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EVOLUTION OF A FRESHWATER BARRIER-ISLAND MARSH IN COASTAL GEORGIA, USA

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Abstract: Beach Pond is a freshwater pond and marsh, located approximately 50–100 m from the beach scarp in the mid-southern portion of St. Catherines Island, Liberty County, Georgia (31°37′N latitude, 81°09′W longitude). A 4.5-m sediment core was obtained from the pond in an effort to reconstruct the paleoecology of the site. The sediments (sand, clay, and peat) are Holocene age (<10,000 years). Gross sedimentological characteristics of the core suggest cyclic depositional trends. The modern vegetation of Beach Pond is dominated by *Pluchea* and other composites, *Typha*, Cyperaceae, and Poaceae. The palynology of the core reveals dynamic changes in depositional environments and plant communities during sediment accumulation. Sediments from the lower portion of the core were derived from nearshore marine environments and probably represent accumulation in a shallow lagoon; these are characterized by the abundant pollen of *Pinus* and a large percentage of broken *Pinus* pollen grains. A piece of wood recovered from the uppermost lagoonal sediments yielded a radiocarbon date (AMS) of 1210 ± 40 BP. These sediments are overlain by tidal-flat-derived sediments, which are overlain by a thin peat layer derived from an interdunal swale community dominated by *Myrica*. A return to brackish marsh conditions then occurred, as indicated by the presence of *Limonium*, Cheno-Am type (e.g., *Salicornia*), and abundant Poaceae pollen. The modern freshwater pond plant community became established as the salinity decreased; this is indicated by the abundance of freshwater plant taxa (i.e., *Azolla, Typha*, Cyperaceae). Sea-level fluctuation, erosion, storm overwash, and anthropogenic factors (i.e., road building, water-well drilling) have all influenced the development of past and modern plant communities by altering the hydrology and salinity of the site.

Key Words: coastal wetlands, paleoecology, palynology, barrier island, vegetation dynamics

INTRODUCTION

Long-term historical perspectives are critical to understanding the development and dynamics of wetlands. Ecological investigations are usually restricted to short-term ecological dynamics. However, paleoecological studies can provide insight into the processes and factors that control long-term (10^2–10^4 yr) ecological and environmental dynamics (Schoonmaker and Foster 1991). Paleoecological studies have provided insight into the relative importance and rates of autogenic (successional) and allogenic (climate, hydrology, disturbance) processes in influencing wetland development (Clark and Patterson 1985, Clark 1986a, Jackson et al. 1988, Singer 1996, Singer et al. 1996). Changes in the physical environment appear to play important roles in determining successional trajectories in coastal wetlands; biotic processes appear less important (e.g., Niering and Warren 1980, Clark and Patterson 1985, Clark 1986a). An understanding of these and other long-term controlling factors, and the documentation of specific wetland responses to particular biotic and abiotic processes, should provide for more comprehensive wetland management programs and may help predict responses of specific wetland systems to future environmental perturbation (e.g., climate or sea-level change).

Many ecological investigations of coastal wetlands in the southeastern United States have focused on the relationships between plant distribution, salinity gradients, hydroperiod, and flooding (e.g., Young et al. 1994, Perry and Atkinson 1997, Tolliver et al. 1997). The responses of plant taxa to these local environmental parameters provides a theoretical basis for interpreting paleoecological records and assessing factors affecting past vegetational change. Paleoecological studies typically rely on stratigraphic sequences of pollen and macrofossil assemblages, and these changes may be compared with associated changes in charcoal, sedimentology, biogenic structures, and other fossil types (e.g., foraminifera, diatoms). Paleoecological studies have been done on coastal wetlands of New England (Niering et al. 1977, Niering and Warren 1980), New York (Heusser et al. 1975, Clark and Patterson 1985, Clark 1986a, 1986b), New Jersey (Carmichael 1980), and North Carolina (Burney and Burney 1987). These studies have provided insight into the responses of coastal wetlands to environmental change and local disturbance, as well as into the origin, vegetation patterns, productivity, and hydrologic fluctuation of these complex systems. Plant distributions in coastal areas seem to not only be the result of local salinity and hydrologic factors as modern ecological studies suggest, but also geologic, climatologic, and historical anthropogenic events (Heusser et al. 1975, Clark 1986a, 1986b).

Few studies have investigated the long-term development and dynamics of coastal wetlands in the southeastern United States. The extensiveness of marine and freshwater wetlands in the coastal southeast, along with the mild climate, large tidal range, and geomorphologically dynamic barrier islands provides a unique setting for testing paleoecological hypotheses. In the present study, we investigate the sedimentological and palynological record recovered from a freshwater pond and marsh on St. Catherines Island, Georgia, USA. Specifically, we attempt to answer the following paleoecological questions. What processes and factors controlled the development of the modern marsh? What is the relative importance of these controlling factors? What can be inferred about the stability of these coastal wetlands? We also evaluate the potential for future paleoecological studies in the region and suggest questions that future investigations might address.

STUDY AREA AND BACKGROUND

St. Catherines Island (31°37′N latitude, 81°09′W longitude) is located along the coast of Georgia about 65 kilometers south of Savannah. Climate data from the Southeast Regional Climate Center for neighboring Sapelo Island indicates an average January low temperature of 4.8°C, average July high temperature of 32.1°C, and an annual precipitation of 131.7 cm. Georgia's coast is characterized by a large tidal range (~2 to 3 meters) and low wave energy, and it is classified as a mesotidal, medium to low energy coast (Oertel 1975, Hubbard et al. 1979, Howard and Frey 1980a, 1980b). Winds are predominantly from the northeast, and thus, wave action causes the net movement of sediment southward through longshore drift (Hayes 1979). St. Catherines is a typical 'drumstick' shaped barrier island, as described by Hayes (1979), consisting of two portions, a Pleistocene core to the north and west and Holocene sediments to the south and east (Figure 1).

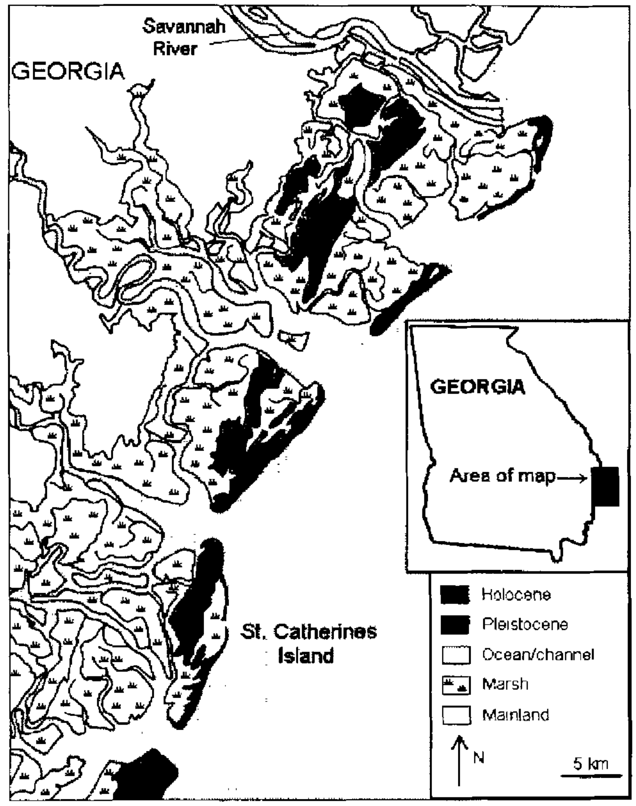

Figure 1. Selected barrier islands on the coast of Georgia, highlighting St. Catherines Island and the distribution of Pleistocene and Holocene sediments (after the Georgia Department of Natural Resources, 1976).

The Pleistocene core of St. Catherines probably formed during a eustatic (global) sea-level highstand at least 40,000 years ago (Hoyt and Hail 1974, Booth 1998). Eustatic sea level dropped at least 80 meters during the Late Wisconsinan (Bloom 1983) due to the accumulation of large volumes of water in continental ice sheets. Sea level then began to rise approximately

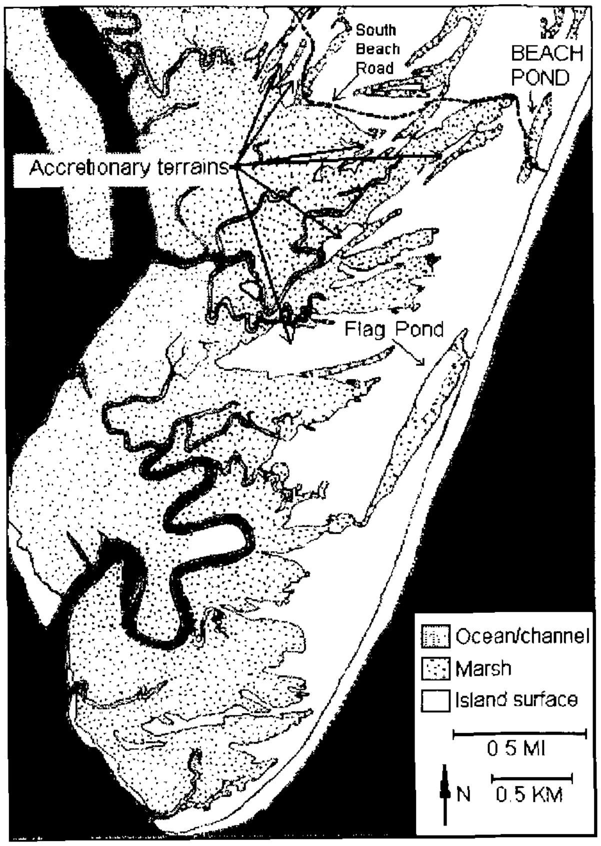

Figure 2. Map of the southern (Holocene) portion of St. Catherines Island highlighting the Beach Pond locality and some prominent accretionary terrains.

15,000 years ago as the continental sheets melted (Webb et al. 1993). Radiocarbon, palynological, and paleontological evidence suggest that St. Catherines Island formed approximately 4060 years ago when sea level rose high enough to isolate the Pleistocene core from the mainland (Booth 1998). Sea level has probably not risen more than a few meters since that time, and evidence suggests that it has risen at varying rates (Fairbridge 1992).

Longshore drift, which causes the net southward migration of sediment, has resulted in the southerly progradation of St. Catherines Island (Figure 2). This progradation has produced accretionary terrains, topographically distinct units of sand ridges and swales that have been progressively added onto the island core from north to south. These accretionary terrains are all presumably younger than 4,000 years in age, and age of the surfaces decreases from north to south (Booth 1998). Deposition and erosion are probably both critical in the formation of these accretionary terrains, although the relative importance of each is unclear.

Beach Pond is a freshwater pond and marsh that lies approximately 50–100 m from the beach scarp on the mid-southern portion of St. Catherines Island (Figure 2). The surrounding regional vegetation is dominated by pine and oak, mostly *Pinus taeda* L. (loblolly pine) and *Quercus virginiana* Miller (live oak), although *Pinus elliotii* Engelm. (slash pine) and *Pinus palustris* Miller (longleaf pine) are also prominent in the upland. The local wetland plant community is dominated by *Pluchea camphorata* (L.) DC. (marsh-fleabane) and other composites, *Typha angustifolia* L. (cattail), Cyperaceae (sedges), and Poaceae (grasses). The marginal plant community contains abundant shrubs and small trees [e.g., *Cephalanthus occidentalis* L. (buttonbush), *Myrica cerifera* L. (wax myrtle), *Sabal palmetto* Lodd. ex Schultes (cabbage palm), and *Salix nigra* Marshall (willow)]. Annual variations in water depth result in fluctuating areas of marsh and pond; on average, the water depth in the pond is approximately one meter. The total surface area of the pond and associated marsh is approximately 30,000 square meters. Salt water breaches the pond occasionally during storm tides, although this has been observed less than five times in thirty years [Royce Hayes (Island Superintendent) pers. com.].

METHODS

A 7.62-cm-diameter, 4.5-m-long sediment core was recovered from Beach Pond using a vibracorer in one drive. The core was described lithologically, noting sedimentological characteristics such as sediment type, grain size, color, and biogenic structures. Color interpretations were determined with a Geological Society of America rock color chart. The core was sampled for pollen and other palynomorphs at sixteen discrete horizons (1–2 cm vertical span, average sample volume ~3 cm^3). Sample selection and volume were based on potential palynomorph productivity as suggested by sediment characteristics (e.g., texture, organic content). Each sample was processed using standard palynological techniques (e.g., Traverse 1988, Faegri and Iversen 1989), which included HF treatment, HCl treatment, and KOH treatment to remove silicates, carbonates, and soluble humic acids, respectively.

Microscope slides were prepared using glycerine jelly as a mounting medium and were examined at 400× magnification. A minimum of 500 terrestrial palynomorphs were identified and counted in each sample, and all terrestrial pollen was included in the 'pollen sum'. We believe that using an arboreal pollen sum is not necessary due to the relatively short temporal focus of the study (i.e., the regional pollen signature is assumed to be nearly constant over time) and inferences are only being made in regard to the local wetland vegetation. Unknown and indeterminate palynomorphs were included in the pollen sum; this category never exceeded an abundance of 1.7%. Dinoflagellates and microforams, the pseudochitinous inner test linings of foraminifera (Cohen and Guber 1968), were included in the palynological analysis (although not the pollen sum).

Broken pine pollen grains were abundant in sediment samples. Two half pine grains were counted as one pollen grain in this study. Rich (1995) has suggested that broken pine grains can serve as indicators of depositional environments in coastal deposits (i.e., high energy marine environments typically contain a greater percentage of broken pine grains than low energy estuaries and lagoons). We attempted to quantify this relationship by calculating the percentage of broken pine grains in each sample.

RESULTS AND DISCUSSION

Local and regional evidence indicates that the basal sediments in the Beach Pond core are mid-Holocene in age (>4000 years old). Other sediment cores from the southern portion of the island preserve a prominent disconformity at a depth of ~5 m. (Booth 1998). This disconformity is characterized by Pleistocene sediments (>40,000 BP) overlain by Holocene marine sediments (~4000 BP) and substantial oxidation of the erosional/depositional interface (Booth 1998). Apparently, the Beach Pond core did not penetrate deep enough to recover this disconformity. The regional presence of this disconformity is supported by similar depositional hiatuses between Pleistocene and mid-Holocene sediments at other coastal plain localities in Florida and Georgia (Watts 1969, 1971, Watts and Hansen 1988, Booth and Rich 1998).

Beach Pond sediments consist of sand, clay, peat, and some shells (Figure 3). To facilitate discussion, the core can be subdivided into four depositional zones (A through D). Each of these zones is generally characterized by two sedimentological trends from bottom to top: increasingly fine grain size and increasing sediment consolidation. Zone C actually consists of three such vertical trends.

The sediments of Zone A were deposited under nearshore marine conditions, as indicated by the presence of shell fragments and the palynological signature of the sediment (Figure 4). The association of taxa found in the lower two zones (e.g., dinoflagellates, microforams, Chenopodiaceae/Amaranthaceae), along with the dominance of pine and the large percentage of broken pine pollen grains, is characteristic of nearshore marine environments in the southeast (Rich and Pirkle 1993, 1994, Rich 1995). Presumably, the high percentages of *Pinus* pollen in nearshore marine sediments is a result of taphonomy (i.e., sorting by wind

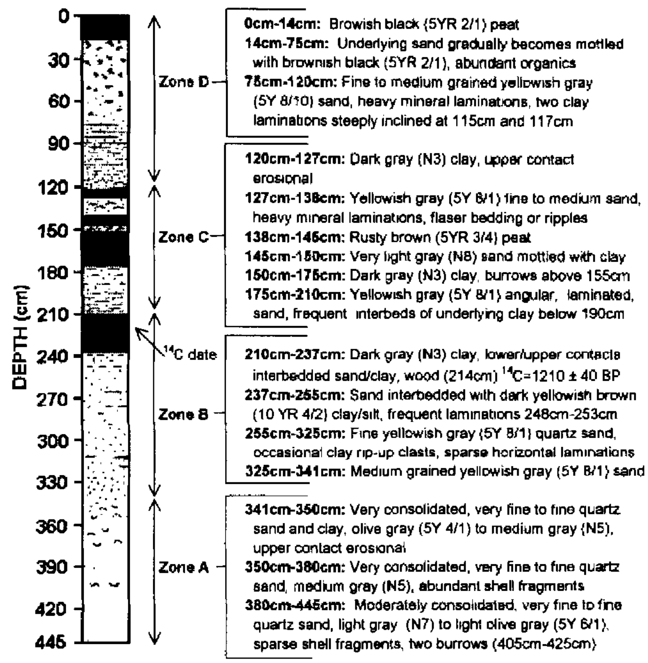

Figure 3. Stratigraphy of the Beach Pond sediment core.

and waves) (Clark and Patterson 1985, Rich and Pirkle 1993).

The cyclic depositional nature of the core seems to be related to the progradation of the island via the deposition of accretionary terrains during the Holocene. The lower sediments of zone A probably accumulated when the shoreline was located some distance (2–3 kilometers?) west and north, and water was several meters deep. The basin became increasingly shallow as sediments accumulated, and this culminated in the deposition of clay and relatively buoyant shell fragments in what was probably a shallow lagoon or runnel. An off-shore sand bar may have aided in the isolation of this lagoon, which had an open connection with the marine environment.

Zone A and B are separated by a disconformity, which was probably caused by a period of substantial erosion. This event may have resulted in the deepening of the basin and the erosion of some of the accretionary terrains. Throughout Zone B, the same general trends as were seen in Zone A are seen again as the basin filled with sediment. An accretionary terrain was built up and culminated with the isolation of a lagoon in which clay was deposited. The lagoon maintained an open connection to the marine environment, as indicated by the palynological composition of its sediments (e.g., microforams, dinoflagellates, high *Pinus* abundance). Similar pollen assemblages are reported by Rich (1995) and Rich and Newsom (1995) from coastal and nearshore marine Pliocene through Holocene deposits in Florida, Georgia, and South Carolina. A solitary piece of wood in the clay at the top of zone

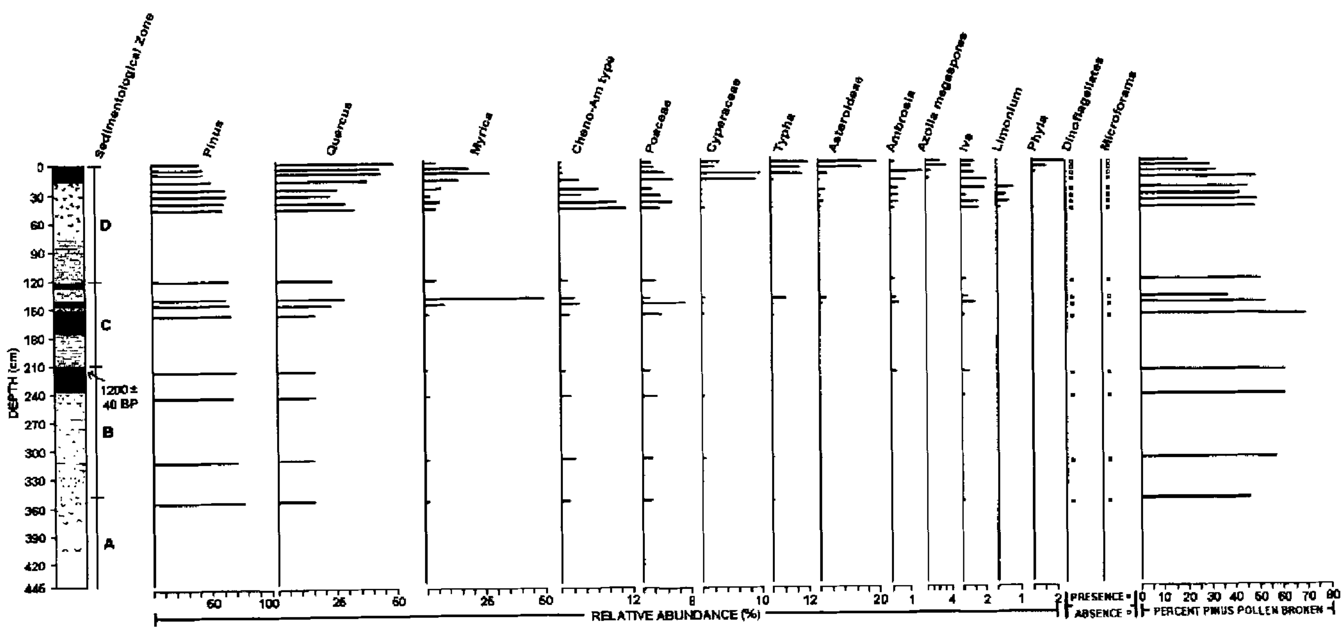

Figure 4. Pollen percentage data for selected taxa encountered in the Beach Pond sediment core.

B (214 cm) has been radiocarbon-dated (AMS) at 1210 ± 40 BP (BETA-115910).

Zone C is characterized by more frequent fluctuations in depositional and erosional events. The laminated sediments and abrupt changes in sediment lithology and palynology (Figures 3 and 4) suggest that the combination of slight sea-level rise (Fairbridge 1992) and basin infilling resulted in greater sensitivity to relatively minor erosional and depositional events, such as storm washovers. Zone C shows increasing terrestrial pollen percentages towards the top of the zone (e.g., *Myrica*, Poaceae, Asteroideae, *Iva*), suggesting that the island had expanded eastward and southward at least to the position of the current Beach Pond. Basal sediments in Zone C probably accumulated in a shallow nearshore lagoon similar to the uppermost sediments of Zone B, but they are overlain by organic-rich clay derived from salt marsh and hammock vegetation at 144 cm depth. This interpretation is supported by the increased percentages of Poaceae, *Myrica*, and Cheno-Am type pollen. The plant community was probably similar to those found today in the marshes and hammocks on the southern portion of the island, which are dominated by *Spartina* (cordgrass) and *Salicornia* (glasswort) in the marsh and *Myrica, Quercus, Iva,* and other composites on the hammocks.

A peat, probably derived from a freshwater swale plant community, was deposited above the salt marsh sediment and may represent accumulation in an open water pond that was surrounded by dense wax myrtle shrub thickets, as suggested by the high *Myrica* pollen abundance (Figure 4). The inference of calm, freshwater conditions is also supported by the low percentage of broken pine pollen grains (38%) and the absence of microforams and dinoflagellate cysts (Figure 4). The establishment of this community was a result of a change in the hydrology of the area, possibly brought on by the deposition of a washover fan or migrating dune. Another washover event, possibly produced by a prolonged storm, deposited sand over the peat; this sand shows evidence of ripples with mud laminae (flaser bedding). A salt- or brackish-marsh-derived clay, as indicated by the presence of microforams and dinoflagellate cysts (Figure 4), was then deposited (121 cm), indicating reopening of the swale to the marine tidal system.

The events of Zone C are a result of the accumulation and erosion of sediments at or near sea level, and the lithology and palynology of these sediments reflect this dynamism. The sediments that accumulated in Zone A and B were not as strongly influenced by storms and tidal conditions, presumably because they were deposited too far below sea level. This interpretation is also supported by the abundance of locally derived terrestrial pollen types in Zone C (e.g., *Myrica*, Asteroideae, *Iva*) and the paucity of these pollen types in Zones A and B.

The sediments of Zone D show similar trends as those in Zone C. Heavy mineral-laminated sediments (e.g., ilmenite or magnetite) comprise the lower portion of the zone (Figure 3) and probably accumulated on the backbeach, where heavy mineral sands tend to be deposited. When enough sand had accumulated, the area was colonized by marsh plants, including chenopods, grasses, and *Limonium*. *Limonium* is a brackish-marsh plant that is spatially confined to the upper parts (high marsh) of salt and brackish marshes (Duncan and Duncan 1987), and its entomophilous habit suggests a very limited pollen dispersal range. The consistent presence of *Limonium* in all four samples (Figure 4) suggests deposition within the upper portion of a brackish marsh environment. The associated palynoflora (e.g., Poaceae, Cheno-Am type) is consistent with this interpretation. Plants such as *Baccharis angustifolia* (Michx.) [false-willow], *Borrichia frutescens* (L.) DC. [sea ox-eye], *Iva frutecens* L., and *Spartina patens* (Ait.) Muhl. [marshhay] probably lived in the vicinity as well, as suggested by the occurrence of Asteroideae, *Iva*, and Poaceae pollen.

An abrupt transition to the modern freshwater pond then occurred at the top of the profile. Increasing percentages of *Ambrosia* (ragweed) coincide with this transition. *Ambrosia* is often used as an indicator of the onset of regional human disturbance (i.e., field clearing for agriculture) or similar environmental perturbation (Webb 1973). The creation of South Beach Road, which runs along the southern tip of Beach Pond, must have affected the local hydrology. In the vicinity of Beach Pond, this road is nothing more than a raised ridge of sand. The road was probably built in the 19th century by farmers who inhabited the southern portion of the island (Thomas et al. 1978). The road was known to exist by 1942, when a Coast Guard barracks was constructed behind the dunes near the site of Beach Pond (Thomas et al. 1978). The road probably altered the hydrology of the site by transecting the swale, isolating the northern part of the basin from tidal influence, which allowed the basin to be colonized extensively by sedges, wax myrtle, and other plants characteristic of freshwater swale communities (Figure 4). Although some marine influence is suggested by the presence of dinoflagellate cysts and microforams, it was probably minor and restricted to storm overwash. This inference is supported by the abundant Cyperaceae and *Myrica* pollen and the presence of *Azolla* megaspores (Figure 4).

The drilling of an artesian well in the early 1950s [Royce Hayes (Island Superintendent) pers. com.] completed the transition to freshwater conditions that was initiated by road construction. The pond filled and was occupied by an open water environment for some time, as indicated by high relative abundance of *Myrica* and Cyperaceae pollen. Those plants were probably left growing around the pond perimeter after it filled with fresh water. As peat accumulated in the pond and water flow from the well stopped in the 1960s, herbaceous species dominated by composites (e.g., *Pluchea*) and cattails were able to colonize the pond as the water level fell. Very recent sediments have high percentages of *Phyla* and *Polygonum* pollen (Figure 4). The appearance of these swale-dwelling plants probably was a result of the lowering of the water level.

CONCLUSIONS

The Beach Pond sediment core records a dynamic developmental history, characterized by substantial vegetational change. Factors directly controlling the modern marsh/pond development at Beach Pond were mostly anthropogenic in nature (e.g., road building, well drilling). However, the dominant, long-term controlling process affecting plant community composition at the site was the erosion and deposition of accretionary terrains, washover fans, and dunes. These events, most of which were probably driven by storm tides, have continually altered hydrology and salinity gradients at the site for the last 1200 years. The number of disconformities (caused by erosional events) and the number of discrete plant communities represented in just 1200 years time, attest to the ephemeral and unstable nature of these coastal wetland systems.

Modern events on the island also illustrate the dynamic relationship between geologically driven processes (e.g., deposition, erosion) and plant community composition. For example, in 1993 after a series of storms, the Atlantic Ocean inundated Flag Pond, which is located several miles south of Beach Pond (Figure 2). Flag Pond, which once had a similar flora to Beach Pond, is now a marine tidal flat containing only scattered clumps of *Spartina*.

The paleoecological record of beach pond indicates that as erosional and depositional events altered local environmental parameters (e.g., salinity, hydrology), similar new habitats were also created by these same processes. However, St. Catherines Island is now being eroded on all sides, so it seems unlikely that new habitats are currently being created. By collecting sediment cores transecting many neighboring hammocks and swales, future studies may be able to determine if comparable periods of erosion existed in the past. Spatially and temporally precise studies may also determine the rate at which these accretionary terrains develop and erode and the historical rate of plant community response to these parameters. Past rates of wetland response have direct implications for wetland management programs and for models of future climate change.

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