/amaranth percentages are slightly larger in the most shallow two samples. These changes suggest an increase in soil disturbance in the upper three quarters of the core with some enrichment of the soil in the upper half of the sequence. Peaks of ragweed-type and degraded pollen percentages in sample PS 19 are accompanied by the only sedge pollen noted in the sample series. These three phenomena suggest a low water episode with some bottom exposed around the edge of the lake or an increase in soil disturbance at the water's edge.

A steady decline in pollen concentrations per gram of matrix appears to register a rather large increase in sedimentation rate. Such increases at other sites were caused by the soil disturbance that is characteristic of Euro-American-era land-use practices. The herb pollen spectra suggest that the onset of such soil disturbance in the Hargrove Lake pollen source area occurred sometime between the deposition of the PS 2 and the PS 10 matrix. If this interpretation is correct, it is probable that less than one-third of the profile was deposited during the prehistoric period. In order to recover a reasonably complete range of variation for the late prehistoric period, it will be necessary to analyze contiguous samples from this portion of the core. Contiguous sampling for the entire core will improve the historical-era vegetation record as well.

Herb pollen will be very important in the interpretation of the Hargrove Lake record, but the herb spectrum constitutes no more than 15 percent of any sum tabulated to date. In order to define patterns among the herb pollen types that the analyst can interpret with confidence, it will be necessary to tabulate large sums—400 to 1,000 grains—per sample or to do a second of several hundred grains from which tree pollen is excluded. This should be economically feasible, given the relatively high pollen concentrations in all samples. Re-sampling the lake with a stationary piston corer or a vibration corer might improve the accuracy of sedimentation rate and pollen influx data by reducing matrix compression. Analysis of the lake pollen spectra should also benefit from a study of the pollen source area. This could be accomplished with a series of pollen traps placed across the lake and surrounding woodland, according to the prevailing winds in the area, and should be accompanied by an inventory of the present vegetation in the area.

END NOTE

David H. Jurney and Timothy K. Perttula

Subsequent to the completion of the report by Gerald Kelso published herein, three radiocarbon dates have been obtained from the Hargrove Lake pollen core. The dates were on pond sediments collected from PS 20 (16-18 cm bs), PS 11 (34-36 cm bs), and PS 3 (50-52 cm bs). The PS 20 assay is modern (106.0 $\pm$ 0.5, Beta-156370, -27.0 o/oo 13C/12C ratio), indicating that at least the upper 20 cm of the pond deposits have been contaminated since the 1950s.

The other two samples have the following two sigma calibrated age ranges (see Stuiver et al. 1998; Talma et al. 1993):

PS 11, cal AD 1310-1430 (Beta-156513, -26.9 o/oo)

PS 3, cal BC 30 to AD 70 (Beta-156369, -27.2 o/oo).

Since the PS 3 date is from near the bottom of the pollen core, it is apparent that the pollen data from Hargrove Lake are relevant concerning changes in pollen and local vegetation from about the last 2000 years. Sediments accumulated very slowly in the lake, based on the two calibrated radiocarbon dates, at about 1.16 cm per 100 years. An additional radiocarbon sample date between PS 11 and PS 3 would better clarify the sedimentation rate in these Late Holocene sediments.

Assuming that the top of the sediment core represents deposition in modern times (ca. 1950), the upper 34 cm of the Hargrove Lake sediment core accumulated about 540 percent faster than in prehistoric times: 6.3 cm per 100 years. An additional radiocarbon sample date between PS 20 and PS 11 would better clarify when sedimentation rates began to increase, and also better establish which pollen samples date prior to Euro-American settlement in this part of the Neches River valley.

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