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VEGETATION CHANGE ON A NORTHEAST TIDAL MARSH: INTERACTION OF SEA-LEVEL RISE AND MARSH ACCRETION[1]

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Abstract. Increasing rates of relative sea-level rise (RSL) have been linked to coastal wetland losses along the Gulf of Mexico and elsewhere. While such losses have yet to be reported for New England tidal marshes, rapidly rising RSL may still be affecting these systems. Studies of the Wequetequock–Pawcatuck tidal marshes over four decades have documented dramatic changes in vegetation that appear to be related primarily to differential rates of marsh accretion and sea-level rise. Other environmental factors such as sediment supply and anthropogenic modifications of the system may be involved as well. When initially studied in 1947–1948 the high marsh supported a *Juncus gerardi–Spartina patens* belting pattern typical of many New England salt marshes. On most of the marsh complex the former *Juncus* belt has been replaced by forbs, primarily *Triglochin maritima,* while the former *S. patens* high marsh is now a complex of vegetation types—stunted *Spartina alterniflora, Distichlis spicata,* forbs, and relic stands of *S. patens.* These changes are documented by vegetation sampling that closely followed the 1947–1948 methods and by peat core analysis. Marsh elevations were determined by leveling, and the mean surface elevation of areas where the vegetation has changed is significantly lower than that of areas still supporting the earlier pattern (4.6 vs. 13.9 cm above mean tide level). The differences in surface elevation reflect differences in accretion of marsh peat. Calculations based on sandy overwash layers deposited during historically recorded storms as well as on experimentally placed marker horizons of known age indicate that stable areas have been accreting at the rate of local sea-level rise, 2.0–2.5 mm/yr at least since 1938; changed areas have accreted at about one half that rate. Lower surface elevations result in greater frequency and duration of tidal flooding, and thus in increased peat saturation, salinity, and sulfide concentrations, and in decreased redox potential, as directly measured over the growing season at both changed and stable sites. It is proposed that these edaphic changes have combined to favor establishment of a wetter, more open vegetation type dominated by two distinctive communities—stunted *S. alterniflora* and forbs. Changes documented on the Wequetequock–Pawcatuck system have been observed on other Long Island Sound marshes and may serve as a model for the potential effects of sea-level rise on New England tidal salt marshes.

Key words: forbs; Juncus gerardi; *marsh accretion; marsh vegetation; salt marshes; sea-level rise; sediment supply;* Spartina; *tidal flooding; tidal marshes; vegetation change.*

INTRODUCTION

Salt marshes along the northeast coast of the United States became established over the last 3000–4000 yr, as post-glacial sea-level rise slowed from ≈2.5 mm/yr to 1 mm/yr (Redfield and Rubin 1962, Redfield 1965, Keene 1971, Van de Plassche et al. 1989). For at least the last 50 yr, however, and probably for about a century or more, the rate of relative sea-level (RSL) rise in southern New England has increased to ≈2.5 mm/yr (McCaffrey 1977, Lyles et al. 1988, Titus 1988, Peltier and Tushingham 1989, Thomas and Varekamp 1991). Accelerated rates of sea-level rise may have serious consequences for both distribution and possible overall loss of coastal wetlands. Such losses are occurring along

are occurring along portions of Chesapeake Bay and the Gulf of Mexico at historically unprecedented rates. In both areas an imbalance between RSL rise and sediment accretion is at least one major factor driving these losses (DeLaune et al. 1983, 1987, Stevenson et al. 1986, Titus 1988). This report addresses the interaction of RSL rise and sediment deposition as a major factor contributing to vegetation change on a New England salt marsh over the last half century.

Forty years ago the vegetation of the Wequetequock–Pawcatuck tidal marshes of eastern Connecticut was described by Miller and Egler (1950) as showing a distinctive belting pattern characteristic of many salt marshes along the eastern seaboard of the United States (Nichols 1920, Niering and Warren 1980, Nixon 1982, Teal 1986). Bordering the upland an essentially pure *Juncus gerardi* zone was replaced seaward by the nearly monospecific *Spartina patens* high-marsh community,

which included occasional pannes with stunted *Spartina alterniflora,* frequently bordered by forbs. Farther seaward the *S. patens* belt was replaced by *S. alterniflora* low marsh at elevations below mean high tide.

Resurveys of this system have found significant vegetation change over the last few decades (Coleman 1978). Currently the former *S. patens* high marsh described by Miller and Egler is dominated by a complex of vegetation types: (1) stunted *S. alterniflora,* (2) forbs (perennials *Limonium nashii, Plantago maritima, Triglochin maritima* and the annual *Gerardia maritima*), (3) *Distichlis spicata,* (4) mixed graminoid–forb stands, and (5) relict patches of *S. patens.* Nearer the upland the formerly conspicuous *J. gerardi* belt has been replaced primarily with an open forb community characterized by *Triglochin maritima.* With the exception of one peat core study (Orson and Howes 1992), such a dramatic shift in marsh vegetation, in the absence of direct human disturbance, has not been reported previously for Northeast tidal wetlands.

Miller and Egler (1950) pointed out correlations in their analysis, but they were cautious in drawing firm conclusions concerning environmental factors that might have been controlling or influencing plant community structure. In this paper we document the vegetation changes that have occurred over the last 40 yr on the Wequetequock–Pawcatuck marshes. In addition we present data on some environmental parameters that appear to be important in structuring the present plant community and influencing the vegetation changes. Finally, we propose a model in which the difference between rates of marsh accretion and sea-level rise is an important primary factor, although certainly not the only factor, influencing vegetation change and species distribution within the tidal wetlands of this system. Additional factors considered, all of which interact to varying degrees with sea-level rise, include changing sediment supply along with the human impacts of ditching and construction of dikes to impound valley marshes landward of and contiguous to the areas described by Miller and Egler. The model proposes an imbalance between marsh accretion and sea-level rise, perhaps magnified by ditching and the presence of dikes, that has resulted in an increase in the hydroperiod over large areas of high marsh. This has in turn produced lower peat redox potential, greater sulfide levels, and altered salinity patterns. These edaphic factors differentially affect marsh angiosperms, resulting in species replacement and overall community change.

Study site

The Wequetequock–Pawcatuck marshes are part of the Barn Island Wildlife Management Area (State of Connecticut) and today are locally called the Barn Island marshes. They include a complex of tidal wetlands (≈ 1.4 km^2) on the Connecticut–Rhode Island border at the eastern end of Long Island Sound (Fig. 1). These wetlands belong to the Little Narragansett Bay marsh estuarine system (mean tidal range: 80 cm) and include a series of valley marshes that were impounded for waterfowl management beginning in the mid-1940s. The areas studied most intensively by Miller and Egler, and the focus of this investigation, are seaward of the two westernmost impoundments, diked initially in 1946 and 1947, and directly face Little Narragansett Bay. Miller and Egler sampled most extensively within a 20-ha ditched section termed Headquarters (Fig. 1).

METHODS

Vegetation

During the 1987 and 1988 growing seasons vegetation was sampled on Headquarters Marsh and on an unditched point of marsh near the bay front, designated as Wequetequock Cove Marsh. Although not sampled by Miller and Egler, Wequetequock Cove supports the typical belting vegetation pattern that they described as characterizing the system in the late 1940s.

The sampling technique duplicated as closely as possible that used by Miller and Egler. Three-metre diameter circular plots were located randomly; for every plot a complete species list was compiled and the percentage of cover was estimated for each species. On Headquarters our plots were located in areas that in 1947–1948 were dominantly: *S. patens* high marsh (50 plots); *J. gerardi* belt along the upland (15 plots); stunted *S. alterniflora* (12 plots). Twenty-six additional plots were placed randomly without respect to previous vegetation. The historic locations of the community types were reconstructed by Coleman (1978) and confirmed by peat core analysis. Twenty-six plots were also placed randomly within the *S. patens* and *J. gerardi* communities of the Wequetequock Cove high marsh.

Peat cores

To further document past vegetation change, peat cores were taken from both Headquarters and Wequetequock Cove. Cores were removed using a knife-sharp, flat-blade spade, and no compression of the peat samples could be detected. Twenty-nine randomly located cores, ≈ 30 cm deep, were removed from Headquarters and six from Wequetequock Cove. Roots and rhizomes preserved in the peat were identified at 1-cm intervals, as described by Niering et al. (1977) and Orson et al. (1987).

Surface elevations

Marsh surface elevations relative to local 1980–1982 summer mean high tide, as determined by Lefor et al. (1987), were measured on both Headquarters and Wequetequock Cove. Elevations were determined by leveling, using a THS-Auto 25 automatic level with a surveying rod graduated in 3 mm (0.01 ft) intervals. Points were located randomly and at 1-m intervals along upland to creekbank or bayfront transects. Three
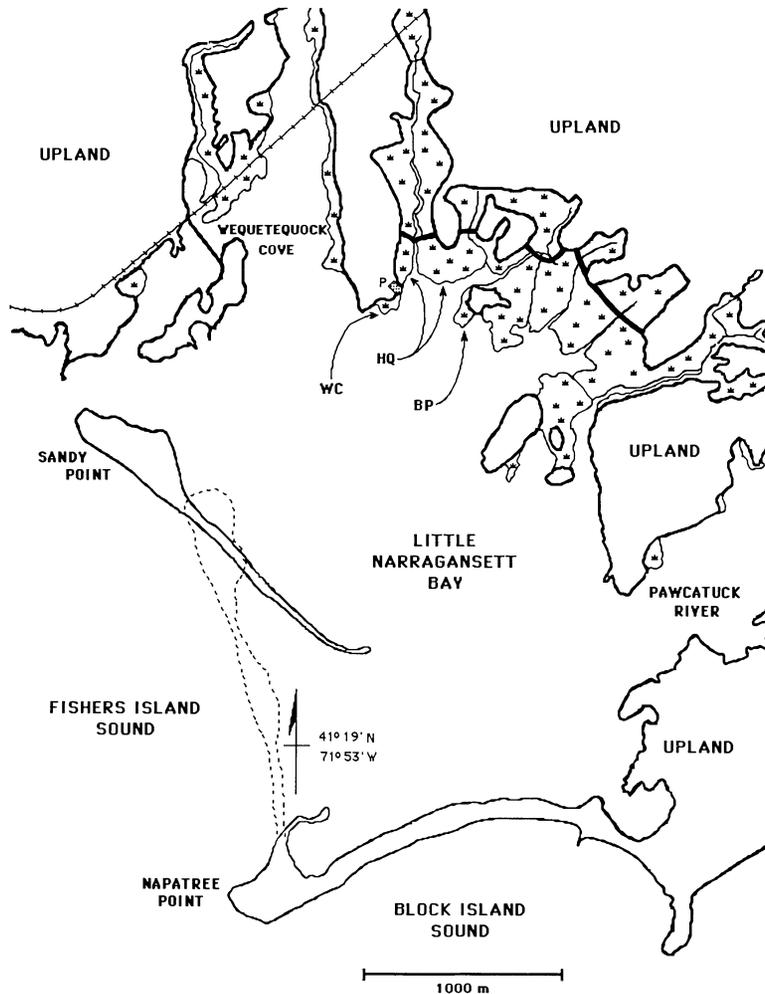
Fig. 1. Site map of the Barn Island tidal marshes (Connecticut, USA). Key to abbreviations: WC = Wequetequock Cove, relatively stable for the past 40 yr; HQ = Headquarters, most extensively studied by Miller and Egler (1950); BP = Bloom's Point, site of artificial marker horizons; P = parking lot separating WC from HQ. —— indicate dikes across valley marshes. ----- indicates location of the Sandy Point tombolo and its attachment to Napatree Point prior to the 1938 hurricane.

hundred and twenty-five points were located on Headquarters and 61 on Wequetequock Cove; mean elevations in different areas were compared by unpaired t tests. Plant species composition by percentage of cover was estimated in a 15-cm radius circle centered at each point.

Edaphic factors

Salinity, redox potential, sulfate, and sulfide levels of the peat were measured over the 1988 growing season. Sites followed were: (1) relic *S. patens,* (2) stunted *S. alterniflora* with <10 cm of peat over *S. patens* peat, (3) forbs with <7 cm of peat over *S. patens* peat, all on Headquarters; and (4) stable *S. patens* on Wequetequock Cove. Triplicate samples were taken weekly at each site for each parameter. There were clear seasonal patterns of increasing sulfide and salinity levels, but only means for the entire summer are compared here. Each sample consisted of a pair of 5 × 5 by 10

cm deep cores; pore water from the bottom 5 cm of one core was mechanically squeezed directly into ice cold anti-oxidant buffer and stored on ice until returned to the laboratory for sulfide analysis. Pore water from the second core was collected and stored in the same manner, but was squeezed into a chilled, dry container without anti-oxidant buffer. This was used for sulfate analysis. The salinity of pore water squeezed from the second core was measured immediately in the field with a Reichert-Jung T/C meter refractometer-salinometer (Cambridge Instruments, Buffalo, New York, USA).

In the laboratory samples were allowed to equilibrate to room temperature. Sulfide was determined with an Orion 941600 sulfide-specific electrode and a Beckman Ag/AgCl reference electrode, calibrated against a dilution series of Orion 100 mg/kg sulfide.

Sulfate samples were vacuum-filtered and analyzed immediately, or frozen for later analysis of sulfate, us-
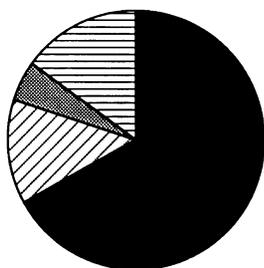
Headquarters   1948

◼ Sp/Ds
▨ Sas
▦ Fbs
▤ Jg
▨ Mix
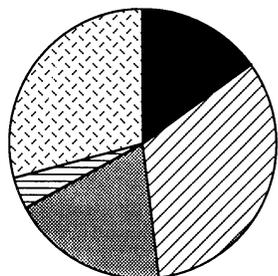
Headquarters   1988
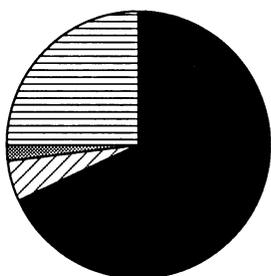
Wequetequock   Cove   1988

FIG. 2.   Plant cover at the Barn Island tidal marshes (Connecticut, USA) by vegetation types, showing both the similarity of Headquarters Marsh in 1948 and Wequetequock Cove in 1988 and how Headquarters has changed over four decades. Key to abbreviation: Sp/Ds = *Spartina patens–Distichlis spicata*; Sas = stunted *Spartina alterniflora*; Fbs = all forb-dominated communities; Jg = *Juncus gerardi*; Mix = mixed graminoid and graminoid–forb communities.

ing the indirect EDTA (ethylene diamine tetracetic acid) titration method (Howarth 1978).

Soil redox was measured at 5 cm depth using an Orion 96-78-00 Pt combination redox electrode following the same sampling regime.

RESULTS AND DISCUSSION

Vegetation change

Vegetation changes on Headquarters Marsh from 1948 to 1988 show a striking decrease in areas dominated by *Spartina patens* and *Juncus gerardi* and a corresponding increase in short *S. alterniflora*, forbs,

and mixed community types (Fig. 2). In contrast, the vegetation pattern on Wequetequock Cove Marsh is similar to that originally described by Miller and Egler in the late 1940s, with extensive, nearly pure belts of *S. patens* and *J. gerardi*. Forb and stunted *S. alterniflora* vegetation types are currently rare on this more seaward section of the Barn Island marshes (Fig. 1).

The vegetation changes that have occurred on Headquarters and the relative stability of Wequetequock Cove are also confirmed by peat cores (Fig. 3). Most Headquarters cores showed a 3–6 cm layer of stunted *S. alterniflora,* forb, or mixed-species peat overlying ≥20 cm of relatively pure *S. patens* (Fig. 3: Cores 2 and 4), indicating the former importance of that species as well as its recent replacement. Near the upland, in the former *J. gerardi* belt, a shallow surface layer of forb peat overlying peat from *J. gerardi* also confirms the previous dominance of this rush (Fig. 3: Core 1). The isolated stands of *S. patens* present on Headquarters are clearly relics, with *S. patens* peat extending from the surface down to at least 15 cm deep in all sites sampled (Fig. 3: Core 3).

In contrast to Headquarters, all cores from Wequetequock Cove revealed essentially pure *S. patens* or *J. gerardi* peat at least 18 cm in depth (Fig. 3: Cores 5 and 6), confirming that the same vegetation pattern as described by Miller and Egler on Headquarters in 1948 has persisted here for several decades.

Marsh accretion

Peat cores also provide evidence that differential rates of marsh accretion may be linked to the vegetation changes on Headquarters and to the comparative vegetational stability of Wequetequock Cove. Thin sand, silt, or clay layers introduced during major storm events are common in peat cores, particularly those taken from within 30 m of the bay front or a creek bank (Niering et al. 1977, Orson et al. 1987, Orson and Howes 1992). Most cores from the Wequetequock Cove marsh had a distinct sand layer 12–13 cm below the marsh surface; others, taken nearer the bay front, had a second layer ≈1 cm below the surface (Fig. 3: Core 6). In bayward and creek bank cores from Headquarters a sand layer occurred only 6–7 cm below the surface (Fig. 3: Core 4). We argue that two major hurricanes (1938 and 1985) account for these sand deposits. The 1938 hurricane was the strongest storm to strike southern New England in over a century, and peak winds were recorded at Little Narragansett Bay (Nichols and Marston 1939). In peat cores from Waquoit Bay salt marshes on Cape Cod Orson and Howes (1992) also report a clear clay horizon dated by ^{210}Pb as 1938. They, too, attribute this horizon to the 1938 hurricane. The 1985 hurricane, Gloria, was less severe, with peak winds of 140–160 km/h, but wind damage from this storm was most severe along Fishers Island Sound. The rate of sea-level rise determined over the last 50 yr from tide gauge data at New London, ≈10 km to the

HEADQUARTERS   WEQUETEQUOCK
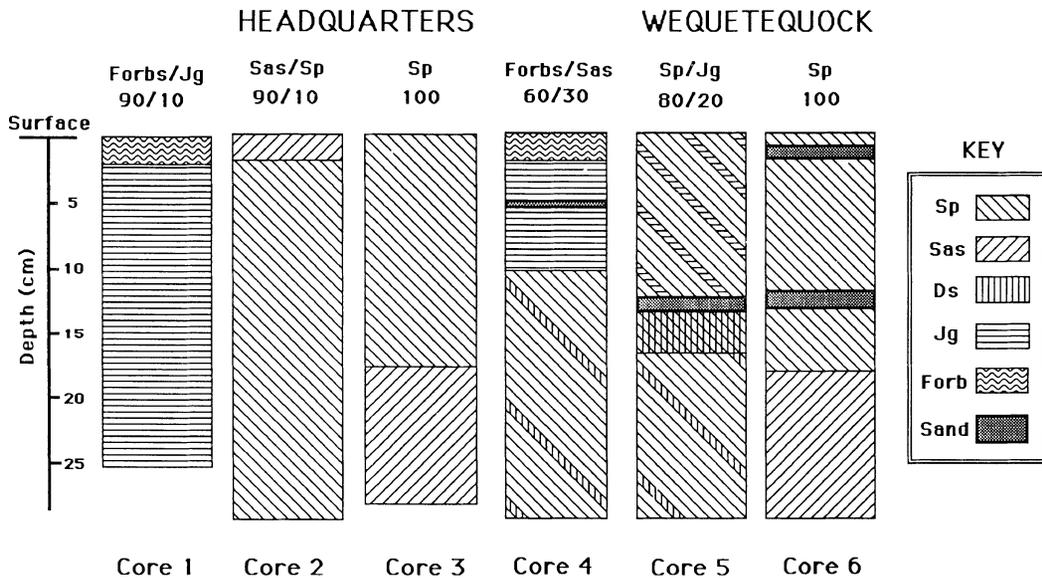
FIG. 3. Representative peat cores from Headquarters Marsh (Cores 1–4) and Wequetequock Cove Marsh (Cores 5 + 6) marshes showing root and rhizome composition in the top 25–30 cm. Species composition by percentage cover of the surface vegetation is noted above each core; see Fig. 2 for abbreviations.

west (Lyles et al. 1988), has been 2.0 mm/yr. When this is compared with rates of marsh accretion estimated from these natural chronostratigraphic horizons, the control marsh appears to be keeping pace with local sea-level rise, building vertically at a rate of 2.0–2.5 mm/yr since the 1938 hurricane.

The salt marsh at Bloom's Point (Fig. 1) has a vegetation pattern very similar to that of Wequetequock Cove. Since 1962 a series of artificial marker horizons on Bloom's Point has been buried at a constant rate of 2.0 mm/yr (Harrison and Bloom 1977, Young 1985). This supports our conclusion that the two sand lines on Wequetequock Cove represent the 1985 and 1938 hurricanes. In contrast, on Headquarters, where the vegetation has changed, the stratigraphic position of the sand layers indicates that the marsh surface is accreting vertically at about one half the rate of Wequetequock Cove and Bloom's Point.

Marsh elevation, inundation, and soils

Differences in vertical growth rates between Wequetequock Cove and Headquarters should be and are reflected in marsh surface elevations. Mean elevation on the Wequetequock Cove high marsh is 13.9 cm above mean high tide (MHT). On Headquarters, in contrast, mean elevation is just 4.6 cm above MHT and there are extensive stunted S. alterniflora and forb stands as much as 1.5 cm below MHT. These differences are all significant at the .001 level.

With a mean annual tidal range of only 80 cm these elevation differences result in significantly greater frequency and duration of flooding on Headquarters as compared to Wequetequock Cove, and a detailed study focusing on the relationships between flooding regime,

marsh elevation, and vegetation is currently underway. Preliminary results from this work relate observed flooding occurrence at known elevations to predicted tide heights at New London (NOAA 1990) and indicate that the mean elevation on Headquarters will be flooded 105 times over a typical 1 June to 1 September growing season, vs. just 34 times for the mean elevation on Wequetequock Cove (Fig. 4). The result of this difference is increased peat saturation on Headquarters relative to Wequetequock Cove. This produces a more anoxic root environment on Headquarters, which will influence plant growth, productivity, and distribution (Mendelssohn and Seneca 1980, Howes et al. 1981, Weigert et al. 1983, Ingold and Havill 1984, DeLaune et al. 1987, Bradley and Dunn 1989, Burdick et al. 1989, Koch et al. 1990).

Both the existing vegetation patterns and soil chemistry are consistent with this model. The S. alterniflora and forbs that now dominate Headquarters are typically considered wetter-site indicators (Nichols 1920, Niering and Warren 1980, Nixon 1982, Teal 1986). The means of peat redox potential at all three Headquarters sites were far more negative than in S. patens high marsh on Wequetequock Cove; sulfide levels were also significantly greater on two of the three Headquarters sites (Table 1). The redox and sulfide data indicate that the localized, less dense S. patens stand sampled on Headquarters is probably being stressed relative to the vigorous, stable S. patens on Wequetequock Cove (Burdick et al. 1989, Koch et al. 1990).

Soil salinity was also significantly higher in the stunted S. alterniflora and forb stands at Headquarters than in the S. patens areas of either marsh site. In contrast to the relatively dense cover in the S. patens stands
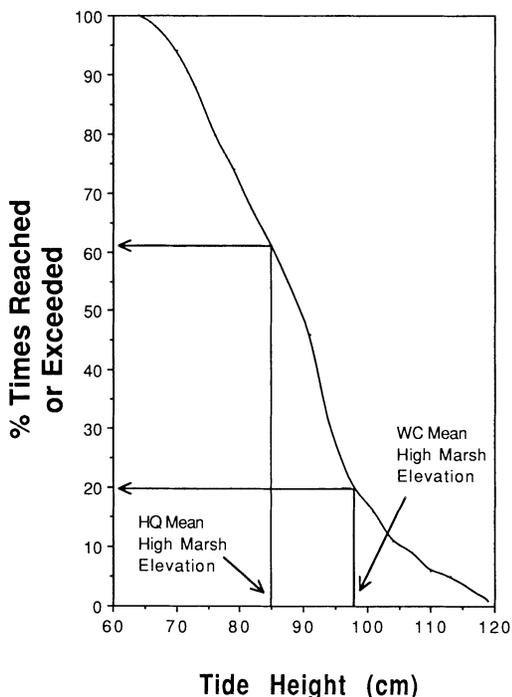
FIG. 4. Relationship between mean high marsh elevations of Headquarters (HQ) Marsh and Wequetequock Cove (WC) Marsh in Connecticut, USA, and the cumulative percentage of times these elevations were potentially subjected to tidal flooding during the 1991 growing season.

($\geq$90%), both the stunted *S. alterniflora* and forb sites are more open (50–75% cover). This sparser plant cover accelerates evaporative water loss and increases salinity in the surface peat (R. S. Warren and W. A. Niering, *unpublished data*). Salinity differences thus probably result from, and simultaneously contribute to, vegetation change.

The vegetation changes documented here apparently result from a lower rate of vertical marsh growth than of local relative sea-level (RSL) rise. The consequent increase in tidal inundation has produced changes in soil chemistry that, through effects on plant physiology, result in floristic change (Ingold and Havill 1984, DeLaune et al. 1987, Bradley and Dunn 1989, Burdick et al. 1989, Koch et al. 1990). Vegetation patterns on areas that have kept pace with RSL have remained relatively stable whereas significant changes have oc-

curred where vertical growth has been less that RSL rise.

Changes in sediment transport and deposition

Orson and Howes (1992) is the only other report of such extensive vegetation changes over a comparable time frame in New England and their work is based on peat core analysis alone. We propose that at Barn Island the shifts in species dominance have resulted from a deficiency in sediment accretion and vertical marsh growth relative to sea-level rise. Jacobson (1988) interpreted the reduction in marsh bordering tidal channels in Wells, Maine, as an imbalance between marsh accretion and sea-level rise. The apparent influence of accelerating RSL rise on much of the Barn Island complex reported here is probably related at least in part to a reduction in available sediments as a result of the 1938 hurricane. The surface of a tidal marsh grows vertically through the combination of sediment accretion and the production of roots and rhizomes (Bricker-Urso et al. 1989). The principal sources of sediment for the Barn Island marshes are Long Island Sound, Fishers Island Sound, and the Pawcatuck River (Fig. 1). Prior to the 1938 hurricane Sandy Point was attached to the western end of Napatree Point, and essentially all sediments transported through Little Narragansett Bay from both sources passed in front of the Barn Island marshes. During spring tides and storm events these sediments were available for marsh building. The hurricane breached the Sandy Point–Napatree Point connection and Sandy Point was moved south toward the Connecticut shore, opening a direct channel to Fishers Island Sound (Nichols and Marston 1939). Today that inlet is nearly a kilometre wide, and at least half of the tidal volume of Little Narragansett Bay moves via this pathway; sediments carried by this route are unavailable to the Barn Island marshes (F. Bohlen, *personal communication*).

The limited areas of marsh (Wequetequock Cove and Bloom's Point) that demonstrably have kept up with RSL, plus a few smaller areas farther east of Bloom's Point that have also retained the classic *S. patens–J. gerardi* belted vegetation pattern, are ideally situated on the bay front to intercept sediments transported by tidal and storm flooding. Further, their eroding peat faces probably provide an additional, imme-

TABLE 1. Seasonal means of soil chemistry parameters followed at sites on the Wequetequock Cove and Headquarters Marsh areas of the Barn Island Wildlife Management Area tidal marshes, Connecticut, USA. Within each parameter means followed by the same letter are not significantly different by paired *t* tests.

Parameter	Wequetequock Cove	Headquarters Marsh		
	Spartina patens	*S. patens* (relic)	stunted *S. alterniflora*	Mixed forbs
Salinity (g/kg)	32 a	32 a	36 b	37 b
Redox (mV)	−114 a	−238 b	−427 c	−225 b
Sulfide (mmol/L)	1.14 a	1.69 b	1.91 c	1.14 a
Sulfate (mmol/L)	30 a	30 a	30 a	30 a

diate sediment source to sustain vertical marsh development (Harrison and Bloom 1977, Young 1985). In contrast, Headquarters Marsh is faced along Little Narragansett Bay by a sandy beach and it is relatively protected compared to Wequetequock Cove and Bloom's Point. It is thus not situated to efficiently intercept tidally borne sediments; in addition, an eroding peat face cannot serve as a supplemental sediment source.

CONCLUSIONS

We propose a multi-factor working model to explain the vegetation dynamics within areas that have remained relatively stable and those that have undergone significant change. The model includes accelerating sea-level rise, a lowered supply of marine sediments due to the 1938 hurricane, and different rates of marsh accretion, which involves both contributions from sedimentation and from in situ organic matter production in the form of roots and rhizomes. Ditching and impoundment dikes landward of the study areas could well also be interacting with the previous factors and be contributing to vegetation change on the Headquarters marsh.

Reduced sediment input would slow vertical growth relative to rising relative sea level (RSL) and contribute to the elevation differences found between changed and stable areas. Increased tidal flooding of sites with lower accretion rates will produce edaphic changes that ultimately result in the replacement of Spartina patens and Juncus gerardi by forbs and stunted S. alterniflora. The lower stem, root, and rhizome density of the S. alterniflora and forbs relative to other high-marsh communities further contributes to slower accretion rates. This is due both to less effective sediment trapping at lower stem densities (Gleason et al. 1979) and to the relatively poor peat development characteristic of forbs (Niering et al. 1977, Orson et al. 1987). Under such conditions the conversion of S. patens and J. gerardi high marsh to a S. alterniflora–forb complex is, at least in part, an autocatalytic process.

Although the 1938 hurricane probably produced changes in sediment transport patterns that locally magnified the effects of rising RSL, anthropic factors also may be contributing to vegetation change at Barn Island. Impoundment dikes constructed across the two valley marshes north of, but contiguous to, Headquarters just a year or two prior to the work of Miller and Egler, and mosquito ditching, done in the mid-1930s, acting separately or together, could have increased peat saturation in the high marsh. The impoundments removed many hectares of marsh from tidal inundation and may have caused excessive flooding below the dikes during spring tides. In addition, although ditching in many cases tends to dry out a marsh, the reverse can occur as well when ditches cut through creek bank levees and provide a pathway for tidal water onto the central high marsh, as has hap-pened on Headquarters, and when spoil banks along ditch edges impound water on the high-marsh surface, as described by Miller and Egler (1950). Thus, along with continuing sea-level rise, multiple factors may be interacting to ultimately produce the striking shift in vegetation patterns reported here.

While changes in marsh vegetation on Headquarters were well under way >15 yr ago (Coleman 1978), it is significant that similar species replacement has been observed on much of the remainder of the Barn Island system as well as on six other unimpounded, ditched high marshes to the west of Barn Island within the last decade. Such changes are well documented at Cottrell Marsh, 6 km to the west. Large areas mapped and photographically documented as S. patens high marsh in 1971 (Steever 1972) now have a significant component of perennial (Limonium nashii and Plantago maritima) and annual (G. maritima and Salicornia europaea) forbs. In addition, significant portions of what was the J. gerardi belt in 1971 today resemble comparable sites now dominated by Triglochin maritima at Barn Island (R. S. Warren and W. A. Niering, personal observations). At both Barn Island and the other Connecticut marshes these vegetation changes typically occur relatively far from creek banks or bay-fronts, or in areas otherwise not well situated to intercept tidally borne sediments. This suggests that accelerating sea-level rise may already be affecting some northeastern United States tidal marshes.

This study provides an insight to the possible vegetation changes that can be expected to occur when marsh accretion, for whatever reasons, fails to keep up with rising RSL. Based on the changes at Barn Island, one can predict the development of a more open high-marsh vegetation on an increasing number of northeastern tidal wetlands, with a different habitat structure for associated fauna, e.g., the salt marsh snail Melampus bidentatus (Fell et al. 1991). In addition angiosperm primary productivity will decline as the high marsh shifts from a S. patens–J. gerardi-dominated community to one in which forbs and stunted S. alterniflora are predominant (Steever 1972, R. S. Warren and W. A. Niering, unpublished data). Such changes may occur prior to any direct wetland loss resulting from coastal submergence.

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