

## Paleoecology of Calf Island in Boston's Outer Harbor

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**Abstract** - We used microfossils preserved in salt-marsh peat to understand the landscape processes (both natural and anthropogenic) that have influenced the environment. Variations in the abundance of fossil pollen of native species suggest that the vegetation of this small, exposed island has been dominated by low, shrubby vegetation since before the arrival of Europeans in the early 1600s. Increases in non-native species since that time may reflect disturbance of the soil associated with grazing and other activities. Sorrel (*Rumex*) pollen, which indicates local grazing, declines by the late 19<sup>th</sup> century, whereas Chenopodiaceae/Amaranthaceae pollen, an indicator of disturbed soil, is most abundant since 1900. Charcoal abundance shows that fires, probably ignited by humans both before and after 1600 A.D., have burned on the island throughout the last 1000 years. In addition, increases in soot and opaque spherules in sediments reflect increased air pollution during the last 100 years. Our analyses provide benchmarks for modern management by documenting pre-European conditions as well as the extent to which the modern environment differs from that prior to the settlement of Massachusetts Bay by Europeans.

### Introduction

Coastal vegetation changes over time periods ranging from nearly instantaneous to almost imperceptibly long. Overwash due to storm surges can obliterate upland vegetation in minutes to initiate new “primary” successions (Zaremba 1982), whereas changes in sea level can cause variations in the patterning of high and low marsh vegetation that are perceptible only after many decades or centuries (Clark and Patterson 1984). Understanding and documenting changes in these environments requires knowledge not only of the biology of the species involved and the factors that drive succession, but also the time frames over which changes are likely to occur. In our broader study of the vegetation history of the Boston Harbor Islands (Richburg and Patterson 2005), we used written records, photographs, and maps to describe vegetation of the islands since about 1600 A.D. In this paper, we examine the history of the vegetation and environment of Calf Island—a small, windswept island in the Brewster group (Fig. 1)—in greater detail over a longer period of nearly 1200 years.

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The earliest descriptions of the Boston Harbor Islands, including those by John Smith, Samuel de Champlain, and William Wood (Barbour 1986, Winship 1968, Wood 1993), suggest the nature of vegetation in the early 17<sup>th</sup> century. These observers described a landscape that was primarily forested, but with open areas maintained around Native American settlement sites, on the larger islands, with the smaller islands dominated by shrubs (Richburg and Patterson 2005). But given the dynamic coastal environment (Clark 1986), we know that vegetation was almost certainly changing rapidly. Even so, Europeans profoundly altered vegetation (Altpeter 1937, Westveld et al. 1956) and the processes that influenced it (Brugam 1978). To better understand the pre-European landscape of one of Boston Harbor's islands, and the processes that influenced the vegetation, we studied a peat core from a small marsh on Calf Island. Fossil analyses, which we report here, provide insights beyond our study of the recorded history of the Boston Harbor Islands group as a whole (Richburg and Patterson 2005).

### Field Site Description

The Boston Harbor Islands lie in Massachusetts Bay and range in size from less than 0.4 hectare to 105 hectares. Calf Island, an island of

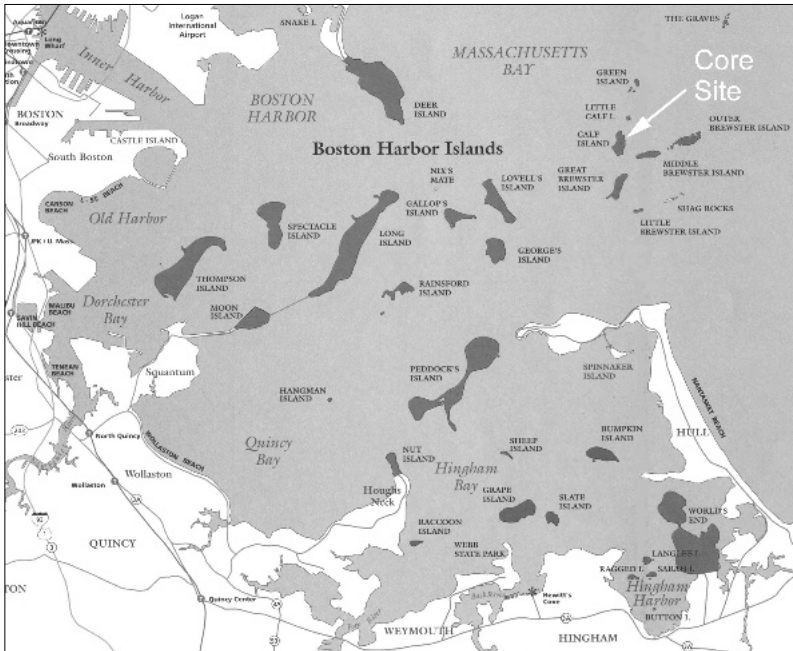


Figure 1. Map of the Boston Harbor Islands (dark shading) showing the location of Calf Island in the outer harbor.

7.5 ha, lies in the outer harbor as part of a group called the Brewsters (Fig. 1). These islands are more exposed to weather than some of the larger islands in the inner harbor. There are no good historical descriptions of the vegetation of Calf Island and no archaeological evidence for cultivation (Luedtke 1980). Houses were built on the island by at least 1860 (Shurtleff 1891, Stark 1880; see Fig. 2), including a Colonial-style, two-story summer estate built in 1902 for Benjamin Cheney and Julia Arthur. Since the estate was burned by vandals in the 1940s, the island has been abandoned. Nineteenth-century accounts of the island describe groves of wild-cherry trees, sumac, and manicured lawns. Once the island was abandoned during the later part of the 1900s, the vegetation became weedy and overgrown with sumac and introduced species of trees, low scrubby weeds, and high grasses (Kales and Kales 1983, Luedtke 1975, Mikal 1973).

The modern vegetation of Calf Island (Elliman 2005) is comprised of 90 species of vascular plants. Of these, 47 are native and 53 non-native. There are 11 woody species including grape (*Vitis* sp.), poison ivy (*Toxicodendron radicans* L. Kuntze), two willows (*Salix* spp.), raspberry (*Rubus idaeus* L.), blackberry (*R. allegheniensis* Porter), staghorn sumac (*Rhus hirta* L. Sudworth), the non-native Morrow's honeysuckle (*Lonicera morrowii* Gray), and three species of *Rosa* including one that is non-native (nomenclature follows Magee and Ahles 1999).

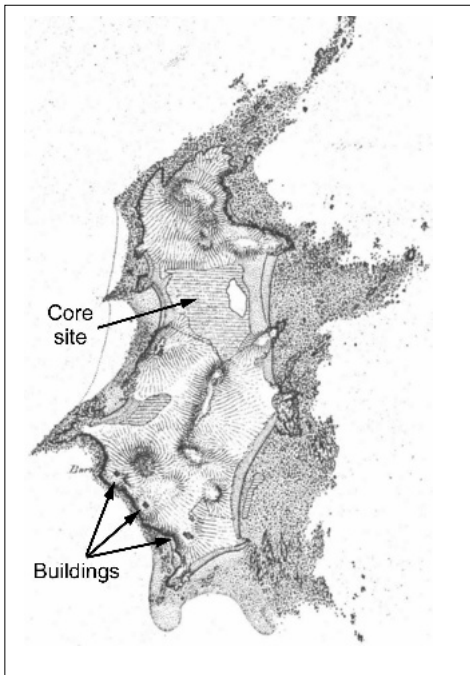


Figure 2. US Coast and Geodetic Survey map of Calf Island, 1860. Structures are shown near the island's south shore. The Calf Island marsh that we cored bisects the northern half of the island.

Elliman describes the modern landscape as including thickets, rough old fields, exposed ledges, rocky beachfront, sandy beach strand, a large brackish marsh in the central part of the island, and a moist semi-open field south of the marsh (T. Elliman, Slingerlands, NY, pers. comm.). He describes the upland vegetation as a whole as maritime shrub (Elliman 2005), with extensive thickets of staghorn sumac (*Rhus hirta*). The approximately 0.4-ha brackish marsh from which we recovered our core nearly bisects the island (Fig. 2). It has a mixture of native plants, such as Olney's three-square (*Scirpus americanus* Pers.) and broad-leaved cattail (*Typha latifolia* L.), and invasive species like purple loosestrife (*Lythrum salicaria* L.) and common reed (*Phragmites australis* (Cav.) Trin. ex Steud.). Salt hay (*Spartina patens* (Ait.) Muhl.) covers much of the marsh.

Ditching suggests that efforts were made to drain the marsh at some time in the past, probably for mosquito control. It is separated from salt water not more than 15 meters to the east by a boulder beach and berm (Fig. 3).

### Methods

A peat core was collected from the Calf Island marsh on 16 October 2001. We used a modified piston corer, 10 centimeters in diameter, with a saw-tooth barrel edge to cut through the peat. The 2-meter-long core was brought to the laboratory and sampled at 5-to-10-centimeter intervals



Figure 3. Coring apparatus at the Calf Island marsh core site, October 2001. The photograph is taken looking to the northeast, with the shoreline just beyond the rocky berm in the background.

for fossil pollen analysis and the quantification of combustion residues (charcoal, soot, and opaque spherules). One-half-cubic-centimeter subsamples were removed and placed in centrifuge tubes, to which 0.5 ml of non-native *Eucalyptus* pollen (86,750 grains/cm<sup>3</sup> in a glycerin suspension) was added as a reference marker. Sediments were treated with 10% potassium hydroxide to dissolve humic compounds, 10% hydrochloric acid to dissolve carbonates, 48% hydrofluoric acid to dissolve silicates, and an acetolysis solution (Faegri and Iversen 1975) to remove organic residue other than pollen, charcoal, and soot. Residual material was mounted in silicone oil and mixed thoroughly. Slides were examined at 400x with a Zeiss Standard light microscope. Fossil pollen grains were identified with the aid of illustrated keys (Kapp 1969, McAndrews et al. 1973) and reference material in the Paleoecology Laboratory at the University of Massachusetts. While identifying fossil pollen grains, we observed that grains of the Chenopodiaceae/Amaranthaceae (Cheno/Am) families appeared to vary, systematically, in numbers and size throughout the core, with more abundant, small grains in samples from the upper 0.5 meter of peat. To quantify this, we measured the diameters of grains from each sample where Cheno/Am pollen comprised more than 10% of the total fossil pollen identified. We also measured the diameters of reference pollen for eight species recently recorded as present on Calf Island. Average grain sizes for fossil pollen were compared with the diameters of reference pollen.

We separated charcoal produced by the combustion of plant material (i.e., dead leaves, grass, and woody material) from soot produced by the combustion of fossil fuels based on morphological characteristics (Fig. 4).

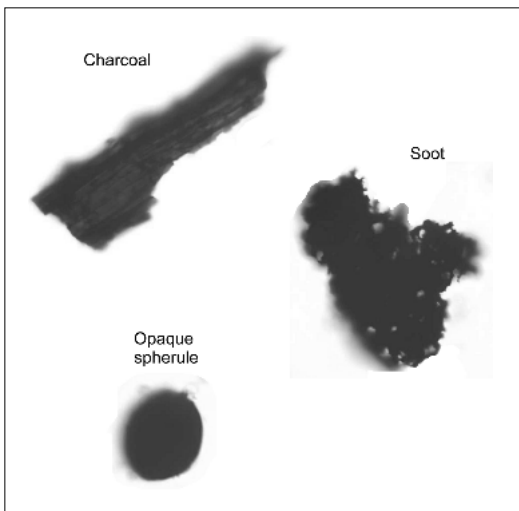


Figure 4. Charcoal (upper left), soot (middle right), and opaque spherules (lower left) shown at 400X on a slide from Calf Island peat prepared for fossil analysis. Soot is distinguishable from charcoal by its perforated nature and lack of any cellular structure. For scale, the opaque spherule is approximately 20 micrometers in diameter.

Charcoal and soot concentrations were quantified using the grid-count method (Patterson et al. 1987), which estimates the surface area of charcoal fragments on microscope slides. *Eucalyptus* grains were tallied at the same time that fossil pollen and charcoal were counted. The ratio of charcoal or soot area divided by the number of grains of *Eucalyptus* pollen, to fossil pollen divided by *Eucalyptus* pollen yields the ratio of charcoal or soot area to fossil pollen ( $\mu\text{m}^2\text{Ch:P}$  or  $\mu\text{m}^2\text{So:P}$ ), which is used as a measure of past fire or air pollution occurrence on the landscape. The abundance of opaque spherules (most likely from industrial combustion; see Huhn [1974] and Nriagu and Bowser [1969]) was determined to identify the depth in the sediments associated with early-20<sup>th</sup>-century industrial activity (Brugam 1975, Clark and Patterson 1984).

A radiocarbon date (standard AMS dating by Beta Analytic Inc., Miami, FL) was obtained for a section of peat taken from 90.5 to 93.5 cm below the marsh surface. Sediment accumulation rates were calculated for the entire section using this date. Chronostratigraphic markers, including increases in the abundance of pollen indicative of agricultural activity (Brugam 1978), the decline in chestnut (*Castanea*) pollen associated with the early-20<sup>th</sup>-century chestnut decline (Anderson 1974), and increases in the abundance of opaque spherules, were also used to calculate the sediment accumulation rates for sections of the upper portion of the core. Calculated sediment accumulation rates combined with fossil concentrations determined with the aid of the added *Eucalyptus* grains were used to calculate the yearly accumulation of pollen and combustion residues.

## Results

### Sediment dating

We focused our analyses on the upper 1 meter of the core because we were primarily interested in documenting how the island's landscape has changed in the several hundred years spanning the arrival of European settlers in the Boston area. The upper core section, as described in the field, was of uniform, humified sedge peat. We observed no obvious discontinuities or dark bands suggesting discrete layers of charcoal. Fossil data for 17 samples between 0 and 95 cm in the core were summarized as percentage (Fig. 5) and fossil accumulation rate (Fig. 6) values using TILIA software (Grimm 1992). Abundant pollen of species indicative of agricultural activity (ragweed [*Ambrosia*], sorrel [*Rumex*], and plantain [*Plantago*]) above 50 cm indicate the period under influence of European settlers. This "settlement horizon" has been identified for sediments throughout North America, and for southern New England it represents the early 17<sup>th</sup> through 20<sup>th</sup> centuries (Brugam 1978). The increase in opaque spherules relative to fossil

pollen at 20 cm and the decline in chestnut (*Castanea*) pollen above 20 cm indicate the past 100 years of peat accumulation in the marsh. A date of  $1290 \pm 40$  radiocarbon years before present (Beta-177807)

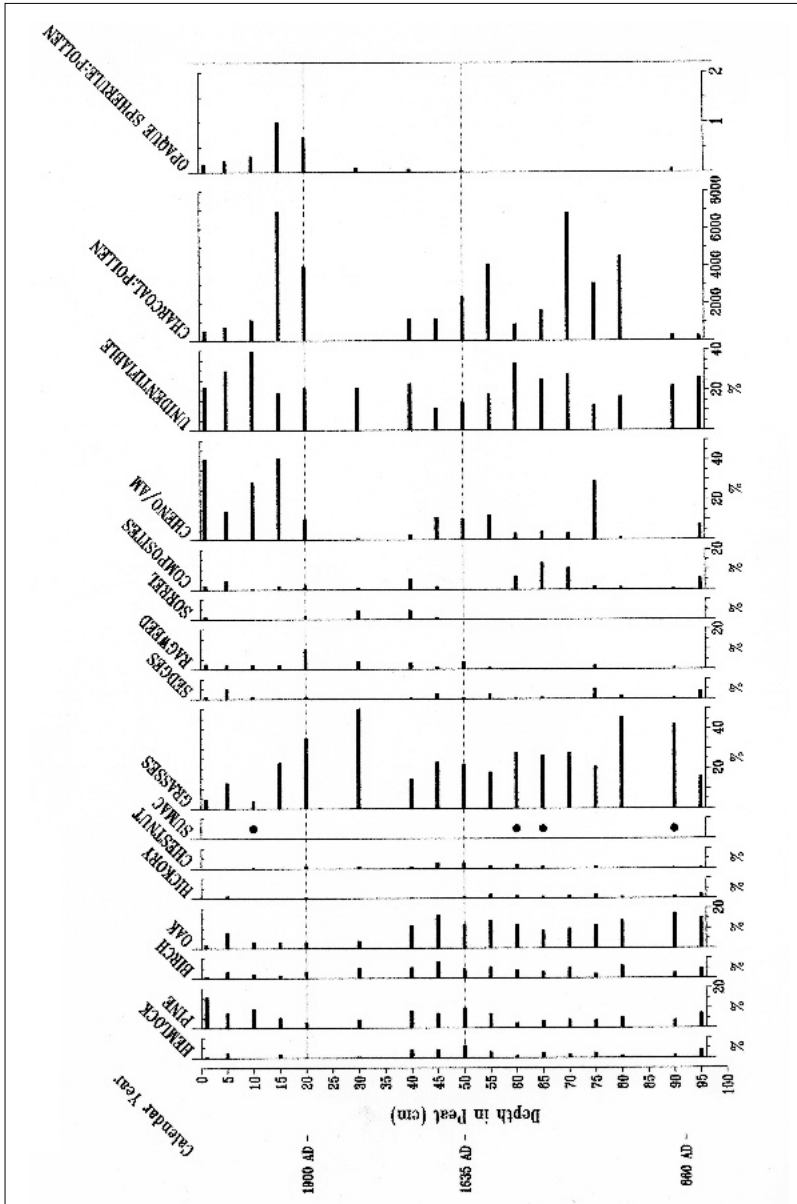


Figure 5. Fossil pollen percentage diagram, plus the ratios of charcoal and soot to fossil pollen for the Calf Island marsh (• indicates the presence of a single sumac grain).

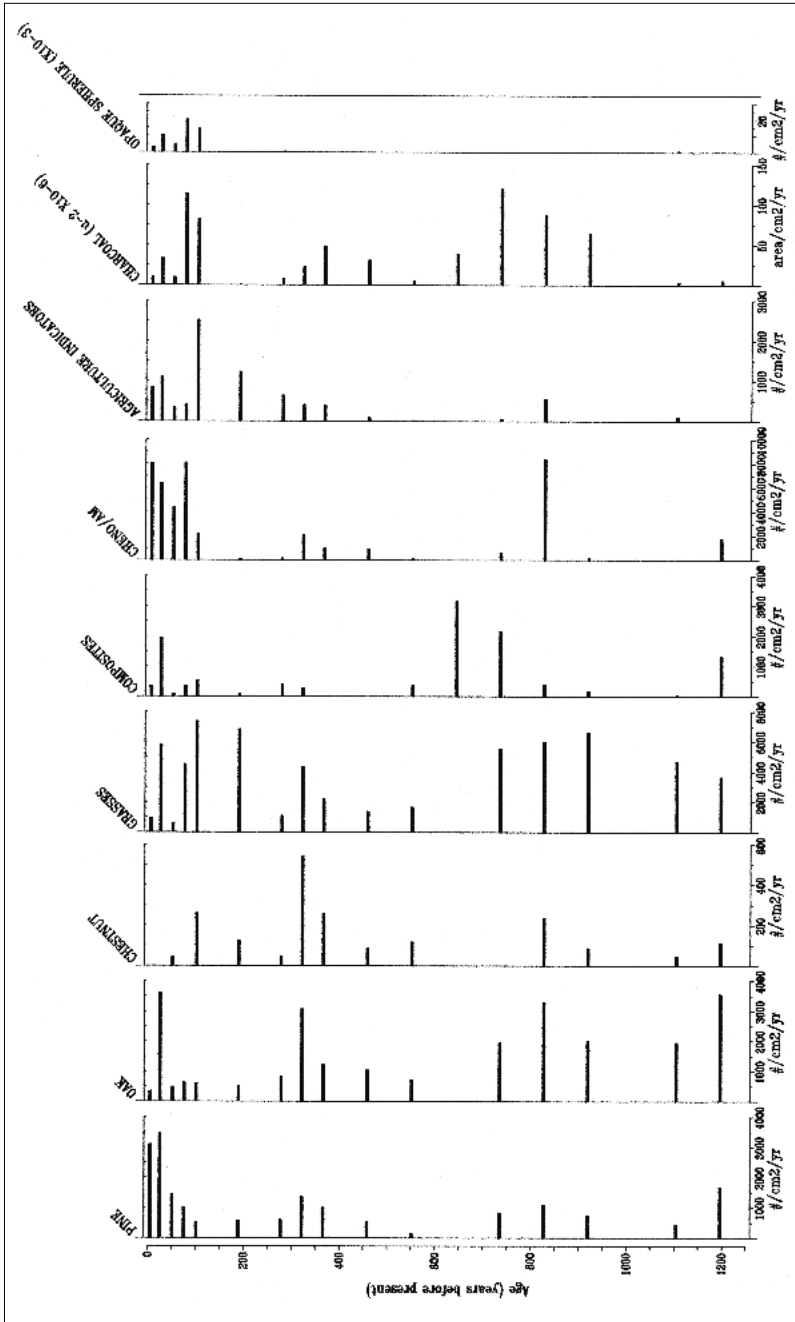


Figure 6. Pollen accumulation rate diagram, plus accumulation rates of charcoal and opaque spherules, for the Calf Island marsh. Agricultural indicators include ragweed (*Ambrosia*), sorrel (*Rumex*), and plantain (*Plantago*).

yields a minimum (2 sigma calibration) calendar age of 840–860 A.D. for the 92 cm depth. These ages are indicated on the depth (y) axis of the percentage diagram (Fig. 5). Assuming a date of 1900 A.D. for 20 cm and 1635 A.D. for 50 cm plus the radiocarbon age for 92 cm yields approximate age/depth associations for the following sections of the core: 5.05 years/cm for 0–20 cm; 8.8 years/cm for 20–50 cm; and 18.5 years/cm for 50–92 cm. Apparent increases in rates of peat accumulation in the upper portions of the core are likely due to increased erosion from uplands with European settlement activities on the island and the lack of consolidation compared to that of the lower sediments which have been subjected to a greater degree of compaction and decomposition. Ages calculated from the above rates are shown on the y-axis of the accumulation rate diagram (Fig. 6).

### Vegetation history

We included all types plus unidentifiable and unknown grains in the pollen sum, as we were interested in changes at the local, extra-local, and regional scales, but poor preservation limited our ability to count and identify large numbers of grains in some samples. Fossil pollen sums averaged 312 grains for the 17 samples, although sums for the 5, 10, 40, and 50 cm samples fell to 150–200, chiefly due to poor preservation. Unidentifiable grains averaged 30% of the pollen sum in these four samples.

Although pollen preserved in small, isolated basins like the Calf Island marsh are more likely to represent local rather than regional vegetation (Jackson 1990, Jacobson and Bradshaw 1981), pollen in the Calf Island peat appears to document both regional and local changes in vegetation, both before and after the arrival of Europeans in the early 17<sup>th</sup> century. The abundance of and changes in major tree species are typical of those seen in cores from other south coastal New England sites (Backman 1984, Brugam 1975, Motzkin et al. 1993, Stevens 1996, Winkler 1985). Oak (*Quercus*) percentages of 10% to 20% and percentages for pine (*Pinus*), birch (*Betula*), hickory (*Carya*), and hemlock (*Tsuga*) of less than 10% suggest that species represented by these types were unimportant before Europeans settled the Boston area. Birch, oak, and especially pine tend to be overrepresented in fossil pollen assemblages, and pine foliage is very sensitive to salt spray. So it seems unlikely that these species were common, if present at all, on Calf Island, which is small and as one of the Brewsters exposed to the harsh maritime climate of Massachusetts Bay. Declines in these types between 15 and 30 cm suggest the regional deforestation that occurred during the late 18<sup>th</sup> and early 19<sup>th</sup> centuries. Increases in the abundance of pine and oak at 10 and 5 cm, respectively, reflect the recent reforestation of southern New England following agricultural abandonment in the late 19<sup>th</sup> century.

Pollen accumulation rates calculated from sediment accumulation rates and pollen concentration (Davis 1965, 1969) support percentage data which may be difficult to interpret due to their relative nature; i.e., if one type increases in absolute terms while others remain the same, the abundances of the others will appear to decline as percentages are adjusted downward to reflect the increase in the more abundant type. This can be a particular problem in cores from wetlands where an abundant pollen producer growing at the core site can mask changes (or the lack thereof) in the abundances of species that are common outside the marsh. Our data (Fig. 6) show, for example, that the rate of oak (*Quercus*) pollen accumulation averages approximately 2300 grains/cm<sup>2</sup>/yr at Calf Island, whereas Davis (1969) reports values for Rogers Lake in southern Connecticut that average approximately three times that figure. Rogers Lake is surrounded by oak forests, and the comparison suggests that oak probably was not present on Calf Island, despite the fact that oak pollen percentages were as high as 15% to 20% before 1600 A.D.

Of the woody species on the island today, sumac (*Rhus hirta*) is the most common. It is a poor pollen producer, and pollen grains of different species of *Rhus* are largely indistinguishable (poison ivy [*Rhus radicans*, now *Toxicodendron radicans*] is also present on the island). Single *Rhus* grains were identified from peat that dates both to before and after settlement (at 90, 60, 55, and 10 cm in the peat), but little can be said of the varying abundances of sumac (and/or perhaps poison ivy) based on the few grains identified, other than the fact that *Rhus* has surely been present on the island for many centuries.

Grass (Gramineae) pollen is abundant, with accumulation rates more than twice those for oak, both before and after European settlement, suggesting that grass species dominated the marsh, and perhaps the upland, throughout the period represented by the core. With few exceptions, it is not possible to identify grass pollen to species. Pollen of corn (*Zea mays* L.) is much larger than pollen of other members of the grass family. Although grass pollen of several different and probably distinct size classes was observed, no corn pollen was identified. Sparse pollen of agriculture indicators below 50 cm suggests that there was little Native American agricultural activity on Calf Island, not surprising given its small size and isolation at the outer entrance of Boston Harbor. Only at 75 cm does *Ambrosia* pollen rise above 1% (to 1.9%), and there are no other indicators of disturbed soil (e.g., abandoned agricultural land) at this level suggesting that the ragweed (*Ambrosia*) pollen may be from regional rather than local sources. Sorrel (*Rumex*), an indicator of grazing (Brugam 1978), first appears at 45 cm (1%) and peaks at 4.7% at 40 and 30 cm before falling to 1.7% at the start of the 20<sup>th</sup> century (20 cm). This probably indicates local

grazing of livestock (perhaps sheep?) in the 18<sup>th</sup> and 19<sup>th</sup> centuries. Absence of sorrel pollen above 20 cm is consistent with a lack of other evidence for grazing on the island in the 20<sup>th</sup> century.

Pollen of Compositae (goldenrods, asters, and the like; but not including wormwood [*Artemisia*] and ragweed [*Ambrosia*] which were tallied separately) fluctuates throughout the core and probably represents variations in the abundance of native species like the sea-side and Canada goldenrods (*Solidago sempevirens* L. and *S. canadensis* L.) and Canada hawkweed (*Hieracium canadense* Michx.), all of which inhabit the island today and are common in coastal environments. The facultative wetland shrub salt bush (*Baccharis halimifolia* L.) is not present on the island today, but may have been in the past, as it is common in coastal wetlands elsewhere in the region. Composites are most abundant in presettlement sediments, with percentages in excess of 5–10% at 60, 70, and 95 cm. Although 12 non-native species of the Composites occur on the island today, percentages exceed 5% only once (at 40 cm) in the past 400 years. In the most recent sample (1 cm), it is 1.8%. Pollen grains of the many species of composites now on the island are not distinguishable at the genus or species level.

The abundances of pollen of Chenopodiaceae and Amaranthaceae (Cheno/Am) fluctuate throughout the core and are consistently abundant

Table 1. Average diameters (of N grains) for pollen of members of the Chenopodiaceae and Amaranthaceae (C/A) species. Included are values for reference pollen of species found on Calf Island today, as well as average values for peat samples with > 10% C/A fossil pollen. Species/samples are ranked by average diameter. In genus/species column NA = native, E = non-native. \* Indicates species currently found in the marsh. Others are found on the beach strand or in upland thickets (*Amaranthus retroflexus* L.). *Suaeda richii* Fern. occurs, but is rare on the island today.

Depth (cm) (%C/A)	Average diameter (µm)	N (#)	Genus/species
10 (17.7%)	17.1	16	-
5 (14.0%)	17.7	7	-
15 (41.3%)	17.8	21	-
20 (10.4%)	18.3	9	-
1 (40.5%)	19.2	25	-
75 (29.4%)	19.2	35	-
-	20.4	50	<i>S. richii</i> (NA)
-	21.1	100	<i>Chenopodium ambrosioides</i> L. (E)
-	22.5	50	<i>Atriplex patula</i> L. (E)
-	22.6	50	<i>Suaeda linearis</i> Ell. Moq. (NA)*
-	23.2	50	<i>Bassia hirsuta</i> (E)
-	23.2	50	<i>Amaranthus retroflexus</i> (E)
50 (10.4%)	23.5	9	-
-	24.0	50	<i>S. maritima</i> L. Dum. (NA)*
-	25.8	92	<i>C. album</i> L. (E)
45 (11.2%)	26.5	20	-

in 20<sup>th</sup>-century sediments, where average diameters are smaller than in older sediments. The diameters of members of these families varies among species, and because several native and non-native species occur on the island today, we attempted to identify patterns related to the abundance of native and non-native species. Fossil grains at 1 through 20 cm in the core are smaller than those below and are smaller than any of our reference types, either native or non-native (Table 1). Most members of the two families currently on the island are found on the beach strand, although the two native *Suaeda* species, tall and salt-marsh sea-blite (*S. linearis* and *S. maritima*), are found both on the strand and in the marsh. *Bassia hirsuta* L. Aschers is also common on the marsh (T. Elliman, Slingerlands, NY, pers. comm.). The pollen grains of these three species are larger than those of the fossil pollen found in 20<sup>th</sup>-century sediments, however (see Table 1). The smallest fossil grains are in samples from 5 to 5 cm (25 to 75 years ago). It is possible that an unknown but probably non-native species was present until very recently. A precedent for such a decline is found in the rise and fall in pollen of sorrel, which we attribute to changes in land use (an increase and then decline in sheep grazing). An as yet unidentified Chenopodiaceae/Amaranthaceae species may have followed a similar pattern in the 20<sup>th</sup> century. The abundance of one or more small-grained species at 75 cm (ca. 1175 A.D., see Figs. 5 and 6), suggests, however, that the recent abundance of Cheno/Am species may not be attributable solely to recently introduced species.

Table 2. Abundances expressed as ratios of charcoal (Ch), soot (So), and opaque spherules (OS) to fossil pollen (P) in samples from the Calf Island marsh.

Depth (cm)	Ch:P ( $\mu\text{m}^2$ )	So:P ( $\mu\text{m}^2$ )	OS:P (#)
1	507	171	0.16
5	727	413	0.23
10	1080	345	0.32
15	6935	2091	1.44
20	3964	942	0.70
30	55	3	0.09
40	1139	13	0.07
45	1199	5	0
50	2367	0	0
55	4088	0	0
65	1646	0	0
60	870	0	0.1
70	6835	0	0
75	3074	0	0
80	4504	0	0
90	284	0	0.07
95	262	0	0

### **Fire history**

The abundance of charcoal (measured as square micrometers relative to fossil pollen) varies enormously at different depths in the core (Fig. 5), with the highest concentrations ( $6935 \mu\text{m}^2$  charcoal:pollen at 15 cm) reflecting the local occurrence of fire. Charcoal to fossil pollen ratios (Ch:P) for sites elsewhere in New England show that values in excess of 500–1000 reflect fires which burned in local watersheds or, in the case of wetlands, through the wetland itself (Clark and Patterson 1997, Motzkin et al. 1993, Patterson and Backman 1988, and others). In the Calf Island core, values exceed 2000 at 80, 75, 70, 55, 50, 20, and 15 cm. The fact that values at other depths are low is not unusual. Unlike pollen abundance, which reflects annual production that usually changes gradually, charcoal is the product of individual fires that are transient on the landscape. Estimates of the importance of fire on the island from these data are almost certainly conservative, as the identification of individual fire occurrences would require sampling the entire core at 1-cm intervals, an extremely time-consuming and costly exercise which was beyond the scope of our study.

### **Environmental pollution**

Few charcoal reconstructions done in conjunction with fossil pollen analysis have attempted to identify the by-products of fossil fuel combustion as distinct from charcoal produced in wildland fires. We earlier identified what we referred to as “opaque spherules” as a by-product of industrial pollution. Increases in opaque spherules in Long Island marsh peat were used to date 20<sup>th</sup>-century sediments (Clark and Patterson 1984). In this study, we also separated what we refer to as “soot” from opaque spherules and charcoal (Table 2). Both soot and opaque spherules rise sharply above 30 cm, as does charcoal abundance. All three measures of combustion co-vary for the five 20<sup>th</sup>-century samples. Correlation coefficients are 0.93 to 0.99 for the three comparisons.

### **Discussion**

The vegetation of Calf Island has been influenced by disturbances ranging from changing sea level and temperatures since the retreat of glaciers to human use and modification of the island's natural resources. Although this small island in the outer harbor may have had less human occupation than other islands within Boston Harbor, evidence of prehistoric fire is found in the abundant charcoal in the pre-European peat. Lightning rarely starts fires in the coastal environment (Patterson 1984), so we assume that fires were started by

Native Americans who visited the island and perhaps established at least temporary encampments to support hunting or fishing activities. Although some fires may have spread from fires lit for cooking or warmth, Native Americans were also observed to ignite fires in natural fuels for a variety of reasons including reducing brush for ease of walking, burning around wetlands to attract waterfowl in the spring, and reducing insect pests in late summer (Day 1953, Patterson and Sassaman 1988).

Calf Island currently has no forests or woodlands, and the pollen record suggests that it has been open since before 1600. Tree species (perhaps oak and birch?) that may have been present were probably scattered or in low, shrubby thickets rather than forming closed-canopy forests. Although the charcoal record shows that fires burned on the island before that time, the open character of the pre-Colonial landscape was not necessarily the sole consequence of burning, at whatever frequency it may have occurred. The harsh maritime climate and exposure of Calf Island to salt spray would have made it difficult for large trees to establish and persist on the island. The Boston area is outside the range of the white and red spruce (*Picea glauca* Moench, Voss and *P. rubens* Sarg.) that cloak small islands on the Maine coast (Davis 1966), and the pollen record provides no evidence for their presence on Calf Island.

The inner harbor islands are larger and more sheltered, and it is not surprising that historical accounts speak of them as being wooded (Richburg and Patterson 2005). The decline of these forests and those of the mainland are detected in the decline in pine and oak pollen in the Calf Island peat. Percentages and accumulation rates for these types are low, indicating they were not locally abundant.

Measures of environmental pollution, in our case the abundances of soot and opaque spherules, rise sharply in the 20<sup>th</sup> century, but have declined by as much as 75% in the top two samples, which correspond to the latter decades of the 20<sup>th</sup> century when air pollution regulations have sought to reduce particulate pollution. Concentrations at the surface remain well above background levels (of near 0 through at least the early to mid-19<sup>th</sup> century; our sampling precision is no better than 50–100 years for the 20–30 cm portion of the core). Although particulate pollution is often thought to be of only regional environmental and public health significance, recent research (Hansen and Nazarenko 2003) suggests that soot can change the albedo (i.e., the ability of a substance to reflect radiation) of glaciers and continental ice masses and thus is a factor in global climate forcing.

Paleoecologists often do not report soot separately from charcoal, and, in fact, it is not clear how often the two are tallied separately. But

there may be benefits in doing so both for interpreting the magnitude of environmental pollution (e.g., Davis et al. 1994) and for comparing modern and prehistoric fire regimes. The strong correlations between charcoal, soot, and opaque spherules for 20<sup>th</sup>-century peat and the lack of any correlation between these parameters for earlier sediments, suggest that some particles (as much as 20–40% for our data) in 20<sup>th</sup>-century sediments may be from industrial pollution rather than from wildland fires. Comparisons between pre- and post-settlement charcoal abundances (e.g., Parshall and Foster 2002, Patterson and Backman 1988) could be influenced by a failure to distinguish between sedimentary carbon particles derived from wildfires and those from the combustion of fossil fuels.

Satisfactory coring sites are few on the Boston Harbor Islands, in part due to their small size and lack of topographic relief, but also because of extensive alteration of wetlands during the past 200–300 years by human activity including draining, dredging, and filling. Although the results of our analysis of the Calf Island core do not necessarily represent what we might find on other, especially larger, islands, they do give us a sense of vegetation change on one island over a time period (i.e., a few hundred years before Europeans first entered the harbor) for which no other data are available. We do feel, however, that the changes we document in our fossil analyses of the Calf Island peat are probably typical of those occurring on at least the other small islands in the outer harbor. Searches of the larger, currently more wooded islands of the inner harbor should continue in an effort to identify appropriate sites for paleoecological investigations like ours at Calf Island. Our studies show that change has been a constant part of these landscapes, and that only a lack of change could be considered to be truly unnatural.

### **Acknowledgments**

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