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Bulletin No. 22: Our Dynamic Tidal Marshes: Vegetation Changes as Revealed by Peat Analysis

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OUR DYNAMIC TIDAL MARSHES

VEGETATION CHANGES AS REVEALED BY PEAT ANALYSIS

THE CONNECTICUT ARBORETUM
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*Front Cover–Mamacoke Island Natural Area, Connecticut Arboretum. The wooded upland which extends into the Thames River is connected to the mainland by this tidal marsh. Tall saltwater cordgrass (*Spartina alterniflora*) forms a narrow border along the shoreline. Saltmeadow cordgrass (*Spartina patens*) dominates most of the high marsh (lighter tone). The slightly darker depression in the center is a stand of short* Spartina alterniflora.

OUR DYNAMIC TIDAL MARSHES

VEGETATION CHANGES AS REVEALED BY PEAT ANALYSIS

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CONTENTS

THE CONNECTICUT ARBORETUM

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INTRODUCTION

The tidal marshes of Connecticut represent a very limited but valuable resource totalling some 15,500 acres (6,277.5 hectares). These coastal wetlands are integrally related to estuarine and coastal zone finfish and shellfish productivity and waterfowl production (1,2), in addition to other ecologically significant coastal marine processes. It is estimated that 50 percent of the marshes that were present in the State in 1914 have been destroyed as a result of man's activities (3). In order to check further losses, legislation was enacted in 1969 to protect the Connecticut marshlands. In 1973 a state-wide inventory of these salt marshes was conducted for the Department of Environmental Protection, with support from the Department of the Interior, Bureau of Sports Fisheries and Wildlife (4). During this inventory an examination of several samples of marsh peat indicated excellent preservation of the dead plant remains, primarily rhizomes. This observation suggested that peat analysis could provide a fascinating approach toward reconstructing vegetation history of tidal marshlands. We were particularly interested at that time in determining the influences of major natural environmental disturbances, such as storms, along with the impact of some of man's activities.

Prior to 3000 to 4000 years ago the sea level rose so rapidly that significant areas of tidal marsh probably could not develop along the North Atlantic Coast. Over the past 3000 years this coastal submergence slowed to about 10 cm per century and tidal marshes became established in the bays and inlets of New England. Within the past 50 to 100 years the average rate of submergence has increased to 2.5-3 mm per year or 25-30 cm per century. A plot of the sea level for this period shows that the rise, instead of being an even one, has consisted of a series of oscillations. For example, during the past 12 years we have been experiencing a very sharp rise with a short-term rate of nearly 1 cm/year or one meter per century. These sea level oscillations may be one of the many interacting factors accounting for vegetation change on the tidal marshes.

The salt marshes of the northeast are dominated by a few species of graminoids. Along the intertidal zone, saltwater cordgrass (*Spartina alterniflora*, hereafter referred to as alterniflora) usually forms a conspicuous belt of varying width (See front cover). On the adjacent higher marsh, a finer and shorter saltmeadow cordgrass (*Spartina patens*, hereafter referred to as patens) forms the matrix within which occur "islands" of short alterniflora, blackgrass (*Juncus gerardi*), spikegrass (*Distichlis spicata*), and forbs, or a mixture of these species. At the upland/marsh interface, *Juncus* often forms a belt along with marsh elder (*Iva frutescens*). Here, reed-grass (*Phragmites communis*) and switchgrass (*Panicum virgatum*) also may be conspicuous.

Three major tidal marsh types (deep and shallow salt marshes and upper river estuarine marshes) are recognized in Connecticut, based on the stratigraphy and geological origin of the deposits (5,6). The deep marshes, mostly west of the Connecticut River, developed in the three to fifteen meter deep bays and lagoons that were formed towards the end of the rapid post-glacial sea level rise (about 3000 years ago). Many of these appear to have formed over pre-existing tidal flats. The shallow marshes, generally less than three meters in depth, were not affected by coastal submergence prior to 3000 years ago, but have formed since that time over upland or freshwater wetland sites as the sea level has risen more gradually. Thus, with coastal submergence, marsh formation can occur landward as well as seaward (7). The third marsh type, which was not sampled, is the estuarine wetlands in the upper river basins, where cattails and reed-grass form the dominant vegetation.

The purpose of this paper is to present the methodology employed in sampling the tidal marsh peat and in identifying the plant remains. A few cores are described and analyzed to demonstrate the potential of this technique in documenting vegetation change. A more detailed paper, currently in preparation, will synthesize all aspects of this research.

The authors wish to thank the National Audubon Society, the Seth Sprague Educational and Charitable Foundation, and the Henry L. and Grace Doherty Charitable Foundation for financial assistance in this research. The authors also thank Dr. R. H. Goodwin for suggesting that this research methodology be shared as an Arboretum Bulletin. We are also grateful to Mrs. Nancy Olmstead for her editorial assistance, Mr. Theodore Hendrickson for photographs of profiles and sampling equipment, to Mr. Hugh Niering for the art work, and to Mr. Christopher Mason for preservation work on the profiles.

METHODOLOGY

Peat samples were collected in 1974 and 1975. A series of twenty-three one-meter length peat cores was carefully cut from eight different marsh systems, representing both shallow and deep marshes along the Connecticut shoreline. The instrument used to obtain intact cores is a special sampling device designed by Dr. Richard McCaffrey (8). To obtain a sample, a 25 × 25 cm block of surface peat is removed with a shovel; a hole is then dug with a post-hole auger to a depth of one meter (Fig. 1). The removed peat is piled on a plastic or canvas sheet so that it can be replaced. The sampler's 10.5 × 12 cm cutting edges are then placed on the marsh adjacent to the hole and, with a knife, an initial cut is made into the dense marsh turf along the three cutting edges in order that they can easily enter the very dense surface peat. The rotating metal bottom door used to cut off the bottom of the core is swung over into the open hole. In the sampler shown on the back cover the bottom cutting door is in the open position. It is opened and closed by turning the top cross bar handle. The handle is connected to the door by a revolving pipe inside a stationary pipe to which three triangular brackets, used as foot braces when pushing the sampler into the marsh, are attached. The cutting edges are now placed into the cut marks along the edge of the hole and the sampler is pushed rapidly and continuously downward into the peat. The bottom of the peat section is completely cut off or disconnected by swinging the bottom door under the intact core. While being pulled up, the peat core lies against the metal plate which is welded to the pipe frame. Three metal straps serve to hold the core against the frame. Figure 1 shows three steps in the process of peat removal. The core is labelled, wrapped in plastic, and returned to the laboratory for analysis. When the peat is replaced and the surface grass plug is carefully set back in the top of the hole, there is little evidence of disturbance. In the laboratory a 2 cm thick slice is cut from the length of the core (about 1 m) and laid out beside a millimeter scale. Peat color, texture and type of sediment are noted. In addition, depth of sand layers and shell fragments is carefully documented. The peat is then teased apart with forceps in order to identify the kinds of rhizomes present. The key which follows was developed to facilitate identification of the various kinds of plant remains commonly found. Throughout the profile the percent of each marsh species or vegetation type is estimated and major associations demarcated as shown in the illustrations.

KEY TO SPECIES IN SALT MARSH PEAT

1. Rhizomes greater than 10 mm in diameter; roots numerous, flaccid, 3-4 mm in diameter extending 20-30 cm or more below the rhizomes; pith hollow ..... *Phragmites communis*

1. Rhizomes less than 10 mm in diameter 2

  2. Rhizomes 1.5 mm or more in diameter present 3

    3. Rhizomes shiny, tannish brown, 2-4 mm in diameter, with conspicuous encircling scars or scales; pith solid with scattered vascular bundles; cortex with thin radial septa delimiting air chambers, when not collapsed (A) ...... *Distichlis spicata*

    3. Rhizomes not as above 4

      4. Rhizomes over 2.5 mm in diameter, tannish-brown, usually collapsed; ensheathing, scale-like leaves shredded; few small roots (B) *Spartina alterniflora*

      4. Rhizomes 1.5 to 2.5 mm in diameter 5

        5. Rhizomes with ensheathing scale-scars present, tannish-brown, pith hollow; cortex with a ring of air chambers; peat dense and fibrous with many fine roots (C) .... *Spartina patens*

        5. Rhizomes lacking ensheathing, scale-like leaves, reddish-brown; pith solid, dark when wet, delineated by a narrow, reddish-brown band; cortex light with septa delineating air chambers; roots distinctly wavy and wiry (D) .... *Juncus gerardi*

  2. Rhizomes absent; peat usually black with numerous rootlets, often white, 0.25-0.5 mm in diameter .... Forb peat
  Root stalks up to 10 mm or more occasionally present 6

    6. Bulb-like root stalks covered with bristle-like fibers; central cylinder very hard, blood red and barbed in longitudinal section, with many fibrous roots up to 1 mm in diameter .... *Triglochin maritima*

    6. Root stalks woody, 5 to 10 mm or more in diameter, with smaller laterals; all parts black, wrinkled, with striated texture; pith and cortex dark and poorly differentiated .... *Limonium carolinianum*

Note: *Panicum virgatum* (Switchgrass) rhizomes are found in upland soil or at the marsh-upland interface. Rhizomes are 1 to 4 mm in diameter, usually collapsed and flaccid with very long, pointed, ensheathing, scale-like leaves and few roots or rootlets.

A *Distichlis spicata* B *Spartina alterniflora* C *Spartina patens* D *Juncus gerardi*

SOME PATTERNS IN MARSH DEVELOPMENT

An analysis of peat profiles from five different marshes demonstrates the potential of this technique in documenting geomorphic processes along with vegetation changes that have occurred over hundreds of years of marsh development. At Chittenden Beach Marsh in Guilford, Connecticut, Sears (9) found that peat one meter below the surface was 1180 years of age. It is also possible to correlate major environmental disturbances such as hurricanes and the impacts of man with specific vegetation changes.

MARSH ENCROACHMENT LANDWARD

Three cores from marshes in eastern Connecticut—two from the Barn Island Game Management Area owned by the State, and one from the Cottrell Marsh, a natural area owned by The Nature Conservancy—represent shallow marshes which have developed over upland sites. The lower level of each core contains remains of species that occur at the upland/marsh interface today or in brackish wetlands along the marsh margin. In two cores *Panicum* rhizomes are recorded at the lower levels where there is a transition from peat to upland soil (Figs. 2, 3). Thus, with coastal submergence, salt marsh grasses have formed several feet of peat over upland that had become flooded. In the third core (Fig. 2), this encroachment has apparently occurred over *Phragmites*, on what was probably a brackish marsh obliterated by the sea level rise.

In all cores, *Distichlis* appears to be the important colonizer following either *Panicum* or *Phragmites*. The colorful forbs typical of the marsh today are often associated in this pioneering transition. Ultimately, a mixture of the high marsh grasses, patens, *Distichlis*, short alterniflora and forbs, dominates the upper levels of all these cores.

Fig. 1. Sequence showing steps in obtaining a peat core with modified McCaffrey sampler. Left—Hole is being excavated with post hole auger. The surface block of grass turf shows to the left. Center—Cutting edges of sampler are placed on edge of hole with bottom door open and over the hole. Sampler is now ready to be pushed down along side of hole just excavated. Two foot braces to aid in the process are shown. Right—Sampler removed with section of peat. Three metal bands hold the peat against the metal frame while extracting.

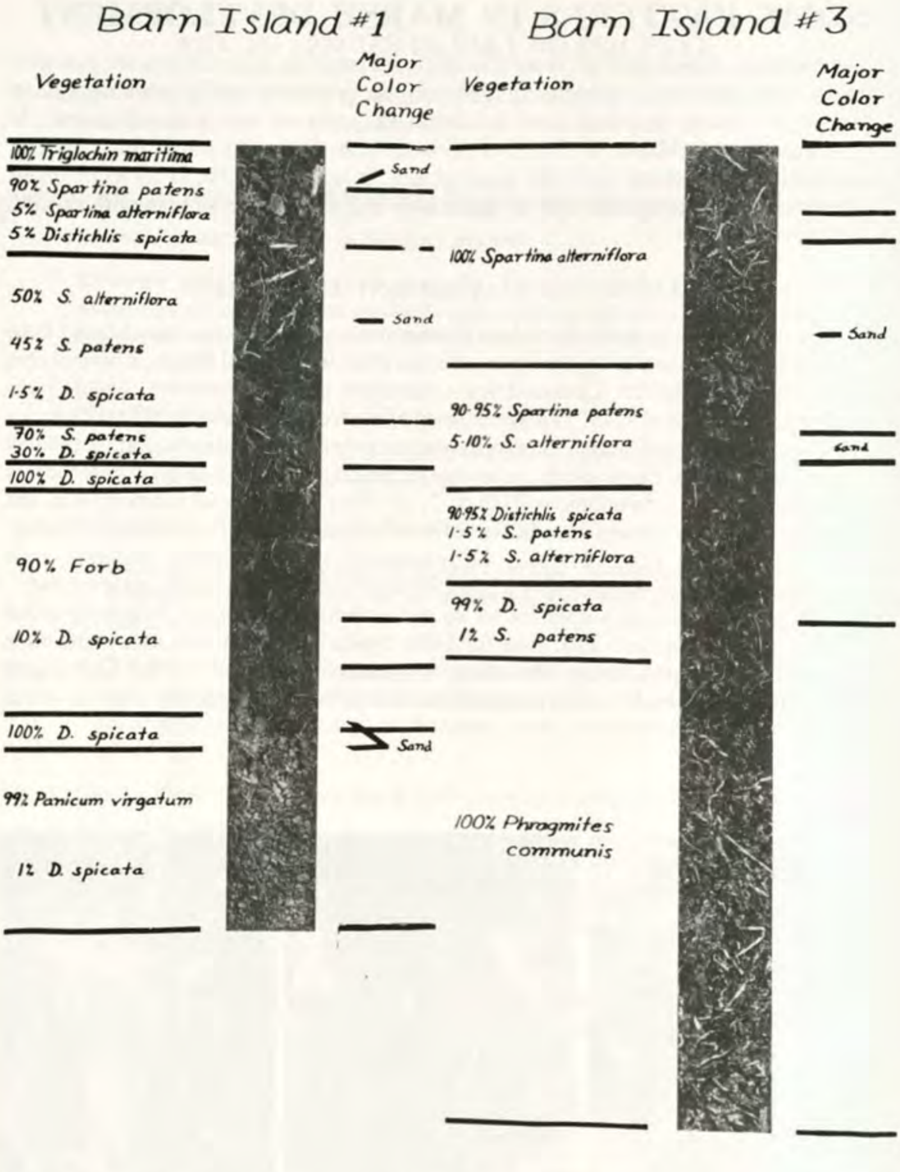


*Fig. 2. Peat profiles from the Pawcatuck-Wequetequock Marsh (Barn Island Management Area), Stonington. Barn Island 1 shows initial establishment of switchgrass (*Panicum virgatum*) in mineral soil and subsequent replacement by spikegrass (*Distichlis spicata*) and forbs as the sea level rose over the adjacent upland. This marsh vegetation was eventually replaced by* Spartina *grasses. Within the last few decades forbs, including arrow-grass (*Triglochin maritima*), have replaced the* Spartina *grasses. Note location of topmost sand line which probably represents the 1938 hurricane. Barn Island 3, taken in short saltwater cordgrass (*Spartina alterniflora*) shows earlier dominance by reed-grass (*Phragmites communis*) and its replacement by* Distichlis *and eventually by* Spartina *species. Total depth of peat cores shown: #1—84 cm; #3—104 cm.*

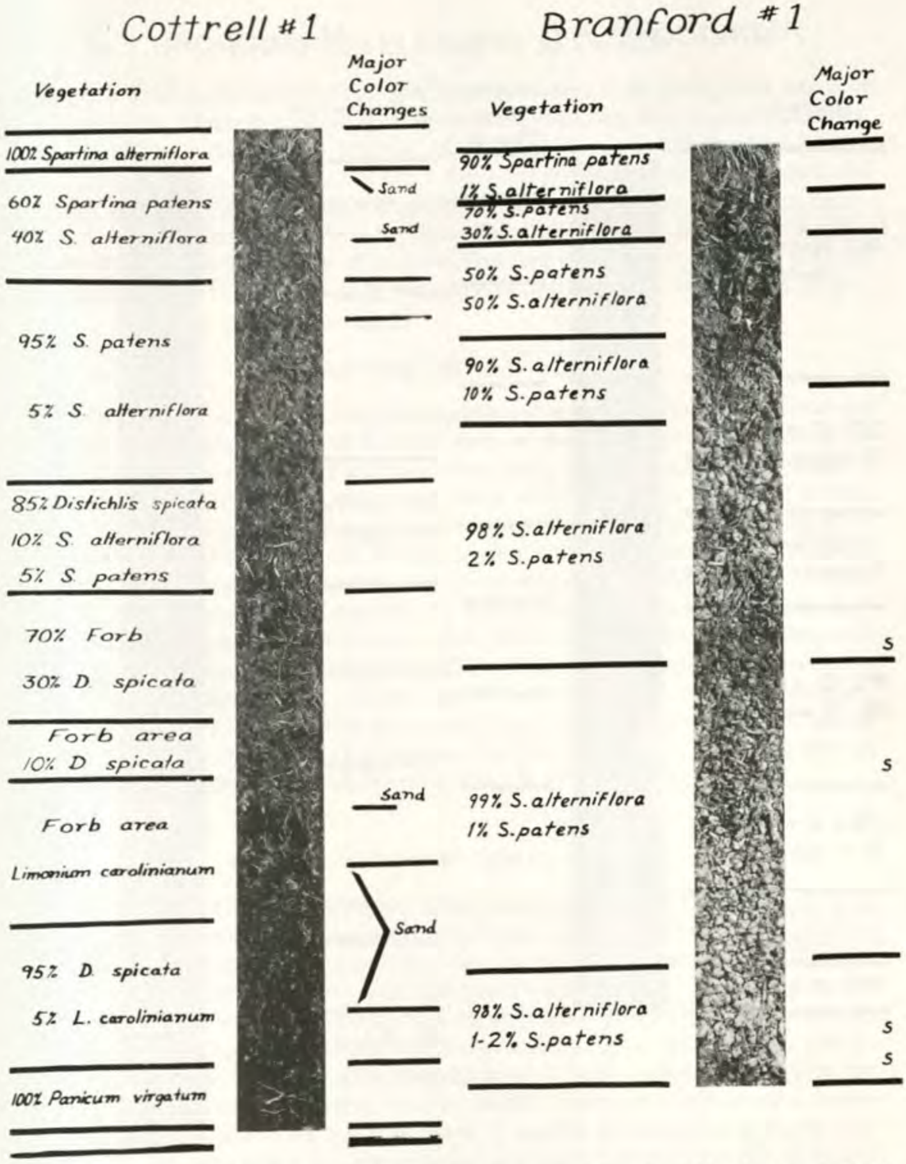
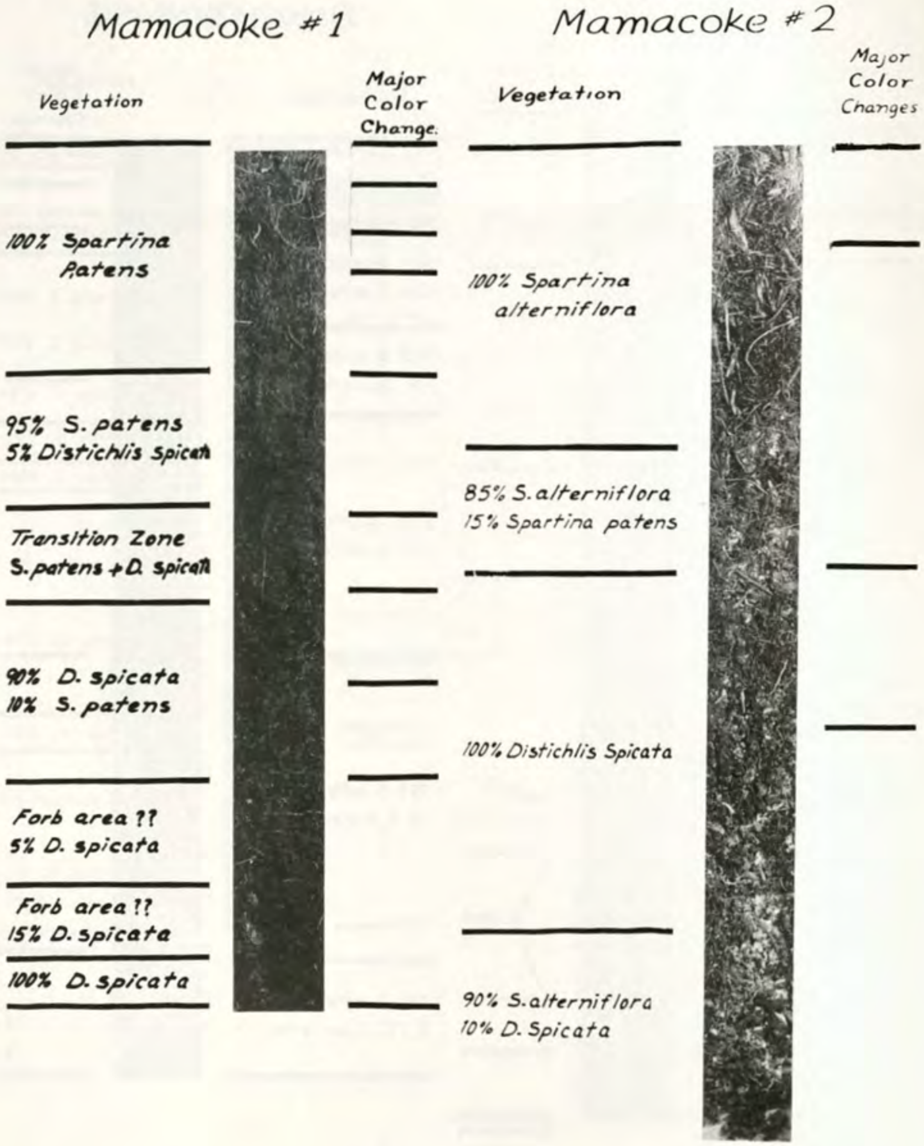


*Fig. 3. Peat profiles from Cottrell Marsh, Stonington and Branford Marsh, Branford. At Cottrell Marsh the initial establishment of switchgrass (*Panicum virgatum*) occurred on mineral soil. With continued sea level rise and its encroachment on the upland, switchgrass was replaced by spikegrass (*Distichlis spicata*) and forbs. Later,* Spartina *grasses dominated. Sample was taken in short saltwater cordgrass (*Spartina alterniflora*). Location of sand lines suggests deposition during severe storms. At Branford, marsh development was initiated by saltwater cordgrass (*Spartina alterniflora*) on silty clay marine sediments along the Branford River. With continued marsh building this tall, intertidal grass was replaced by the high-marsh saltmeadow cordgrass (*Spartina patens*). Core was taken 35 m from the riverfront in an area currently dominated by intertidal tall* alterniflora. *Total depth of peat cores shows: Cottrell #1—102 cm; Branford #1—97 cm.*



*Fg. 4. Peat profiles from Mamacoke Marsh, Waterford. Core 1 was taken in saltmeadow cordgrass (*Spartina patens*) on the high marsh 40 meters from the upland. Spikegrass (*Distichlis spicata*) was the initial marsh species established and was gradually replaced by patens. Forbs may have been present in the transition. Total depth of marsh at the point sampled was 1.6 m. Mamacoke 2 was located in a short saltwater cordgrass (*Spartina alterniflora*) depression farther from the upland, between two higher patens areas. Here alterniflora dominated earlier, with one oscillation to* Distichlis. *Total depth of peat cores shown: #1—91 cm; #2—106 cm.*

MARSH DEVELOPMENT SEAWARD

The Branford Harbor Marsh (Pawson Marsh), located in an embayment along the Branford River, illustrates marsh development seaward over fine marine sediments. Here alterniflora is the pioneer species. Much fine gray silt is incorporated into the peat profile as seen in Fig. 3. Below 1 to 1.5 m plant remains are no longer found, and this fine, gray, silty clay, mixed with shells, extends four meters or more in depth. With continued marsh development the intertidal alterniflora is ultimately replaced by patens, which is found at the top of the core. This type of marsh development has been reported elsewhere in Connecticut by Knight (10) and on Cape Cod by Redfield (8).

MAMACOKE ISLAND MARSH

The small marsh seen in the cover photograph is five miles up the Thames River and is part of the Mamacoke Island Natural Area of the Connecticut Arboretum. Its vegetation pattern is more representative of a coastal marsh than an upper estuarine marsh and it illustrates how two cores taken only 30 meters apart can exhibit extremely different patterns of vegetation history. This shallow *Spartina* marsh is dominated by patens with a narrow, fringing belt of alterniflora. Sandwiched between two strips of patens is a low, wetter area dominated by short alterniflora. In 1957, when this marsh was initially mapped (11), the depression was predominantly short alterniflora with a patch of *Distichlis*. Two decades later, short alterniflora still dominates, but patens is more frequent and *Distichlis*, while still persisting, seems to be becoming less important (12). Cores were taken from both these vegetation types. The alterniflora core indicates that this species has been dominant in the past except for one oscillation to *Distichlis* (Fig. 4, Core 2). The patens core shows *Distichlis* as the initial species and its replacement by patens (Fig. 4, Core 1).

IMPACT OF MAN: TIDAL GATES

On the Hammock River in Clinton, tidal gates have been in existence for many years at a bridge over the river on what is now Route 145. There is evidence that a road or path across the marsh, with a crossing over the river, was present in 1874. State Highway Department maps show that tidal gates existed in 1913. The present tidal gates were installed when a new bridge was constructed in 1947. The marsh below the bridge, which receives full tidal flushing, is covered by a mosaic of *Spartina* grasses and other typical marsh species. That portion above the gates, where tidal flushing has been nearly eliminated, is covered by *Phragmites*. Sediment accumulation is also greatly accelerated above the tidal gates (16.5 mm/yr) as compared to below (3-6 mm/yr) (13). This has raised the marsh surface and combines with the loss of regular tidal inundation to drastically alter the ecological conditions above the gate. By comparing two cores taken above and below the gates one can see the dramatic change which has been documented in the peat profiles (Fig. 5). The productive *Spartina* grasses, originally dominant above the bridge, have been replaced by *Phragmites* (Fig. 6). Tidal gates such as those described here are having a drastic effect on a great number of Connecticut's marshes. As can be seen, their use results in the loss of the *Spartina* grasses, whose detrital contribution to estuarine productivity is essential, and in their replacement by *Phragmites*.

From these few examples one begins to see the potential of this fascinating technique for unravelling coastal processes, marsh vegetation dynamics, and the

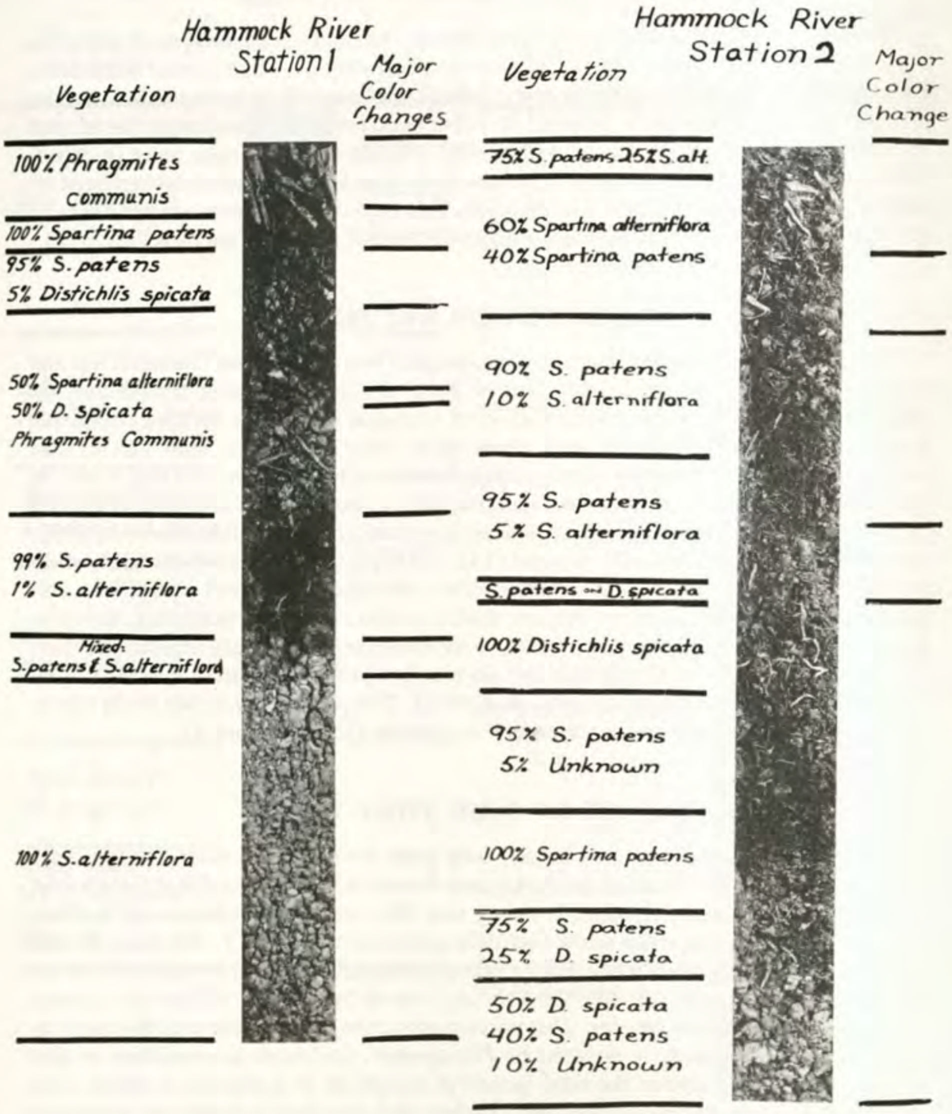


*Fig. 5. Peat profiles from Hammock River Marsh, Clinton. Station 1 was located in reed-grass (*Phragmites communis*) dominated marsh above the tidal gate. With tidal restriction* Phragmites *(note very large rhizomes) has replaced a saltmeadow cordgrass (*Spartina patens*) salt marsh. Lowest level of profile shows initial dominance of saltwater cordgrass (*Spartina alterniflora*) intermixed with silty sediment. Station 2 was located nearby, but below tidal gates in* Spartina*-dominated marsh. Spikegrass (*Distichlis spicata*) was formerly more important in the lower half of the profile and the* Spartina *species have more recently predominated. Total depth of peat cores shown: Station 1—92 cm; Station 2—96 cm.*

effects of man's activities. Among other factors to be studied in greater detail is the impact of storms. These leave evidence of their occurrence in "sand lines," some of which are associated with vegetation changes. The profiles also tend to show the major vegetation changes that have occurred over the past 500 to 1000 years. In addition, these profiles indicate that the vegetation pattern is an everchanging phenomenon on the tidal marshes of Connecticut. As Miller and Egler so aptly stated, "The present mosaic may be thought of as a momentary expression, different in the past, destined to be different in the future, and yet as typical as would be a photograph of moving clouds" (14).

It is hoped that the methodology presented here will assist others in pursuing similar studies elsewhere.

Fig. 6. Hammock River Marsh, Clinton. Left—View south toward Long Island Sound showing typical Spartina-dominated salt marsh subjected to normal tidal flushing. Right—View north above tidal gates under bridge shows replacement of Spartina *marsh by reed grass (*Phragmites communis*). Also see Fig. 5.*

LITERATURE CITED

1. Niering, W.A. 1966. The Life of the Marsh. McGraw-Hill Book Co., New York, Toronto, London.

2. De la Cruz, A.A. 1973. The role of tidal marshes in the productivity of coastal waters. Assoc. of Southeastern Biologists' Bull. 20: 147-156.

3. Niering, W.A. and R.M. Bowers. 1966. Our disappearing tidal marshes. *In* second reprinting of Connecticut's Coastal Marshes: A Vanishing Resource. Connecticut Arboretum Bull. No. 12. 1961. Connecticut College, New London, Conn.

4. Niering, W.A. and R.S. Warren. 1974. Tidal marshes of Connecticut: Vegetation, micro-relief and environmental impacts. *In* Tidal Wetlands of Connecticut: Vegetation and Associated Animal Populations. (W.A. Niering and R.S. Warren, eds.) Report to the Department of Environmental Protection, State of Connecticut.

5. Bloom, A.L. and C.W. Ellis. 1965. Postglacial stratigraphy and morphology. Guidebook No. 1 (L.W. Page, ed.). State Geological and Natural History Survey of Connecticut. State Librarian, Hartford, Conn.

6. Hill, D.E. and A.E. Shearin. 1970. Tidal Marshes of Connecticut and Rhode Island. Bull. No. 709. The Connecticut Agricultural Experiment Station, New Haven, Conn.

7. Redfield, A.C. 1965. The ontogeny of a salt marsh estuary. Science 147: 50-55.

8. McCaffrey, R. 1976. A record of sediment and trace metals in a Connecticut salt marsh. Ph.D. Thesis. Yale University, New Haven, Conn.

9. Sears, P.B. 1963. Vegetation, climate and coastal submergence. Science 140: 59-60.

10. Knight, J.B. 1934. A salt-marsh study. Am. Jour. Sci. 28: 161-181.

11. Niering, W.A. 1961. Tidal marshes: Their use in scientific research. *In* Connecticut's Coastal Marshes: A Vanishing Resource. Connecticut Arboretum Bull. No. 12. Connecticut College, New London.

12. Niering, W.A. and R.S. Warren. 1975. Tidal Wetlands of Connecticut: Vegetation and Micro-Relief. Vol. II, Part 4. Report to the Department of Environmental Protection, State of Connecticut.

13. Harrison, E.Z. 1975. Sedimentation rates, shoreline modification, and vegetation change on tidal marshes along the coast of Connecticut. Masters Thesis, Cornell University, Ithaca, N.Y.

14. Miller, W.R. and F.E. Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal-marshes, Connecticut. Ecol. Monographs 20: 143-172.

BACK COVER Left–Post-hole auger used first to excavate hole in order to operate sampler. Right–Modified McCaffrey peat sampler with door swung open. After insertion into the marsh, the door is swung shut, cutting off the section of peat against metal plate. Metal straps serve to hold peat against the frame. (For equipment in use see Fig. 1.)

Connecticut Arboretum Bulletins

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Artistic map of Arboretum Showing Features and Trails

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