VEGETATION OF THE WEQUETEQUOCK-PAWCATUCK MARSHES

STONINGTON, CONNECTICUT - A COMPARATIVE

STUDY 1948 AND 1976

In Partial Completion of the Requirements
for the Masters of Art Degree in
the Department of the Biological Sciences

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for Benjamin Stillman Howe

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INTRODUCTION

Numerous vegetational studies have been conducted on the tidal marshes of the eastern United States (Chapman 1940, Conrad 1924, 1929, Conrad and Galliger 1935, Gross 1966, Dowhan 1972, Good 1965, Johnson and York 1915, Kerwin and Pedigo 1971, Knight 1935, Miller and Egler 1950, Nichols 1920, Redfield 1972, Silander 1976, Spagnolli 1968, Steever 1972, and Taylor 1938). Chapman (1974) has proposed various successional sequences for New England salt marshes based on observations from several of these studies. However, few studies have compared vegetational changes over a period of time, and there is little data that would support these successional schemes. Peat cores provide information on vegetational changes which have occurred over centuries, but data on short term succession is scarce. Whether changes in vegetational belting and community structure on a marsh are the results of environmental fluctuations or indicate permanent succession is hence often difficult to determine.

Miller and Egler (1950) studied the Headquarters area of the Wequetequock-Pawcatuck Marshes in Stonington, Connecticut during the summer of 1948. They delineated the marsh into four major belts or zones. The single dominant species composing the belts, progressing from the bayfront to the upland were: *Spartina alterniflora*, *Spartina patens*, *Juncus gerardi*, and *Panicum virgatum*. Salt pannes, forb pannes, and stunted *Spartina alterniflora* pannes were interspersed throughout the Spartina patens belt. The vegetation composing each belt was sampled for frequency and coverage. I re-examined Headquarters during the summer of 1976 to determine what changes had occurred in the vegetational community structure and belting patterns on the marsh. The study was conducted to elucidate successional patterns on a tidal marsh in southeastern Connecticut.

In addition, three other areas on the Wequetequock-Pawcatuck Marshes were sampled to obtain baseline data for future studies.

LOCATION AND DESCRIPTION OF THE STUDY SITE

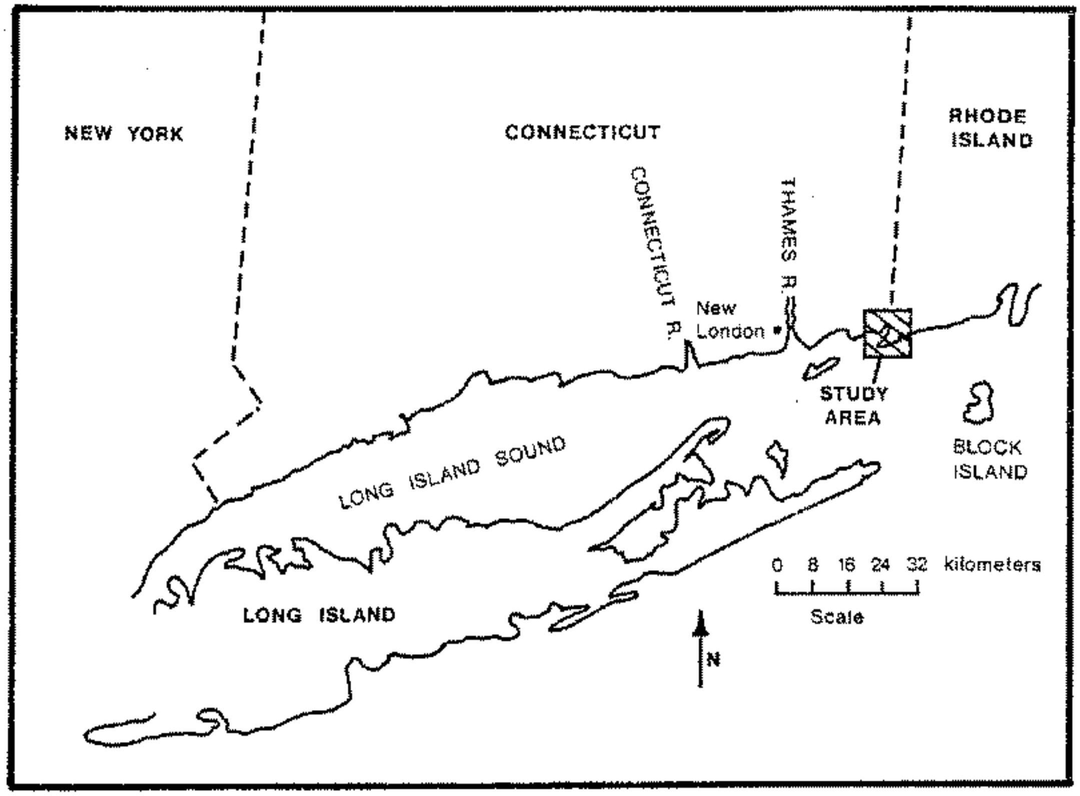
The Wequetequock-Pawcatuck Marshes are shallow coastal marshes located in Stonington, Connecticut, at a latitude of 41°20' (Figures 1-4). Davis Marsh is privately owned and covers approximately 40 acres. The three other study areas are part of the Barn Island Hunting Area acquired by the state of Connecticut in the 1940's (Figure 5). The area contains 187 acres of marsh which are distributed as follows: 75 acres of shallow fresh marsh, 250 acres of salt marsh, and 45 acres of regularly flooded salt meadow (Bishop 1963). Palmer Neck Marsh is approximately 18 acres, Headquarters Marsh 20 acres, and Lower Brucker Marsh 35 acres.

The Wequetequock-Pawcatuck Marshes are bordered to the south by Little Narragansett Bay. The marsh complex is protected from deep water processes by Napatree Tombolo, Sandy Point Island, and Fisher Island Sound. Near shore processes are slight due to the shallow nature of Little Narragansett Bay, 2.1 M maximum, and a short fetch (Sakalowsky 1975). Further protection is afforded by the headlands which border the marsh to both the east and west (Figure 4). The tide is semi-diurnal with a mean range of .79 M (Sakalowsky 1975).

The Wequetequock-Pawcatuck Marshes are located on a gently sloping coastal plain which is underlain by gneiss and granite of the Ordovician period (Goldsmith and Dixon 1968). Surficial geology of the area has been shaped by the Wisconsin glacier which covered the southern portion of New England 20,000 - 14,000 years before present. The Charlestown and Fishers Island Moraines are in close proximity to

Figure 1. Connecticut coastline. The square indicates the location of the Wequetequock-Pawcatuck Marshes.

Figure 2. Wequetequock-Pawcatuck Marshes and vicinity.


NEW YORK
CONNECTICUT
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THAMES R.
New London
STUDY AREA
BLOCK ISLAND
LONG ISLAND SOUND
LONG ISLAND
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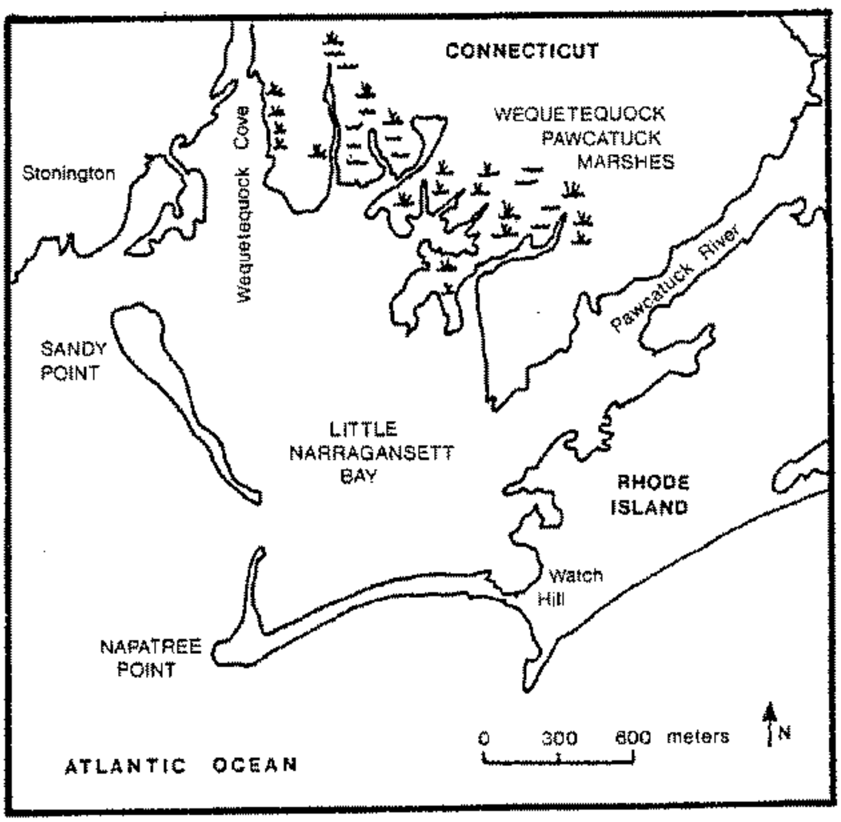
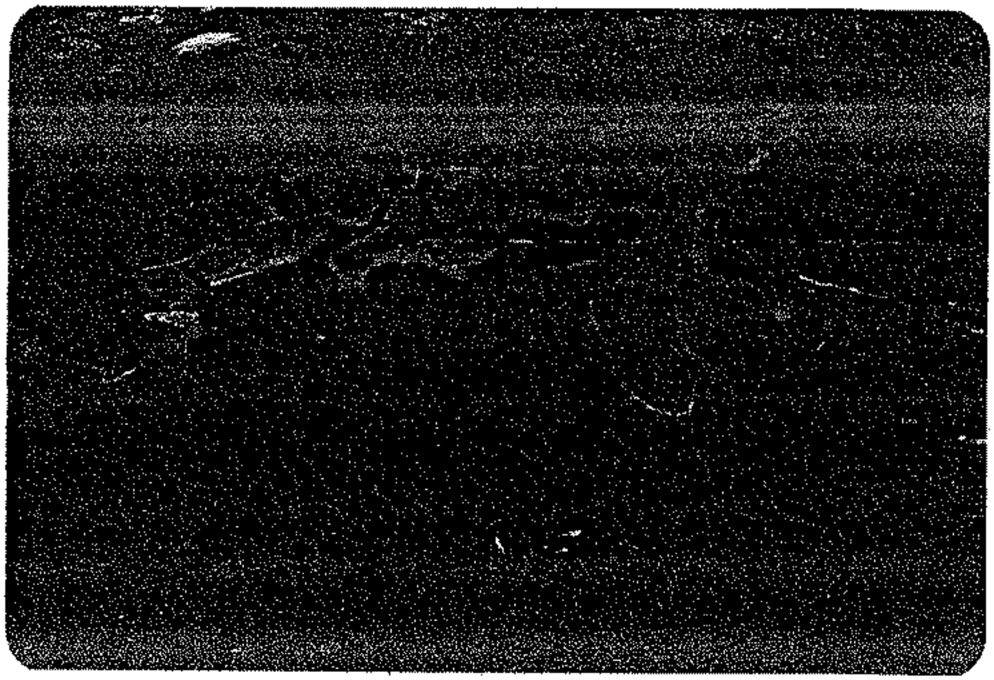

CONNECTICUT
WEQUETEQUOCK PAWCATUCK MARSHES
Stonington
Wequetequock Cove
Pawcatuck River
SANDY POINT
LITTLE NARRAGANSETT BAY
RHODE ISLAND
Watch Hill
NAPATREE POINT
ATLANTIC OCEAN
0 300 600 meters
N

Figure 3. Aerial view of the Wequetequock-Pawcatuck Tidal Marshes, Stonington, Connecticut. The photograph was taken looking northwest from Little Narragansett Bay, September 1976.

Figure 4. Aerial view of the Wequetequock-Pawcatuck Marshes, Stonington, Connecticut, looking southwest into Little Narragansett Bay. The Napatree Tombolo is in the extreme left of the photograph. Fishers Island is in the extreme right of the photograph, and Sandy Point Island is in the center of the bay.



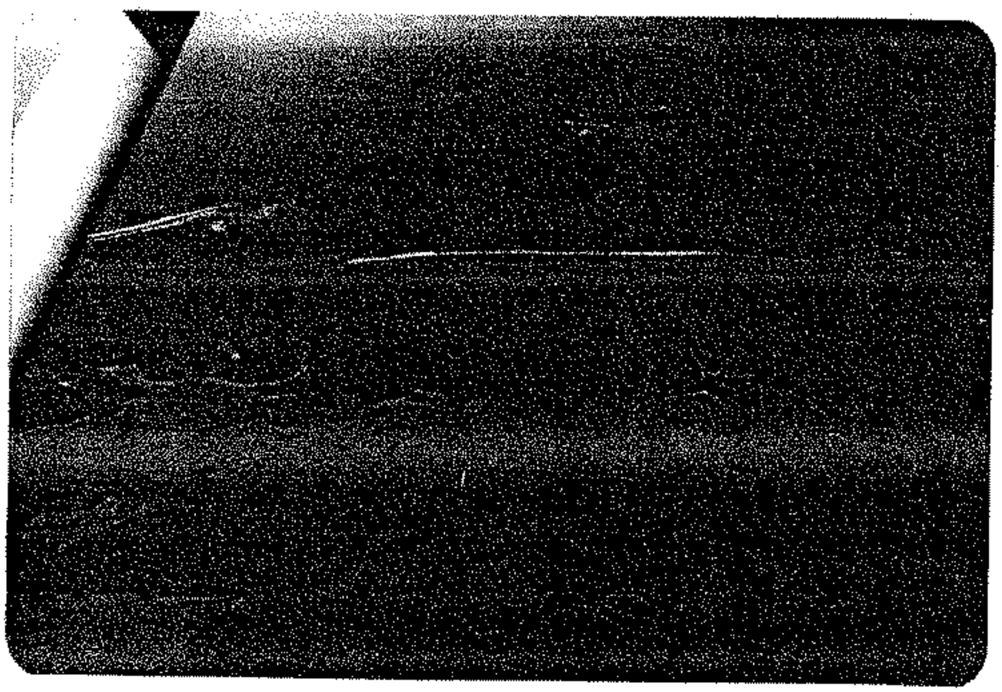
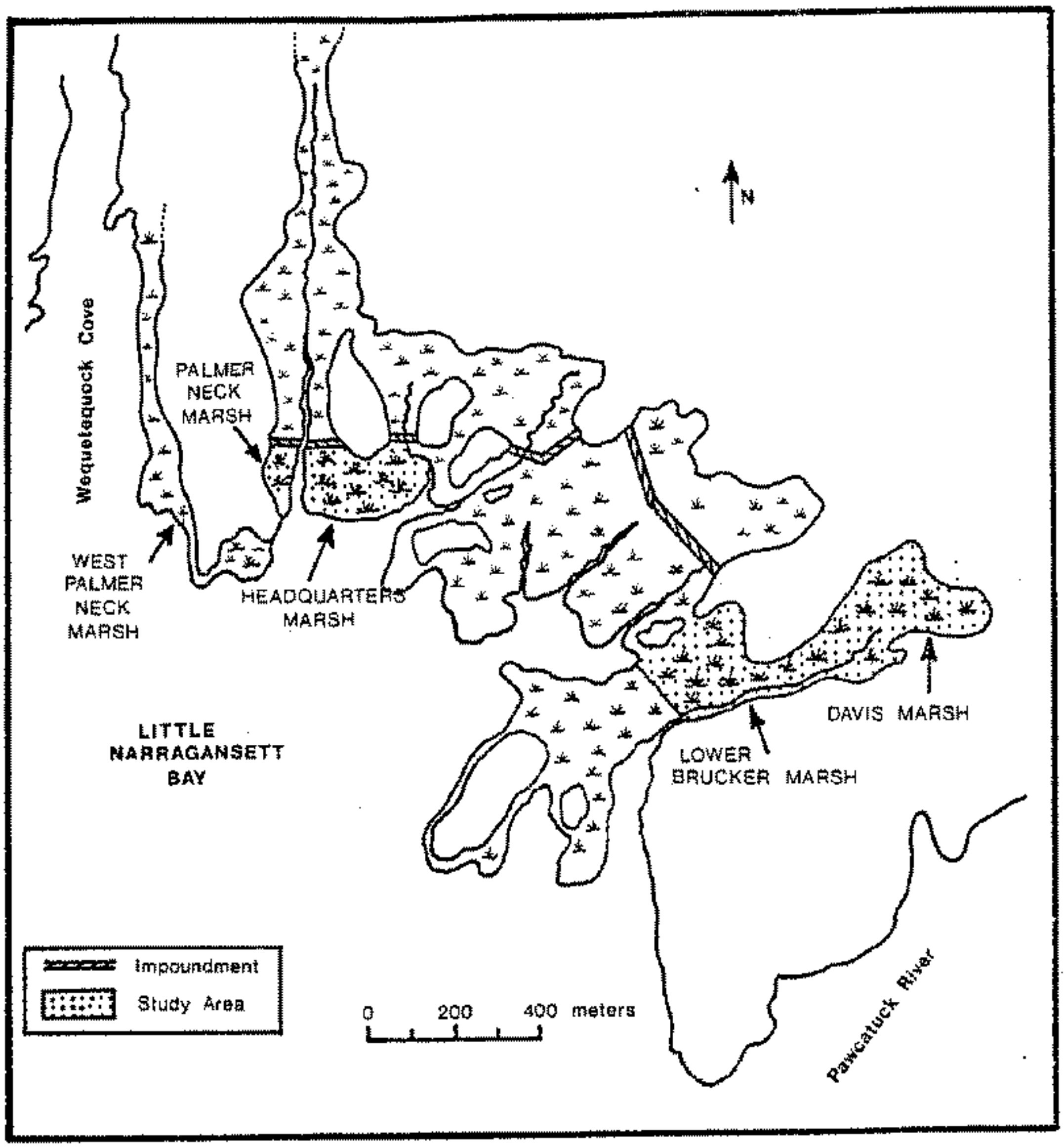


Figure 5. The Wequetequock-Pawcatuck Marshes. The dotted areas are the locations of the study sites.


N
Wequetequock Cove
PALMER
NECK
MARSH
WEST
PALMER
NECK
MARSH
HEADQUARTERS
MARSH
LITTLE
NARRAGANSETT
BAY
DAVIS MARSH
LOWER
BRUCKER MARSH
Pawcatuck River
Impoundment
Study Area
0 200 400 meters

the marsh; as a result, there is an abundance of glacial boulders scattered throughout the marsh complex.

The soil of the study site is a histisol of the Pawcatuck series (Hill and Shearin 1970) which ranges from 40 - 210 cm in depth. The soil overlies sand or a sandy loam. The organic material ranges from 45 - 65% in the surface layers to 20 - 45% in the bottom tiers. The mineral sediments mixed with the peat are 50 - 70% silt and 15 - 20% clay. This soil characteristically has poor drainage and slow surface runoff. The water table is 15.2 - 25.4 cm from the surface of the peat at low tide (Hill and Shearin 1970).

The soil of the till island at the north end of Headquarters is a Narragansett Glouster Comply. This is a mixture of 50% well drained sandy soil and 50% deep and coarse textured soil. The island is on top of protruding bedrock. The predominant deposit of the surrounding uplands is glacial till ranging from .3 M - 24 M in depth.

SEA LEVEL CHANGES

In general, there has been a continuous rise in sea level during the last 9,000 years as a result of deglaciation; however local uplift and subsidence alters the rate of sea level rise locally. Changes in sea levels may also reflect seasonal, daily, and irregular vacillations (Emery and Uchupi 1972). Although fluctuations in river discharge may vary year to year, Mead and Emery (1971) found no significant trends in river discharge on the East or Gulf coasts between 1931 - 1969. The sea is rising at an average rate of 2.6 mm per year in Connecticut (Harrison 1975).

Kaye and Stucky (1973) present evidence that an 18.6 year lunar nodal cycle controls the annual mean level of high and low tides on the east coast of North America. During the last nodal high, the sea level rose at a rate of just under 1 cm per year (Harrison 1975). This rapid rise in the sea level is counteracted in periods when the nodal cycle is at its low point and sea level actually falls.

MARSH DEVELOPMENT

The soils of New England marshes are peats which have an organic constituent ranging from 20% - 90% of the total soil content (Buckman and Brady 1956). Two types of marsh development are accepted: the Shaler model and the Mudge-Davis model. According to the Shaler model, all marshes develop in shallow lagoons protected by sandbars and spits (Chapman 1974). Currents entering the lagoon from deeper water deposit their sediment load as their velocity decreases, due to the increased friction with the bottom of the lagoon. As sediment continues to be deposited the depth of the lagoon decreases further, and Zostera marina is able to become established. The shoals continue to develop until they are exposed at low tide. At this point, Spartina alterniflora is able to become established and aids in marsh buildup until the peat is above mean high tide level and Spartina patens becomes established. The Shaler model presupposes a constant sea level in the lagoon. If the sea level is constant during development, one finds uniformly thick layers of Spartina patens overlying layers of Spartina alterniflora with a basement of silt or sand.

Davis (1910) observed two types of peat in the Boston area marshes. In one type were thick layers of Spartina patens which extended several layers below the present low tide. He concluded that the thickness of the peat was a record of the change in sea level and that marsh grasses accumulated at an annual rate which was quick enough to prevent marsh submergence. The second peat type was not uniformly thick. The depth of the peat became thinner as one moved landward and was superimposed over freshwater peat. He concluded that the marshes were invading the upland as the sea level rose.

More recent work has proven that both types of marsh development occur (Knight 1935, Redfield 1972, Niering et al. 1976). Redfield observed that if peat is formed as Spartina alterniflora extends onto sandflats the peat is stratified in the Shaler mode. If the peat is developing landward, it exhibits the Mudge-Davis stratifications. Both processes can occur simultaneously.

CLIMATE

The study site is located on the coastal plain and has a climate modified by its proximity to Long Island Sound. The climate is generally milder than the rest of Connecticut and has fewer temperature extremes. Winds from the sound cool the area in the spring and summer and have a warming effect in the fall and winter. The mean temperature for New London was 51.3°F from 1931 - 1960, with an average of 194 frost free days. The average precipitation in Groton is 49.8" and is evenly distributed throughout the year. There are 30 - 40" of snow annually (Brumbauch 1965). Fog is common in the spring and late summer and occasionally during the fall. Fog occurs an average of 30 days a year. From October to April the prevailing winds are from the Southeast. Wind velocity averages 7.5 mph in the early summer and fall and 9.5 mph in winter and spring (Steever 1972).

Ice storms occur in winter causing damage to trees and other vegetation. Severe storms and hurricanes occur occasionally during late summer and early fall (Figure ~~6~~ 9). Catastrophic hurricanes which originate in the tropics occur approximately once a century (Brumbauch 1965). The last three catastrophic hurricanes were August 19, 1788, September 23, 1815, and September 21, 1938. The hurricane of 1938 had a storm tide which was 10 - 15 feet above mean high tide. The high tides resulted because the storm struck during both a high and a spring tide (Nichols and Marston 1939). A hurricane of August 12, 1976, during the study period, caused no observable damage to the Wequetequock-Pawcatuck Marshes.

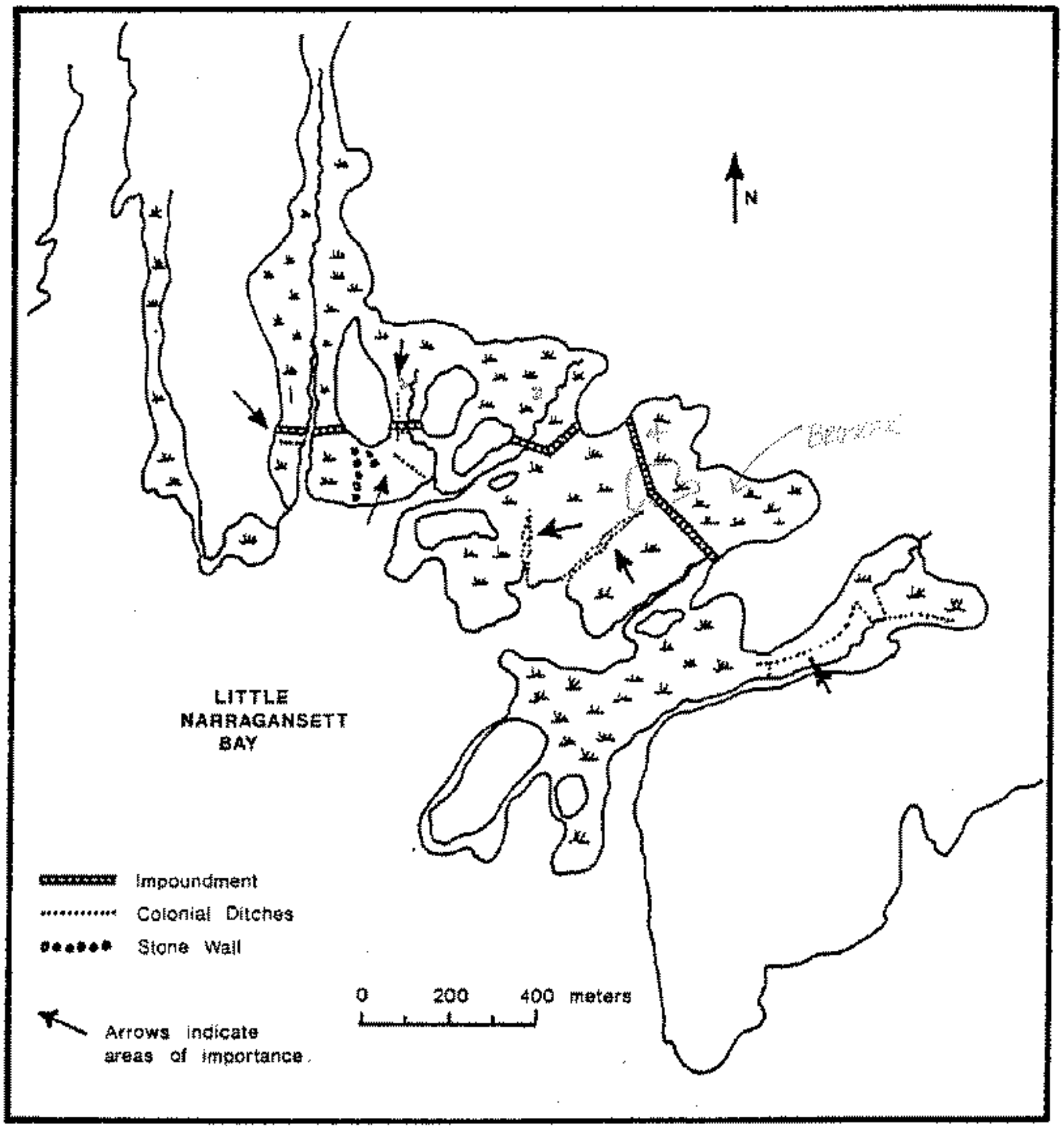
Figure 6. During the winter of 1976, large sheets of ice sheared pieces of peat from the edges of the marsh. The piece of peat extending across the colonial ditch was 30 - 40 ft. in length. Spring 1977.

HISTORY OF THE STUDY AREA

The Pequot Indians settled in the area between the Thames River, in New London, and the Pawcatuck River, which divides Rhode Island and Connecticut (Crandall 1975). Evidence of a village and numerous Indian artifacts have been found in the vicinity of the Wequetequock-Pawcatuck Marshes. Moreover, local farmers have found several pits used to cook clams and other shellfish on the marshes (John Davis and Henry Stewart personal communication). Although the Indians burned the adjacent forests to facilitate hunting (Bromley 1935, Day 1953), it is probable that the Indians' impact on the marsh was slight. An upland fire may have spread to the marsh occasionally, but no charcoal has been found in the cores taken by Niering et al (1976).

Stonington was settled by Thomas Cheesbourgh in 1649, one to two miles northwest of the Wequetequock-Pawcatuck Marshes (Wheeler 1903). Early diaries mention salt marsh grass haying and grazing of the local marshes by cattle. *Distichlis spicata*, *Juncus gerardi*, and *Spartina patens* were used by the farmers for packing, mulch, and fodder (Smith 1907). The farmers began manipulating the marshes almost immediately to facilitate mowing and to increase the yield of the marsh grasses. In 1904 the Connecticut Agricultural Experiment Station Report stated that 50% of all salt marshes in Connecticut had been drained extensively for salt hay farming. References to salt marsh ditches are frequent in early Stonington deeds and evidence of colonial ditches exists throughout the Wequetequock-Pawcatuck Marshes (Figure 7).

Figure 7. Locations of colonial ditches on the Wequetequock-Pawcatuck Tidal Marshes.


N
LITTLE
NARRAGANSETT
BAY
Impoundment
Colonial Ditches
Stone Wall
Arrows indicate
areas of importance.
0 200 400 meters

The large ditch on Palmer Neck which resembles an extension of the tidal creek was an established boundary in 1756 (Volume 7 Stonington Land Records). The ditch was probably constructed earlier, but difficulty in tracing the original ownership of the land prevented determination of the precise date of construction. The L shaped ditch on Headquarters is mentioned in a deed dated 1885 in a land transfer from Nathaniel S. Babcock to Henry C. Randall. The ditch could not be traced earlier because I could not determine how Babcock acquired the land. The aggraded ditch indicated by the arrow in Figure 7 is the remnant of a colonial ditch, most of which had been filled in. Note the position in relation to the 1930's mosquito ditches as well as the highly eroded mouth. A stone wall ran the entire length of Headquarters Marsh. A section of double wall is probably a cow lane leading onto a pasture and the wall itself may have been the boundary between two pastures.

The Headquarters Marsh was grazed every summer until the 1940's (Frank A. Vargas personal communication). The upper portion of the Lower Brucker Marsh was grazed until the early 1950's (Henry Stewart personal communication). Portions of the Davis Marsh are still grazed regularly by cattle (John Davis personal communication).

The area between Headquarters and Lower Brucker Marshes contains two large ditches which I believe to be colonial (Figure 7). I could not find these ditches mentioned in deeds and it is likely that they were not land boundaries. These ditches are more eroded than the ditches known to have been constructed in 1932, and probably were constructed prior to those ditches.

Davis Marsh contains several ditches that were built prior to mosquito ditching in 1931 (John W. Davis personal communication). Old deeds mention ditches on the eastern portion of the Wequetequock-Pawcatuck Marshes. These ditches date back to 1767 (Volume 8 Stonington Land Records). I was unable to determine the exact location of these ditches, but I suspect that they are present on Davis Marsh (Figure 7). Davis (personal communication) has pointed out one colonial ditch he knows of. Examination of aerial photographs indicate that the Davis family, who has owned the marsh since the 1700's, probably has altered the drainage patterns to improve mowing and grazing conditions. The lower portions of the Davis Marsh are surrounded on the east by a large levee which supports stands of *Spartina patens*, *Juncus gerardi*, and *Iva frutescens*. An upland island extends down along the western portion of the marsh. Thus the central portion of Davis would receive runoff water from the upland as well as any excess runoff water from the levee. Consequently, the central portion of the marsh was probably substantially wetter than the outer edges. It appears that the farmers may have alleviated this problem by digging a small drainage channel along the western portion of the marsh.

A large ditch connects the small drainage channel with Half Mile Brook. This ditch is larger than the mosquito ditches which were dug in 1938 and I suspect it was constructed in the early 1700's. The "L" shape of this ditch and the small drainage channel is identical to the shape of a colonial ditch on Headquarters. The water movement is greater near Davis than near Headquarters and erosion has been greater on this ditch. In addition, another channel was dug further up Davis

Marsh, connecting the top of the small ditch to Half Mile Brook. Consequently, any excess water on the lower portion of Davis Marsh could drain directly and rapidly into water ways.

The course of Half Mile Brook also appears altered. There is a large stretch of brook which is abnormally straight and has a 90^{o} turn. It seems as if the brook should connect with the tidal creek at a lower portion of the creek where one of the colonial ditches drains the lower segment of Davis Marsh. It is possible the alteration of the brook was related to the drainage of Lower Davis Marsh.

After the completion of mosquito ditches, the Lower Davis Marsh had mosquito ditches running from the western colonial ditch into Half Mile Brook. The portion of mosquito ditches in the eastern levee was filled by the Davis family because they interfered with mowing. A large stand of Spartina patens exists up to the point where the mosquito ditches begin and here the vegetation abruptly changes to stunted Spartina alterniflora.

Salt hay harvesting occurred annually until the 1940's. Local farmers attribute the breaks in the Napatree spit during the 1938 hurricane to an increased tidal amplitude which made harvesting difficult except in the marshes furthest from the bay (Henry Stewart) (Figures 8 and 9). Only the Davis Marsh is still mowed and the frequency of mowing is governed by the fall tides and the wind conditions. In the fall of 1976, for example, weather conditions prevented the harvesting of salt marsh hay.

As early as 1913, the Connecticut State Legislature enacted bills which allocated funds for mosquito eradication (Britton et al 1915).

Figure 8. Napatree Tombolo prior to the September 21, 1938 hurricane.

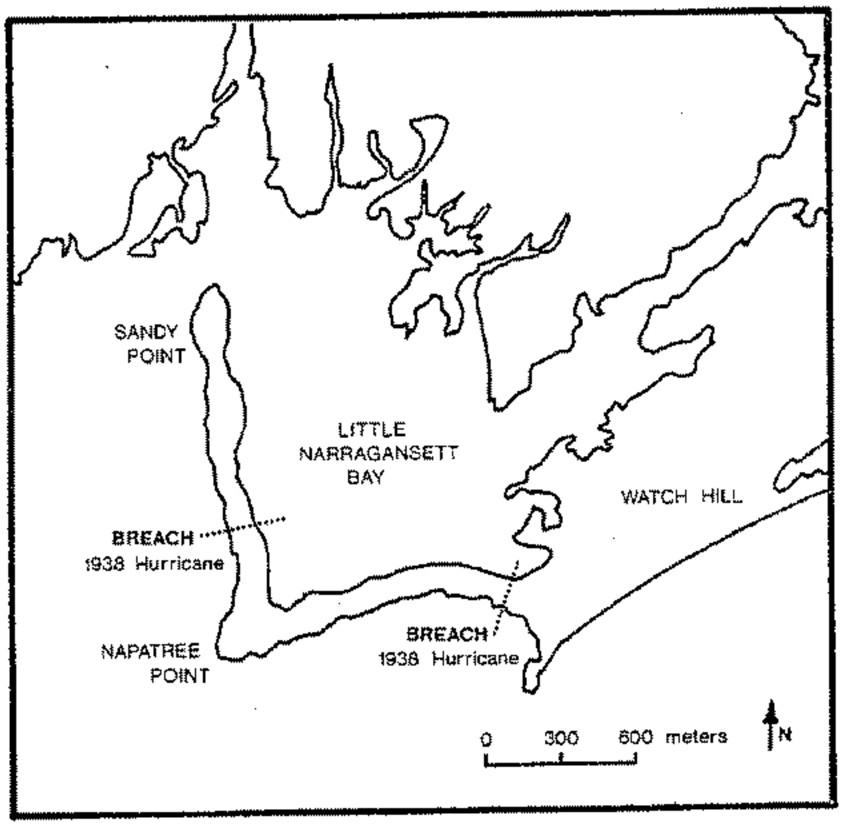

SANDY POINT
LITTLE NARRAGANSETT BAY
WATCH HILL
BREACH
1938 Hurricane
NAPATREE POINT
BREACH
1938 Hurricane
0 300 600 meters
N

Figure 9. View of Headquarters Marsh during a spring tide. The water is lapping the edge of the <u>Panicum virgatum</u> community. The browning of the upland bushes is the result of saltspray during a hurricane on August 12, 1976.

These funds were appropriated annually and their distribution depended on the financial situation of the state. In the 1930's the director of the Connecticut Agricultural Experiment Station was placed in charge of mosquito control work. The thrust of the program was the filling and ditching of the tidal marshes. The towns were to conduct the initial ditching with private funds. Once the ditching was completed, the State assumed responsibility for the ditches' maintenance (Botsford 1930, 1932, 1937). By 1935 virtually all mosquito ditching was completed in Connecticut. In the late 1930's the Connecticut State Health Department assumed responsibility for the ditch maintenance. Maintenance varied from marsh to marsh. In some areas recutting was done annually, while on other marshes the ditches remained functional for 5 - 8 years without recutting (Botsford 1935).

Records of the Connecticut Agricultural Experiment Station (1931) indicate that ditching of the Stonington tidal marshes commenced in the spring of 1931 under the contract of John R. Ross. The ditching was completed in 1932. The ditches were hand dug in a parallel grid pattern, approximately 150 feet (30 M) apart. Data on the original depth and width of the ditches could not be obtained, but in 1976 the ditches ranged from 10 - 60" wide and from 4 - 28" deep (Figure 10). No maintenance log has been kept; however the upkeep of the ditches has been sporadic in the last decade (Julius Elston personal communication). Five ditches were hand cleaned on Palmer Neck Marsh during the summer of 1976. DDT has been locally applied on the Wequetequock-Pawcatuck Marshes, but its use was halted in 1965. According to Elston (personal

Figure 10. View of a typical mosquito ditch on Headquarters Marsh. *Spartina patens* lines the ditch in the foreground, this grades into a forb panne, which grades into a stand of *Iva frutescens*. *Spartina alterniflora* is the vegetation lining the ditch in the background. Summer 1976.

communication), approximately 5 gallons of 5% DDT was used per acre. Malathion was used in 1966 - 1969 (Wedmore 1970).

The Connecticut State Board of Fisheries and Game began to purchase parcels of land in the Wequetequock-Pawcatuck Marshes in 1944 with the intention of establishing the Barn Island Shooting Area (Bishop 1963). Between 1945 - 1947 the State constructed earth dikes across four tidal creeks, slightly below the highest level of the spring tides. The location allowed sea water to flow over the dikes during the perigee tides and replenish the supply of water that evaporated during the dry season (Martin 1964). The impoundments flooded approximately 135 acres of land in four fingers of the marsh that extended toward the upland and created several shallow brackish water ponds. The ponds were intended to increase the waterfowl population which had been declining since the early 1930's. The original dikes were rebuilt in 1970 and equipped with water control structures which regulated water levels behind the impoundments as well as the amount of sea water entering the impoundments. New channels were built at the same time, resulting in the creation of three shallow ponds. In 1968 the Brucker Marsh was impounded and 48 acres flooded. This impoundment also had water control devices (Bishop 1971). The only upper marsh which remains unimpounded is the Davis Marsh which is privately owned. The effects of the impoundments on the outer marshes are not readily apparent. It is not known whether changes in patterns of runoff or changes in groundwater levels due to the impoundments have resulted in changes in vegetational patterns.

In 1955 the State built two semi-circular duck ponds, approximately 400 by 120 feet, in the Lower Brucker Marsh (Bishop 1971). The spoils were deposited adjacent to the pools. In the same year a ditch 12 feet wide, 4 feet deep, and 600 feet long was constructed. The ditch separated Barn Island from the mainland and was to shorten the return route for duck hunters. A boat launch was built on the Palmer Neck Peninsula in 1957 and was expanded during 1976 - 1977.

During the late 1940's and 1950's the Headquarters Marsh beach was open for public swimming. Paths created by pedestrian traffic were apparent in the 1951 aerial photographs. The paths were still present as small pannes in 1976. In the 1970's the marshes were primarily used by birdwatchers and by hunters in the fall. Numerous duckblinds were constructed every fall and during the hunting season the marshes experienced heavy pedestrian traffic. The hunters do not seem to create specific trails, but rather wander randomly over the marsh. The birders tend to remain on the impoundment road. A substantial amount of traffic is from school classes visiting the marsh. Slumping along the mosquito ditches is noticeable where the students have jumped across the ditches to get to the bay front. Occasionally scooter bikes are driven off the impoundment road and onto the marsh. The tire tracks create depressions which retain water.

METHODS

An initial reconnaissance of the area was made in the spring of 1976. Vegetation sampling and mapping began in July 1976 and terminated in November 1976. A second reconnaissance was made July 10, 1977. At this time the study area was briefly re-examined to determine the extent of yearly fluctuations in the abundance of the grass populations. In addition, observations were made on the marshes to the west of the Barn Island Boat Launch and the Juncus gerardi community on these marshes sampled to determine whether the deterioration of this community on Headquarters was occurring on these marshes as well. Frank Egler was consulted about vegetation changes and the negatives of his original photostations were obtained.

The records of the Connecticut Board of Fisheries and Game were examined to obtain information concerning the state's activities on the marsh. Julius Elston of the Mosquito Control section of the Connecticut State Department of Health provided information on mosquito control on the Wequetequock-Pawcatuck marshes. Numerous local residents, John W. Davis, Frank A. Vaargas, and Henry Stewart, provided information on local history and farming practices. Information on colonial ditches and land boundaries was obtained from the deed records of the town of Stonington.

Vegetation Sampling

Fifty circular 10 M^2 quadrats were used to measure species composition and species distribution within each community type, following Miller and Eglers' (1950) techniques. I used elliptical quadrats in the segments of Spartina alterniflora community which were too narrow for circular quadrats.

Miller and Egler (1950) estimated the relative dominance of each species in the quadrat by designating coverage as rare, occasional, and abundant. However, the criteria by which these categories were determined was not defined. I examined several cover scales (Oosting 1956, Chapman 1974, Dieter Mueller-Dombois 1974) and decided to use the following classification: rare, 1 - 5%, occasional, 6 - 35%, abundant , 35 - 100% coverage. Percent cover was also recorded as baseline data for future studies.

The communities were named for the dominant species. Communities which had a single dominant species, 50% coverage or more, were named for that species. When two species each had a coverage of 33% or more the community was named for both. Communities with no dominant species were named for the three most abundant species. The latter were not sampled. Because the dominant species within the forb panne communities varied from location to location, the community was not named for individual species. I wanted to ensure that variations in populations on different sections of the marsh were accounted for. Thus the marsh was divided into small sections delineated by mosquito ditches, and each community type present was sampled. I established quadrats randomly in each community by tossing a stake over my shoulder and using the point where the stake landed as the center of the quadrat (Oosting 1948). Percent cover was measured by visual estimate.

Three additional community types were sampled as well as the six recognized by Miller and Egler (1950). These communities were:

Distichlis spicata type (47 quadrats), Distichlis spicata/Spartina patens type (6 quadrats), and Spartina alterniflora/Spartina patens type (36 quadrats). The three additional communities did not cover as large an area as the six original communities, yet because they occurred frequently and were distinct entities, I classified them separately. The number of quadrats employed to sample these communities was a function of the size of the community. Consequently, the Distichlis spicata/Spartina patens community was sampled six times while the Spartina alterniflora/Spartina patens which was a larger community was sampled 36 times.

Many of the community types were not as common on Lower Brucker and Davis Marshes as on Headquarters and Palmer Neck Marshes. As a result, the number of quadrats sampled varied from community to community, and the sample size was determined by the distribution and size of the individual community. The community types sampled were: Spartina alterniflora type (7 quadrats), Spartina patens type (23 quadrats), Spartina alterniflora/Spartina patens type (29 quadrats), Juncus gerardi type (15 quadrats), forb panne type (17 quadrats), Spartina alterniflora stunted type (40 quadrats), and Panicum virgatum type (12 quadrats). Vegetation sampled on the Davis Marsh was: Spartina patens type (20 quadrats), Juncus gerardi type (10 quadrats), Spartina alterniflora stunted type (50 quadrats) and the Panicum virgatum type (26 quadrats).

Aerial Photography

Flights were made on September 10 and November 6, 1976 in a Cessna 172 aircraft. Both flights were made on clear, sunny, relatively windless days during high tide. A 60^{o} turn was made and cameras positioned for a 90^{o} shot. Passes were made at 1500 and 1000 feet.

Cameras used were Cannon FT with a 50 mm f 1.8 lens, Asahi Spotmatic with a 28 mm f 3.5 lens, and a Minolta with a 135 mm f 2.5 lens. The film, Kodachrome 64 color slides, was shot at a shutter speed of 1/500 of a second.

Vegetation Mapping

Vegetation maps were made for each area studied. Maps were constructed by projecting color slides on a wall and tracing distinctive vegetation community types onto a sheet of mylar. Various maps were made using slides from different heights and angles. All maps were field checked to record maximum detail for the final maps. Slides taken at 90^{o} from a height of 1000 feet with a 50 mm lens were used to construct the final three maps. Details from other maps were added when useful. The relative percent coverage of each belt in the marsh was determined from a vegetation map.

Photostations

Miller and Egler (1950) established 12 photostations below the impoundments. These stations were relocated by using a map constructed in 1948. Photographs were taken in 1976, using glacial boulders in the original photographs as guides for the correct photoangle.

I was unable to locate five of the negatives of the photostations mentioned on the original map and copies of these photographs were not on file at the Connecticut Board of Fisheries and Game Office in Hartford. I photographed all the photostations on the 1948 map, but no comparative shots exist for the missing photographs.

RESULTS

Vegetation Patterns and Community Structure

General Overview

The Headquarters and Palmer Neck Marshes contained a complex mosaic of vegetational communities which was not apparent during the initial reconnaissance made in the spring of 1976. Thirty-two vegetational communities were present on the two marshes (Table I). In 9 of the communities there was one dominant species which covered 50% or more of the community. The *Panicum virgatum* community was an exception. The dominant species, *Panicum virgatum*, covered, on the average, only 41% of each quadrat. Two codominant species prevailed in 14 communities and the remaining 9 communities had three or more species which were common, none exceeding a 30% coverage.

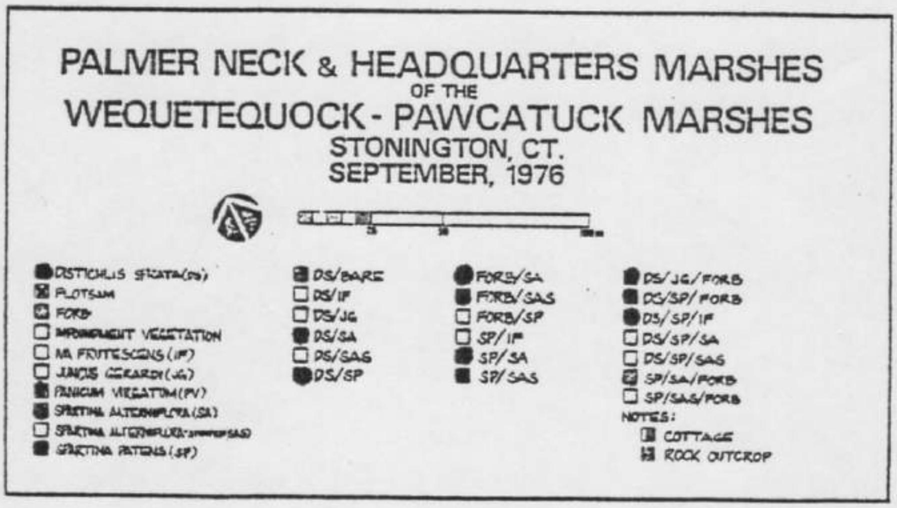
Although mapped as two distinct areas the Lower Brucker and Davis Marshes are a single marsh complex. There is a distinct transition from low marsh to high marsh and finally upland vegetation. Twenty-eight communities are present on this complex. There is one dominant species in seven of the communities, two codominant species in ten communities, and three or more codominants in eleven communities, with all species covering an average of 30% or less (Figures 11 - 13).

The three major species on both Palmer Neck and Headquarters Marshes were *Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata*. *Spartina alterniflora* was dominant on both Headquarters and Lower Brucker and had three forms: tall (50 - 100 cm), intermediate (15 - 50 cm) and stunted (9 - 15 cm). This species was found in every

TABLE I. PERCENT COVERAGE OF 23 COMMUNITY TYPES ON FOUR MARSHES OF THE WEQUETEQUOCK-PAWCATUCK MARSH COMPLEX, Summer 1976

Community Types	Palmer Neck	Head-quarters	Lower Brucker	Davis
Distichlis spicata	6.0	14.0	8.0	4.0
Distichlis spicata/Forb	1.0			
Distichlis spicata/Forb/Juncus Gerardi	0.1	0.1	0.1	
Distichlis spicata/Forb/Iva frutescens				
Distichlis spicata/Forb/Spartina patens	0.1	0.1	0.1	
Distichlis spicata/Spartina alterniflora	0.1	0.3	0.3	
Distichlis spicata/Spartina alterniflora/ Spartina patens	3.0	1.0	0.2	
Distichlis spicata/Spartina patens	8.0	5.0	2.0	8.0
Forb	19.0	20.0	4.0	5.0
Forb/Spartina alterniflora	2.0	0.3	1.0	
Forb/Spartina alterniflora stunted/ Spartina patens	4.0	2.0		
Forb/Spartina patens	0.1			
Impoundment bank vegetation	2.0	1.0		
Intermediate Spartina alterniflora		3.0	1.0	
Iva frutescens	3.0	3.0	2.0	8.0
Juncus gerardi	17.0	6.0	2.0	10.0
Panicum virgatum	10.0	2.0	6.0	10.0
Phragmites communis				8.0
Spartina alterniflora	4.0	5.0	7.0	3.0
Spartina alterniflora/Spartina patens	3.0	10.0	6.0	5.0
Spartina patens	8.0	7.0	3.0	23.0
Stunted Spartina alterniflora	10.0	16.0	53.0	14.0
Upland Island			3.0	
Unvegetated		2.0		

Figure 11. Vegetation map of Headquarters and Palmer Neck Marshes, Summer 1976. A key to the map appears below.



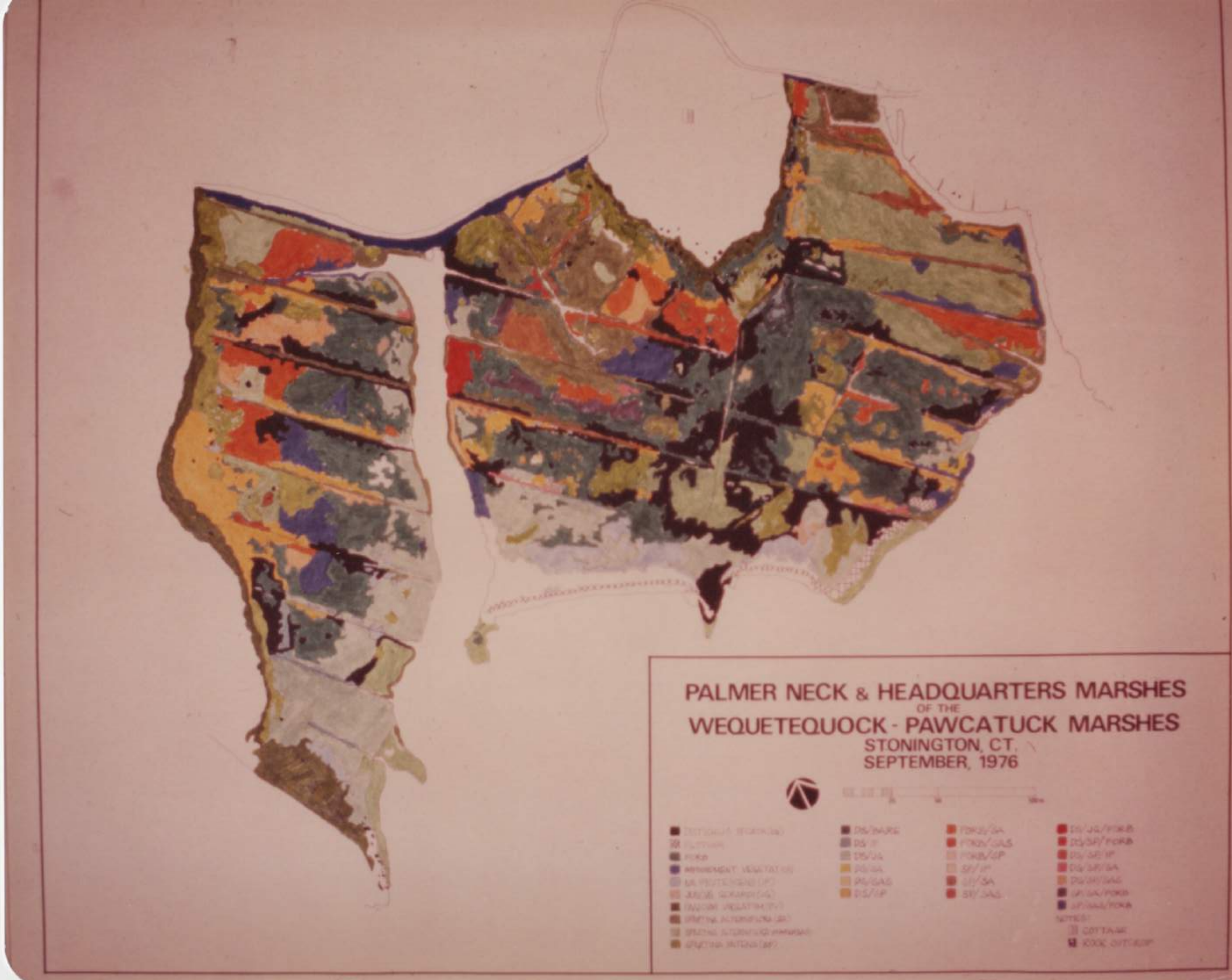
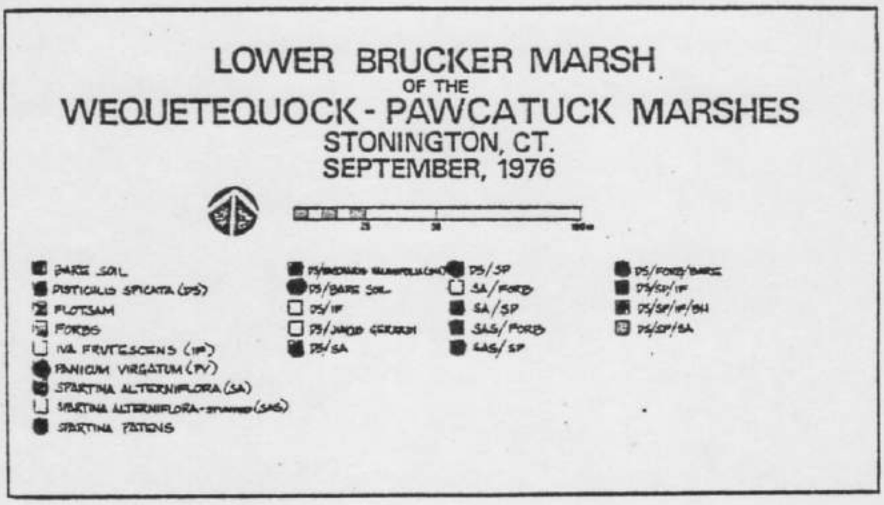
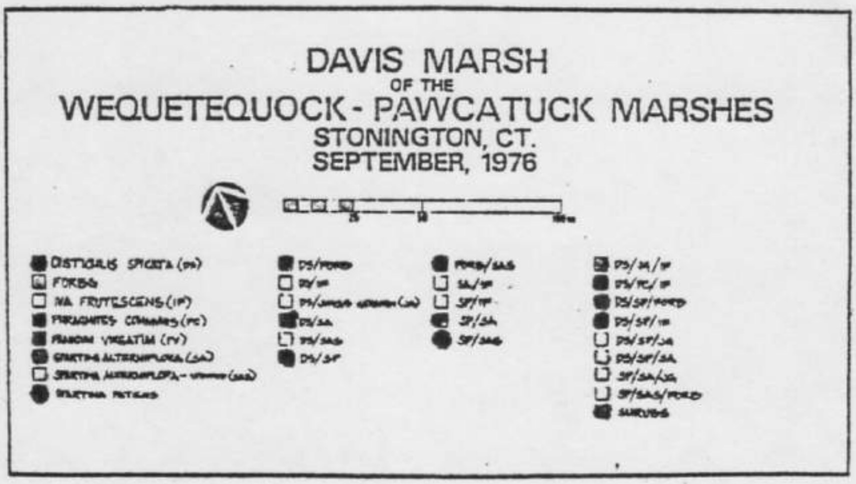

PALMER NECK & HEADQUARTERS MARSHES
OF THE
WEQUETEQUOCK - PAWCATUCK MARSHES
STONINGTON, CT.
SEPTEMBER, 1976

Figure 12. Vegetation map of Lower Brucker Marsh, Summer 1976.
A key to the map appears below.




LOWER BRUCKER MARSH
OF THE
WEQUETEQUOCK - PAWCATUCK MARSHES
STONINGTON, CT.
SEPTEMBER, 1976

Figure 13. Vegetation map of Davis Marsh , Summer 1976. A key to the map appears below.




DAVIS MARSH
OF THE
WEQUETEQUOCK - PAWCATUCK MARSH
STONINGTON, CT.
SEPTEMBER, 1976

community on both Headquarters and Palmer Neck Marshes, as was Spartina patens. Spartina alterniflora was dominant in two communities which together covered 24% of Headquarters Marsh and 14% of Palmer Neck Marsh. Spartina patens was dominant in only one community which covered 7% of Headquarters and 8% of Palmer Neck. An algal scum was also present in all the communities, but was only significant in three communities: Spartina alterniflora, stunted Spartina alterniflora and forb panne.

The four major communities present on Headquarters Marsh are: Distichlis spicata (14% total cover), forb panne (20% total cover), Spartina alterniflora/Spartina patens (10% total cover) and Spartina alterniflora stunted (16% total cover). Four additional communities occupied 5% or more of the marsh: Spartina alterniflora (5% total cover), Spartina patens (7% total cover), Juncus gerardi (6% total cover) and Distichlis spicata/Spartina patens (5% total cover). High marsh communities were common on Palmer Neck Marsh. The four predominant communities were: forb panne (17% total cover), Juncus gerardi (17% total cover), Panicum virgatum (10% total cover) and stunted Spartina alterniflora (10% total cover). Three other communities had over 5% coverage: Distichlis spicata (6% total cover), Distichlis spicata/Spartina patens (8% total cover), and Spartina patens (8% total cover).

Only three communities have a coverage of 10% or more on the Davis and Lower Brucker Marshes: Spartina alterniflora (34% total cover), Spartina patens (13% total cover) and Juncus gerardi (12% total cover). The Spartina patens and Juncus gerardi communities become significant only as one approaches the upper portions of Davis

Marsh. On Lower Brucker the two communities are limited to the narrow tidal creeks and ditch levees. The high marsh communities are most frequently found along the vertical ditch whereas Spartina alterniflora (tall) is found along the ditch edge of the horizontal ditches.

Spartina alterniflora (tall) Community

The Spartina alterniflora community is located on the lower marsh and is innundated twice daily. The Spartina alterniflora community on both Headquarters and Palmer Neck Marshes forms an intermittent border along the bayfront, tidal creeks, and ditch banks. On both marshes, the community occupies 4% of the total area. The community averages .75 M in width along the bayfront and tidal creeks, reaching its maximum development of 5 M on the eastern portion of Headquarters Marsh. The community is absent where there is a steep scarp. There is often a zone of stunted Spartina alterniflora present behind the scarps where Spartina alterniflora is absent. Large sections of the western bayfront of Headquarters lack a Spartina alterniflora community. When the community is present, often it is less than a meter wide. The Spartina alterniflora community of the ditch edges is frequently less than .5 M and is not as lush as its counterparts on the bayfront and tidal creek edges. As the ditches enter the central portion of the marsh the Spartina alterniflora community becomes narrower and is absent along several ditches. There are several stands of Spartina alterniflora in wet areas near clogged ditches and poorly drained tidal creeks.

The Spartina alterniflora community of the Lower Brucker Marsh forms a conspicuous belt along the bayfront, tidal creeks, and virtually all the mosquito ditches. The community ranges from less than a meter to 18 M in width on the bayfront and tidal creeks and averages 1/2 M in width on both Lower Brucker and Davis Marshes (Figures 11 and 12). Occasionally the community is absent from the meanders of the Half Mile Brook which runs through the Davis Marsh. The community was also absent along the southwestern bayfront of Lower Brucker Marsh. The Spartina alterniflora community is replaced by dense stands of Iva frutescens along the ditches as one approaches the landward sections of Davis Marsh. The Spartina alterniflora community comprises 6% of the total coverage of Lower Brucker and Davis Marshes.

Spartina alterniflora was the only dominant species in the Spartina alterniflora community on all the marshes studied (Table II - III). Spartina patens was the only other phanerogam which covered 1% or more in the quadrats in all the Spartina alterniflora communities studied. The density of the culms of Spartina alterniflora varied from marsh to marsh. On Headquarters and Palmer Neck Marshes Spartina alterniflora had an average coverage of 58% whereas on Davis and Lower Brucker Marsh the average percent coverage was 48% (Tables II - IV). An algal scum encrusted the soil between the culms of plants. The scum was more prominent on the eastern marshes covering 48% of the Spartina alterniflora community on Davis Marsh and 49% of the community on the Lower Brucker Marsh. On both Palmer Neck Marsh and on Headquarters Marsh only 38% of each quadrat was covered by an algal scum.

TABLE II. Mean Cover (C) and Frequency (F) for species of nine marsh communities on Headquarters and Palmer Neck Marshes Summer 1976. Only those species with a frequency of greater than 20% in at least one community are included.

Species	Major Communities*																	
	Ds		Ds/Sp		Forb.		Jg		Pv		Sa		Sa/Sp		Sas		Sp	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis alba var. *maritima*	-	-	-	-	-	-	-	-	4	54	-	-	-	-	-	-	2	2
Algal species	3	45	-	-	19	98	+	16	-	-	38	98	-	-	10	96	+	22
Aster tenuifolius	+	76	1	67	+	32	+	80	+	42	+	44	12	47	+	14	+	52
Atriplex patula var. *hastata*	+	5	-	-	-	-	+	12	+	42	+	4	+	56	-	-	+	4
Convolvulus sepium	-	-	-	-	-	-	-	-	6	73	-	-	-	-	-	-	-	-
Distichlis spicata	79	100	50	100	7	76	46	100	3	50	+	34	+	44	+	4	1	64
Elymus virginicus	-	-	-	-	-	-	-	-	+	31	-	-	-	-	-	-	-	-
Gerardia maritima	+	21	+	17	6	64	+	36	-	-	-	-	+	50	+	20	+	22
Iva frutescens	-	-	-	-	+	4	1	36	+	15	+	4	+	14	-	-	+	18
Juncus gerardi	2	40	-	-	5	26	46	100	2	27	-	-	+	3	-	-	+	10
Limonium carolinianum	+	23	+	33	3	96	+	22	-	-	+	10	+	58	+	50	+	22
Panicum virgatum	-	-	-	-	-	-	-	-	41	100	-	-	-	-	-	-	-	-
Plantago maritima	+	34	+	33	39	98	+	48	-	-	+	6	+	28	+	14	+	12
Potentilla anserina	-	-	-	-	+	2	-	-	+	38	-	-	-	-	-	-	+	4
Rhus radicans	-	-	-	-	-	-	-	-	+	42	-	-	-	-	-	-	-	-

TABLE (continued)

Species	Major Communities*																	
	Ds		Ds/Sp		Forb		Jg		Pv		Sa		Sa/Sp		Sas		Sp	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Rosa carolina	-	-	-	-	-	-	-	-	3	80	-	-	-	-	-	-	-	-
Salicornia bigelovii	-	-	-	-	+	60	-	-	-	-	-	-	-	-	+	2	-	-
Salicornia europaea	+	66	+	50	+	46	+	58	-	-	+	32	+	94	+	76	+	66
Solidago graminifolia	-	-	-	-	-	-	-	-	5	50	-	-	-	-	-	-	-	-
Solidago semperivens	+	3	-	-	+	4	+	14	18	100	-	-	-	-	-	-	+	14
Spartina alterniflora	+	55	+	100	3	84	+	38	-	-	58	100	32	100	76	100	+	46
Spartina patens	11	76	47	100	3	52	2	12	2	27	4	64	35	100	13	74	90	100
Spartina pectinata	-	-	-	-	-	-	-	-	3	46	-	-	-	-	-	-	-	-
Teucrium canadense	-	-	-	-	-	-	-	-	2	81	-	-	-	-	-	-	-	-
Triglochin maritima	+	11	+	17	15	88	+	6	-	-	-	-	+	6	-	-	+	14

+ : < 1% - : absent

*Ds - _Distichlis spicata_
Ds/Sp - _Distichlis spicata_/_Spartina patens_
Forb - Forb panne
Jg - _Juncus gerardi_
Pv - _Panicum virgatum_
Sa - _Spartina alterniflora_
Sa/Sp - _Spartina alterniflora_/_Spartina patens_
Sas - Stunted _Spartina alterniflora_ panne
Sp - _Spartina patens_

TABLE III. Mean Cover (C) and Frequency (F) for species of eight marsh communities on Lower Brucker Marsh, Summer 1976. Only those species with a frequency of greater than 20% in at least one community are included.

Species	Major Communities*															
	Ds		Forb		Jg		Pv		Sa		Sa/Sp		Sas		Sp	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Achillea millefolium	--	--	--	--	--	--	+	33	--	--	--	--	--	--	--	--
Algal sp.	1	27	13	100	+	20	--	--	49	100	6	69	23	100	1	39
Aster novi-belgii	--	--	--	--	--	--	+	25	--	--	--	--	--	--	--	--
Aster tenuifolius	2	91	20	77	1	100	--	--	+	20	+	62	10	5	1	78
Carduus acanthoides	--	--	--	--	--	--	+	33	--	--	--	--	--	--	--	--
Convolvulus sepium	--	--	--	--	43	100	+	50	--	--	--	--	--	--	--	--
Distichlis spicata	78	100	1	24	+	20	--	--	+	16	+	12	+	5	2	65
Gerardia maritima	+	18	4	82	+	7	--	--	--	--	+	25	+	5	+	8
Juncus gerardi	9	73	--	--	51	100	+	50	--	--	+	3	--	--	--	--
Limonium carolinianum	+	27	6	100	+	20	--	--	+	8	+	50	+	13	+	26
Onoclea sensibilis	--	--	--	--	--	--	+	33	--	--	--	--	--	--	--	--
Plantago maritima	+	9	32	100	+	47	--	--	--	--	+	38	+	3	1	17
Panicum spp. smooth	--	--	--	--	--	--	+	33	--	--	--	--	--	--	--	--
Panicum spp. hairy	--	--	--	--	--	--	+	50	--	--	--	--	--	--	--	--
Panicum virgatum	--	--	--	--	--	--	73	100	--	--	--	--	--	--	--	--

TABLE (continued)

Species	Major Communities*															
	Ds		Forb		Jg		Pv		Sa		Sa/Sp		Sas		Sp	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Rosa carolina	--	--	--	--	--	--	+	25	--	--	--	--	--	--	--	--
Salicornia europaea	+	27	+	47	+	40	--	--	+	8	+	50	+	80	+	87
Solidago graminifolia	--	--	--	--	--	--	+	75	--	--	--	--	--	--	--	--
Solidago rugosa	--	--	--	--	--	--	+	25	--	--	--	--	--	--	--	--
Solidago sempervirens	--	--	--	--	--	--	+	67	--	--	--	--	--	--	--	--
Spartina alterniflora	+	86	14	90	+	33	--	--	48	100	32	100	74	100	+	48
Spartina patens	7	73	11	94	2	67	+	8	2	54	35	100	3	48	90	100

+ : < 1% -- : absent

* Ds - _Distichlis spicata_
Forb - Forb panne
Jg - _Juncus gerardi_
Pv - _Panicum virgatum_
Sa - _Spartina alterniflora_
Sa/Sp - _Spartina alterniflora_/_Spartina patens_
Sas - Stunted _Spartina alterniflora_
Sp - _Spartina patens_

TABLE IV. Mean Cover (C) and Frequency (F) for species of five marsh communities on Davis Marsh, Summer 1976. Only those species with a frequency of greater than 20% in at least one community are included.

Species	Communities*									
	Jg		Pv		Sa		Sas		Sp	
	C	F	C	F	C	F	C	F	C	F
Algal species	4	90	--	--	48	100	35	98	+	32
Aster novi-belgii	--	--	2	100	--	--	--	--	--	--
Aster tenuifolius	+	90	--	--	+	20	+	2	+	37
Distichlis spicata	67	100	+	19	+	16	+	2	+	5
Gerardia maritima	+	30	+	11	--	--	+	4	+	37
Iva frutescens	+	20	+	4	--	--	--	--	--	--
Juncus gerardi	23	100	--	--	--	--	--	--	--	--
Limonium carolinianum	+	80	--	--	+	8	+	2	+	47
Myrica pensylvanica	--	--	+	23	--	--	--	--	--	--
Plantago maritima	+	50	--	--	--	--	--	--	--	--
Rosa carolina	--	--	+	31	--	--	--	--	--	--
Salicornia europaea	+	90	--	--	+	12	+	28	+	16
Solidago graminifolia	--	--	2	55	--	--	--	--	--	--
Solidago sempervirens	+	20	+	87	--	--	--	--	--	--
Spartina alterniflora	+	20	--	--	48	100	64	100	+	5
Spartina patens	4	10	18	85	1	48	+	22	96	100
Triglochin maritima	+	90	--	--	--	--	--	--	--	--
Panicum virgatum	--	--	57	100	--	--	--	--	--	--

+ : 1% -- : absent

*Jg - *Juncus gerardi*
Pv - *Panicum virgatum*
Sa - *Spartina alterniflora*
Sas - Stunted *Spartina alterniflora*
Sp - *Spartina patens*

The frequency of the associate species was consistently higher on Palmer Neck and Headquarters Marshes than on either Davis or Lower Brucker Marshes. On the former marshes Salicornia europaea was the only vascular plant scattered throughout the zone. The other species usually occurred at the transition zone to the high marsh. On Lower Brucker Marsh, circular clumps of Spartina patens are found within the community. The Spartina patens is found on clods of peat which have been washed ashore during the previous winter.

Four species of vascular plants were present in the Spartina alterniflora community in 1976 that were not present in 1948 (Table V). They are: Atriplex patula variety hastata, Distichlis spicata, Iva frutescens, and Plantago maritima. The addition of these species, as well as an increased frequency of Spartina patens and Aster tenufolius, may be explained by sampling error. Use of the elliptical quadrats in the narrowest portions of this community prevented the exclusion of several high marsh species that were frequent along the border of the Spartina patens and Spartina alterniflora communities. Salicornia europaea has decreased in frequency in this community as well as all others.

Spartina patens Community

On New England marshes, Spartina patens, Distichlis spicata, Spartina patens/Distichlis spicata communities often cover large expanses of the high marsh (Chapman 1974). Usually there are small stands of forb pannes and Spartina alterniflora pannes interspersed throughout the high marsh. Yet on Headquarters Marsh these communities

TABLE V. Frequency for species of five marsh communities on Headquarters Marsh, Stonington, Connecticut, Summers of 1948 and 1976.

Species	Communities									
	Forb		Jg		Sa		Sas		Sp	
	1948	1976	1948	1976	1948	1976	1948	1976	1948	1976
Agrostis alba	--	--	--	--	--	--	--	--	--	--
Algal species	--	98	--	16	--	98	--	96	--	22
Aster tenuifolius	66	32	86	80	12	44	8	14	44	52
Atriplex patula var. *hastata*	--	--	56	12	--	4	--	--	30	4
Distichlis spicata	64	76	98	100	--	34	20	4	94	64
Elymus virginicus	--	--	--	2	--	--	--	--	--	--
Gerardia maritima	100	64	42	36	--	--	20	20	22	22
Iva frutescens	--	4	70	36	--	4	--	--	14	18
Juncus gerardi	10	26	100	100	--	--	--	--	6	10
Limonium carolinianum	100	96	88	22	2	10	40	50	20	22
Phragmites communis	--	--	--	--	--	--	--	--	--	2
Plantago maritima	100	98	6	58	--	6	4	14	--	12
Potentilla anserina	--	2	--	--	--	--	--	--	--	4
Salicornia bigelovii	90	60	8	--	--	--	46	2	--	--
Salicornia europaea	86	46	98	58	10	32	88	76	82	66
Solidago sempervirens	--	4	4	14	--	--	--	--	--	--
Spartina alterniflora	100	84	28	38	100	100	100	100	20	46
Spartina patens	90	90	26	12	6	64	64	74	94	100
Spergularia canadensis	--	--	--	2	--	--	--	--	--	--
Sueda maritima	--	--	4	2	--	--	--	--	--	--
Triglochin maritima	100	88	6	6	--	--	8	4	14	6

Jg = *Juncus gerardi* Sas = Stunted *Spartina alterniflora*
Sa = *Spartina alterniflora* Sp = *Spartina patens*

-- = absent or not sampled in 1948

have a coverage of only 26% and on Palmer Neck Marsh they cover only 24% of the total area. The pannes cover 26% and 31% of the marshes respectively. The only sizeable stands of Spartina patens community are limited to the upper, well drained portions of the marsh, directly seaward of the Panicum virgatum community. Numerous small stands of Spartina patens community are scattered throughout both Headquarters and Palmer Neck Marshes.

The mosaic of communities is not as complex on Davis and Lower Brucker Marshes. A substantial portion of both marshes supports stands of stunted Spartina alterniflora communities. The Spartina patens community constitutes only 3% of the total vegetation cover on Lower Brucker Marsh. The community forms no conspicuous belt and is restricted to the levees along the tidal creeks and the large mosquito ditch which bisects the marsh. The Spartina patens community is not common along the smaller mosquito ditches except near the upland. The frequency of Spartina patens community on Davis Marsh increases between mosquito ditches toward the upland. The mosquito ditches on the lower portion of Davis Marsh originally extended the entire width of the marsh but were filled in by the Davis family in the 1930's. A large stand of Spartina patens community is present in this area. A stand of Juncus gerardi is also present. The Spartina patens community stops abruptly as soon as the mosquito ditches are reached.

The species Spartina patens grows in dense formation and has an average percent coverage of 90% in Spartina patens communities on all the marshes except Davis Marsh where its average percent coverage is 96% (Figures 14 and 15). Numerous associate species occurred; however,

Figure 14. Closeup view of a stand of Spartina patens, Davis Marsh. Summer 1976.

Figure 15. Davis Marsh, looking northwest. A dense stand of Spartina patens is in the foreground, and stands of Iva frutescens line the ditches in the background. Note the dead trees in the background where the tidal marsh is encroaching upon the upland. Summer 1976.

these associate species had an average coverage of less than 1%. The frequency of Distichlis spicata is high except for communities on the Davis Marsh.

A prominent feature of the Spartina patens community on all marshes was a layer of dead Spartina patens which had accumulated over the past several growing seasons. The depth of the mat ranged from 3 - 6 cm. The mat occurred in all the quadrats on Davis Marsh and in 52% of the quadrats on Palmer Neck and Headquarters Marshes. The coverage was higher on the latter marshes, 6 - 10% as opposed to 2.7% on Davis Marsh. The stands of Spartina patens were smaller on Brucker Marsh and the accumulation of dead material was less. Large areas of flattened vegetation known as "Cowlicks" were common in this community (Figure 16).

Eight new species were observed in the Spartina patens community in 1976. They were: Agrostis alba variety maritima, Juncus greenii, Phragmites communis, Plantago maritima, Potentilla anserina, Scirpus americanus, Solidago sempervirens, and Triglochin maritima. The frequency of Spartina alterniflora has more than doubled between 1948 and 1976, yet the average coverage of stunted Spartina alterniflora remains less than 1% per quadrat. Distichlis spicata is no longer a subdominant species as it was in 1948. Iva frutescens is present occasionally; it is always observed in the seedling stage, except along ditch edges.

Figure 16. Cowlicks in the Spartina patens community. Summer 1976.

Spartina alterniflora/Spartina patens Community

Small, irregularly shaped stands of Spartina alterniflora/Spartina patens occurred throughout both Headquarters and Palmer Neck Marshes covering 10% and 3% of the marshes respectively.

The Spartina alterniflora/Spartina patens community is largely restricted to the northwest corner of Headquarters Marsh, which is dissected by an arm of a tidal creek. The peat of this area is softer than the rest of the marsh and may be forming rotten spots as described by Chapman (1974). This community is also found between several mosquito ditches.

Spartina alterniflora/Spartina patens occurs along the ditch levees on the Lower Brucker Marsh. This community usually grades into one which contains pure stands of Spartina patens community. Stunted Spartina alterniflora/Spartina patens community is a common transition between the stands of stunted Spartina alterniflora pannes and the pure stands of Spartina patens community. When one approaches the uplands the stands of stunted Spartina alterniflora pannes are less frequent and are smaller. These pannes are replaced by large stands of stunted Spartina alterniflora/Spartina patens communities.

The Spartina alterniflora/Spartina patens communities are similar on Palmer Neck, Headquarters, and Lower Brucker Marshes. The two grasses are not clumped as densely as in the Spartina patens community, yet there is not as much space between each individual as in a pure Spartina alterniflora community. The space between the culms is covered with an algal scum. The frequency of the dominant species varies from marsh to marsh. On Headquarters and Palmer Neck the species covers 35% of each quadrat and the Spartina alterniflora covers 32%. On Lower Brucker 41% and 34% of the marshes are covered respectively. The Spartina alterniflora ranges from 9" (22.86 cm) to 26" (66.04 cm) on Headquarters and Palmer Neck and from 12.7 to 76.2 cm on Lower Brucker. All associated plants have very low average percent cover.

Distichlis spicata/Spartina patens Community

The Distichlis spicata/Spartina patens community on the Palmer Neck Marsh, formed a distinct belt below part of the Panicum virgatum community and was present along many of the ditch edges. The community was not as prominent on Headquarters Marsh.

The Distichlis spicata/Spartina patens community of Lower Brucker and Davis Marshes is the most frequent upland community along the ditch edges. This community is also frequent seaward of the Panicum virgatum community of the Davis Marsh. This community is infrequent on the Lower Brucker Marsh and is restricted to the levee adjacent to the Half Mile Brook.

The Distichlis spicata/Spartina patens community was sampled only on Headquarters and Palmer Neck Marshes. Distichlis spicata had an average cover of 50% per quadrat and Spartina patens 47%. No other species had a significant cover in the community.

Distichlis spicata Community

The Distichlis spicata community was most extensive in the center of Headquarters Marsh. This area had poor drainage and often had a higher soil moisture than the other parts of the marsh. However, the Distichlis spicata community was also found on high marsh where there was little soil moisture. The Distichlis spicata community of Lower Brucker and Davis Marshes is not as extensive as on the western sections of the marsh complex. Frequently the Distichlis spicata community of these marshes is restricted to areas near the upland, which may be related to fresh water seepage.

Observations suggest that the Distichlis spicata community is found on parts of the marsh that have been environmentally disturbed. One large stand of Distichlis spicata community is in an area of Headquarters Marsh which is subjected to erosion as water piles up against the impoundment during high tides. A large stand of Distichlis spicata community exists on an area of Brucker Marsh which receives heavy pedestrian traffic during the hunting season and in addition is perpetually wet. The extensive eroded edge surrounding the large till island on Lower Brucker Marsh is another area where the Distichlis spicata community is predominant. This area has been severely disturbed since a duck pond was constructed in the 1950's. The peat is extremely compacted between the culms and there are virtually no other species in the community. The individual culms of the Distichlis spicata are widespread and the species covers only 45% of each individual quadrat. However, there are large areas where the cover is substantially less. In some parts of the eroded edge Phragmites communis is locally abundant, invading from a colony on the upland island. In addition, the Distichlis spicata community was common along the ditch edges of all the marshes except Lower Brucker. Frequently the community was associated with the species Iva frutescens.

Distichlis spicata in the *Distichlis spicata* community has an average cover of 77% on Headquarters and Palmer Neck Marshes and 78% on Lower Brucker and Davis Marshes. On Davis Marsh there is a larger percentage of *Juncus gerardi* and *Distichlis spicata* covers only 67% of each quadrat. There are numerous accessory species on all the marshes, however the frequencies of the species vary from marsh to marsh. *Spartina patens* is the major associate on both Headquarters and Palmer Neck Marshes, with *Juncus gerardi* and *Spartina patens* occurring at the same frequency on Lower Brucker. *Juncus gerardi* is more extensive on Davis Marsh, covering an average of 23% in each quadrat.

Iva frutescens Community

The *Iva frutescens* community was small, covering an area of 3% on Palmer Neck Marsh and 3% on Headquarters Marsh. On the latter marsh the community was virtually restricted to the dune area in front of the marsh. An occasional stand occurred along the ditch edges. The *Iva frutescens* community was more frequent along the ditch edges of Palmer Neck Marsh. The community occurred as belts along the ditches and usually ranged from 1 - 2 M in width. Within the community the species *Iva frutescens* had an average percent coverage of 70%. *Iva frutescens* is associated with the transition zone of many marshes. However on Headquarters and Palmer Neck Marshes this species was rare in the *Panicum virgatum* community.

An *Iva frutescens*/*Distichlis spicata* community occurred along several ditch edges on Davis Marsh. The community represented 8% of the total vegetation on this marsh. There was also a large stand of this community on the levee of Half Mile Brook of Davis Marsh. The Iva frutescens community was restricted to the edge of a stone wall near the uplands on Lower Brucker and to the spoils of a duck pond on the marsh proper. A small stand also existed along the large channel which separates Lower Brucker Marsh from Barn Island.

Forb panne Community

A panne is a small irregularly shaped area which has poor drainage. Miller and Egler (1950) suggested that pannes may have occupied up to 20% of the New England marshes prior to the ditching of these marshes. Both forb pannes and Spartina alterniflora stunted pannes are common on the Palmer Neck and Headquarters Marshes. The forb panne community occupies 20% and 19% of the two marshes respectively. The algal pannes mentioned by Miller and Egler (1950) were infrequent in 1976 and the concentric belting of the pannes was not observed in 1976.

The forb panne which is usually no larger than 10 M^2 on other New England marshes, attain larger proportions on Palmer Neck and Headquarters Marshes (Figure 17). The pannes often occupy the entire area between mosquito ditches and acquire a rectangular shape. However, the shape of individual forb pannes is variable and often small islands of grass communities are scattered throughout the forb pannes. On the eastern portion of Headquarters, the forb pannes often extend across the ditches and no ditch levee community is observed. On Palmer Neck Marsh the forb panne community has few other community types within its boundaries and forms a distinct band down the center of the marsh. This community is bordered by a distinct Juncus gerardi

Figure 17. View of a forb panne community on Headquarters Marsh. Small islands of Spartina patens are dispersed throughout the panne. Summer 1976.

belt toward the estuary and grades into a mixture of forb panne/stunted *Spartina alterniflora* communities, *Spartina patens*/stunted *Spartina alterniflora* communities, and a *Distichlis spicata*/forb panne/stunted *Spartina alterniflora* community toward the upland. Most of the forb panne communities of Headquarters are located in the central part of the marsh. However, there is a distinct belt of forb panne community directly seaward of the *Panicum virgatum* community ranging from 1 - 12 M in width.

The forb panne communities of Davis and Lower Brucker are not as extensive as on the other two marshes. On Davis Marsh the forb panne community is virtually absent except for a small band seaward of the *Panicum virgatum* community. On the Lower Brucker Marsh, the forb panne community intermingles with the *Panicum virgatum* community. The forb panne community contains more species than any other community on the marsh proper. The species composition of the forb panne community remains constant throughout the marsh. Nine species have a frequency of 50% or higher on Palmer Neck and Headquarters Marshes. On Lower Brucker there are seven species which have a frequency of over 50%. The dominance of individual species varies in different locations on the marsh. *Triglochin maritima* is dominant on Palmer Neck Marsh whereas *Plantago maritima* is dominant on Headquarters and Lower Brucker Marshes. Although most species occurred frequently they had a low percent cover. *Gerardia maritima* had an average cover of 10% or more on Headquarters and *Distichlis spicata* in 24% of the quadrats. *Juncus gerardi* was locally abundant along the *Panicum virgatum* belt where its average cover reached 70%. Large spaces occurred between individual plants. Often an algal scum covered the surface of the marsh and occasionally the algae had a rubbery crust and resembled a foliose lichen.

Iva frutescens, Potentilla anserina and Solidago sempervirens were present in the forb panne community in 1976. The percent frequency of the remaining species has fluctuated and unlike the situation in 1948, no individual species has a percent coverage of 100%. Decrease in numerous species including Aster tenufolius, Gerardia maritima, Salicornia bigelovii, Salicornia europaea, Spartina alterniflora, Spartina patens, and Triglochin maritima, have occurred. The percent coverage for both Juncus gerardi and Distichlis spicata has increased. Juncus gerardi is most frequent in the forb pannes that were part of the Juncus gerardi zone in 1948.

Stunted Spartina alterniflora Community

The stunted Spartina alterniflora panne communities on Headquarters and Palmer Neck Marshes assume various shapes and range from 1 - 30 M in width. The largest stand of stunted Spartina alterniflora community is located in the northwest corner of Headquarters Marsh. Here the pannes occupy the entire area between the ditches and are rectangular in shape. Unlike the forb panne communities, the stunted Spartina alterniflora stands rarely have stands of other communities scattered internally. In areas which are not adjacent to the estuary the stunted Spartina alterniflora pannes are substantially smaller and more irregularly shaped. The stunted Spartina alterniflora panne community covers 16% of the Headquarters Marsh. On Palmer Neck Marsh the pannes are both irregularly shaped, and irregularly distributed on the marsh. Usually the community is restricted to areas which are near clogged mosquito ditches and are perpetually covered with standing water. Toward the bayfront on the tidal creek levee, there is a strip of stunted Spartina alterniflora community which ranges in width from less than a meter to 15 M wide. This community covers 10% of the Palmer Neck Marsh.

Fifty-three percent of Lower Brucker Marsh is covered by stunted Spartina alterniflora community (Figure 18). These pannes are rectangular and occupy the entire area between the ditches. Davis Marsh also has large areas of stunted Spartina alterniflora communities. There are no ditch levee communities until one reaches Davis Marsh and the upper portions of Lower Brucker Marsh.

The Spartina alterniflora of the stunted Spartina alterniflora panne community had an average cover of 76% on Headquarters and Palmer Neck Marshes. The species was sparser on Lower Brucker and Davis Marshes, 74% on Lower Brucker and 64% on Davis Marshes. The average height of the Spartina alterniflora was 9 cm, but ranged from 5 - 30 cm in height. The height of the grass increased as one moved from the center of the panne toward the mosquito ditch, ranging in height from 30 - 65 cm here. The height of the grass was taller on Davis Marsh averaging 26 cm. The level of standing water under the community was noticeably higher than on Headquarters and the smell of hydrogen sulphide was evident. An algal scum occurs between the culms of Spartina alterniflora. Salicornia europaea and Spartina patens are common associates on all marshes. The Spartina patens on Davis Marsh had a lower frequency and average percent cover than on any of the other three marshes.

Figure 18. View of Lower Brucker Marsh, looking east. Note the pure stand of stunted *Spartina alterniflora*. *Iva frutescens* lines a ditch in the background. Summer 1976.

The structure of the stunted *Spartina alterniflora* panne communities has remained virtually constant since 1948. *Salicornia bigelovii* and *Distichlis spicata* decreased significantly in frequency while *Plantago maritima* is no longer present in the community.

Juncus gerardi Community

The *Juncus gerardi* community forms a continuous belt along the tidal creek levees and is occasionally found along the ditch edges of Palmer Neck Marsh. No stand representing the *Juncus gerardi* community was observed on the upper slope. On Headquarters there was no continuous belt of *Juncus gerardi* community on either the bayfront or the tidal creeks. Instead, small patches of this community alternated with a variety of other communities. Often the species *Juncus gerardi* or *Distichlis spicata* will be mixed in with various combinations of forb, *Spartina alterniflora*, or *Spartina patens*. The only concentrated zone of *Juncus gerardi* community on Headquarters Marsh is an area directly behind the sand dunes which are slightly elevated above the marsh. The *Juncus gerardi* belt described by Miller and Egler (1950) no longer exists and has been replaced by a forb community.

A *Juncus gerardi* community is present on both Lower Brucker and Davis Marshes. On Brucker Marsh the community represents 2% of the total vegetational cover and is restricted to the tidal creek levees and small patches below the *Panicum virgatum* belt. Toward the upland the community is adjacent to a forb panne community and several forbs have a high frequency in the community.

To the west of the Barn Island boat launch is a small unditched marsh, which was surveyed briefly during the summer of 1977. There is a distinct belt of Juncus gerardi community. In some places this belt is 20 M wide and the species Juncus gerardi has an average coverage of 60%. Beyond this small marsh is another marsh area which was mosquito ditched during the 1930's. This area contained a Juncus gerardi belt which ranged from less than a meter to 11 M in width. Here the average percent coverage of the species Juncus gerardi was variable, ranging from 30 - 80%. In the areas which had a low percent coverage of the species Juncus gerardi, a forb cover predominated. In some spots Triglochin maritima and Plantago maritima had a greater percent coverage than the species Juncus gerardi. In these areas the forb stands had the same general appearance as those on the other Wequetequock-Pawcatuck marshes. As on the other marsh complexes, the upper slope Juncus gerardi community seems to be disappearing on the West Palmer Neck Marshes.

Iva frutescens seedlings were prominent in the community, yet full grown bushes are rare except along ditch edges and on the marsh side of the sand dunes. Juncus gerardi was a common associate under the Iva frutescens bushes on the sand dunes.

"Cowlicks" are frequent in the Juncus gerardi community. Cowlicks are more frequent toward the end of the growing season. In the spring the Juncus gerardi has a dark green color which turns to a brown hue by mid August.

A brief survey of the marsh on July 10, 1977, suggested that there was a denser stand of Juncus gerardi than in 1976 and that the densities of the rush may fluctuate yearly. A small border fringe of Juncus gerardi, often no wider than 50 cm, was present on the upland side of the forb panne and occasionally along the bottom border of the panne. The small areas of concentrated Juncus gerardi seemed more extensive in 1977. Unlike 1948, Juncus gerardi is no longer the sole dominant in the remaining community. On Palmer Neck and Headquarters Marshes both Juncus gerardi and Distichlis spicata have an average cover of 46%. The dominance of the two species varies on different parts of the marsh with Distichlis spicata covering a larger portion of the quadrat than Juncus gerardi. On Lower Brucker the species cover 43% and 51% of the quadrat respectively. No distinct Juncus gerardi community existed on Davis Marsh.

Atriplex patula variety hastata, Iva frutescens, Salicornia europaea, and Limonium carolinianum have decreased dramatically since 1948. Plantago maritima, on the other hand, has increased in frequency by 42%.

Panicum virgatum Community

The Panicum virgatum community represents the transition zone between the marsh and the upland. The upland border of the Panicum virgatum belt in both Headquarters and Palmer Neck Marshes is a forest with the species Quercus alba and Q. velutina predominating. Other trees include Prunus serotina and Pyrus malus. Shrubs such as Myrica pensylvanica and Rhus copillina are locally dominant. The land on which the Panicum virgatum community is located is at a slightly higher elevation than the rest of the marsh and the spring tides only reached the edges of the community. Patches of tidal debris are frequent throughout the belt. On Palmer Neck Marsh this community ranges from 1 - 30 M in width whereas on Headquarters the belt was narrower and only represented 2% of the total marsh vegetation. On Davis and Lower Brucker Marshes the Panicum virgatum community forms an intermittent belt which often intermingles with the forb community. On Davis the belt grades into islands of dead Quercus spp. and Acer rubrum. Local farmers say that 40 years ago these trees were alive. On Lower Brucker Marsh fingers of forb community penetrate the Panicum virgatum community. Panicum virgatum community is also present on the large glacial till island which extends onto the Brucker Marsh.

After the hurricane of 1956 a large and nearly impenetrable stand of Phragmites communis became established in the upper portions of the Davis Marsh. The community appears to be moving marshward and one can observe Spartina patens succumbing to shading by Phragmites communis.

Although the Panicum virgatum community contains more species than any other marsh community, the frequency and average percent cover of most species is low. Panicum virgatum has the following average percent coverage: Headquarters and Palmer Neck Marshes 41%, Lower Brucker 73%, and Davis Marsh 57%. Upland species predominate in the community. Eleocharis rostellata was observed but was not present in any of the quadrats sampled. Flotsam was scattered throughout the belt and in some areas covered a large portion of the quadrat. In addition, dead Panicum virgatum is common between the live tussocks.

No comparative tables were made for the Panicum virgatum community. Miller and Egler (1950) studied the Panicum virgatum community of Brucker Marsh. The size and species composition of this community was reduced after the construction of the Brucker Impoundment in 1968.

Aerial Photography

Aerial photography was found to be a feasible method for making vegetation maps, but contained inherent problems that were not anticipated. The patterns of *Spartina patens*, *Spartina alterniflora*, forb pannes, *Distichlis spicata*, and *Juncus gerardi* were distinguishable. Each community had to be field checked because their color values varied considerably as the angle of grasses or the amount of water under a stand varied. It was difficult to distinguish the boundaries of mixed communities such as *Spartina alterniflora*/*Spartina patens* and *Distichlis spicata*/*Spartina patens* especially when these communities graded into pure stands. The boundaries were determined after field checks had been completed. The aerial photographs were useful in determining landmarks which could be checked in the field. Boulders, flotsam, and bodies of water were distinct. Black and white photographs taken by the Keystone Aerial Surveys Incorporated were useful in distinguishing vegetational patterns on the marsh prior to 1976. These photographs were almost as helpful in distinguishing vegetational patterns as color slides.

Figure 19. Photostation 9, 1948. The photostation is along a ditch edge on Palmer Neck Marsh. Iva frutescens borders the ditch in a belt 2 - 3 meters in width. Distichlis spicata and Spartina patens intermingle with the Iva frutescens bushes. There is no Spartina alterniflora along the ditch edge. Occasional clumps of Iva frutescens are observd along the other ditches in the photograph. It is probable that the grass between the ditches is Spartina patens and that the circular depression between the two ditches is a forb panne.

Figure 20. Photostation 9, 1976. The picture was shot at a slightly different angle than in 1948. Bushes of Iva frutescens are scattered along the ditch edge. Spartina alterniflora is the predominant species along the ditch edge, occurring in a belt which averages a meter in width. A stand of Distichlis spicata community, approximately 2 meters wide, extends down the right side of the mosquito ditch to the creek. The yellow green circular patch of vegetation on the left side of the ditch is a stand of Spartina patens/ Distichlis spicata community. This circular patch is an extension of a strip averaging 2 meters wide that borders the entire length of the ditch grading into a Juncus gerardi community 10 meters from the tidal creek. The grasses in the foreground of the picture, between the ditches, are a mixture of Spartina alterniflora, Spartina patens, Distichlis spicata, and forbs. As one approaches the tidal creek, stands of forb become prevalent. Juncus gerardi and Distichlis spicata are dominant along the tidal creek levees. There is an extensive stand of Iva frutescens along the ditch opposite that in photostation 9, on Headquarters Marsh.

Photostations

Figure 21. Photostation 18, 1948. The photostation is located to the east of Headquarters Marsh, looking southwest into Little Narragansett Bay. There is a small drainage ditch to the right of the 4 rocks. Spartina patens and Distichlis spicata are the dominant species with an occasional individual of Solidago sempervirens. Iva frutescens is present at the end of the ditch which is close to the tidal creek. Note the dark circular patch of vegetation which abuts the stone wall and another dark irregularly shaped patch of vegetation to the left of the ditch. It is probable that the vegetation is a Juncus gerardi community.

Figure 22. Photostation 18, 1976. The drainage ditch is obscured by a dense stand of Iva frutescens. Spartina patens is dominant below the Iva frutescens. There is a circular patch of forb panne which abuts the stone wall. Another circular area of forb panne community is observed to the left of the drainage ditch behind 4 rocks. The vegetation beyond the Iva frutescens stand and toward the tidal creek is stunted Spartina alterniflora.

Figure 23. Photostation 12, 1948. The dark band of vegetation in the foreground directly seaward of the Panicum virgatum community, is a stand of Juncus gerardi community. The Spartina patens community is to the left of the Juncus gerardi community. The 4 posts in the background are located in a mixed stand of stunted Spartina alterniflora and Spartina patens community. The lichen encrusted rock in the foreground is flanked by Juncus gerardi and Solidago sempervirens. The dividing point between the Juncus gerardi and Spartina patens community is a rock which is diagonal to the latter rock. The level of the impoundment is not much higher than the level of the marsh.

Figure 24. Photostation 12, 1976. No distinct Juncus gerardi community exists. Instead a forb panne community is adjacent to the Panicum virgatum belt. A Spartina patens community is found seaward of the Panicum virgatum community in areas where the forb panne community is absent. The lichen encrusted rock is now surrounded by a forb panne. The 4 posts in the background are in a stand of stunted Spartina alterniflora community. Taller Spartina alterniflora and an occasional bush of Iva frutescens are found along the ditch edges. The level of the impoundment is higher than in 1948 and is covered by both Iva frutescens and several upland grasses. Phragmites communis is encroaching onto the marsh from several spots on the impoundment.

Figure 25. Photostation 14, 1948. Miller and Egler (1950) described this photostation as follows: "Erosion on the margins of a Panicum virgatum and Juncus gerardi "island" in the tidal marsh. The black border is the undercut and receding margin of the eroding soil. The light strip about a meter wide is the eroding soil zone in part invaded by Distichlis spicata." The grass in the foreground is Distichlis spicata with stunted Spartina alterniflora scattered throughout.

Figure 26. Photostation 14, 1976. This picture is taken slightly closer to the upland than 1948. A stand of forb panne community is revegetating the eroding margin. Distichlis spicata is prevalent with several small stands of Spartina patens scattered throughout the community. Iva frutescens and Spartina patens are the dominant species on the small upland island. A dense stand of Iva frutescens is visible on the sand dunes in the background.

Figure 27. Photostation 19, 1948. Flotsam covers a large percentage of the area in this photostation. The vegetation beyond the flotsam is sparse. The vegetation within the depressed ellipsoid area seems to be either a forb panne community or a stand of stunted Spartina alterniflora community.

Figure 28. Photostation 19, 1976. Stunted Spartina alterniflora predominates. Several upland grasses and Iva frutescens are growing on the impoundment which has been rebuilt since 1948. A new ditch has been excavated since 1948. Iva frutescens is growing along the edge.

Figure 29. Photostation 23, 1948. Miller and Egler described photostation 23 as follows: "Killed areas of *Spartina patens* (appearing smooth) and stunted *Spartina alterniflora* (appearing rough) in new pannes created by blocking of a mosquito ditch." Before the plug occurred, the area had a dense stand of *Spartina patens*, *Spartina alterniflora* and forb community. The *Spartina patens* appeared flattened in the picture because it was covered with a thick algal scum.

Figure 30. Photostation 23, 1976. This area contains stunted *Spartina alterniflora* community. *Iva frutescens* is scattered throughout, mainly along ditch edges. The browning of the tree canopy, in the upper left hand corner of the picture, is a result of the hurricane of August 12, 1976.

Figure 31. Photostation 25, 1948. This photostation is in the same vicinity as photostation 23. Spartina alterniflora dominates the area. Taller Spartina alterniflora abuts the mosquito ditch which is situated in the left hand corner of the picture. There is an area of dead Spartina patens landward of the boulder in the lower right hand corner of the photograph. Another small patch of Spartina patens is located in the upper left hand corner of the photograph. An algal crust covers the prostrate Spartina patens. Spartina alterniflora is flowering along the ditch.

Figure 32. Photostation 25, 1976. The predominant species is stunted Spartina alterniflora with Spartina alterniflora occurring along the mosquito ditch. Iva frutescens is also common along the mosquito ditches. The photograph was shot at low tide, yet there is a substantial amount of standing water.

DISCUSSION

The zonation and structure of some plant communities on the Wequetequock-Pawcatuck Marshes changed markedly between 1948 and 1976, while other communities remained virtually unchanged. The area covered by Spartina patens, Juncus gerardi, and Panicum virgatum communities decreased while that covered by forb panne and stunted Spartina alterniflora communities increased. In addition, the percent coverage of Spartina alterniflora, Distichlis spicata, and Plantago maritima increased in the Spartina patens and Juncus gerardi communities. Photographs indicate a landward migration of both the Panicum virgatum and Spartina patens communities. The upper slope Juncus gerardi community has disappeared from Headquarters Marsh and has been replaced by a forb panne community. In 1976, unlike 1948, there was no dominant community type on Headquarters and the marsh was a heterogenous mosaic of stands. Several factors may have resulted in overall vegetational changes. These factors are related to increased innundation as a result of rise in sea level as well as changes in tidal amplitude, sedimentation and erosion patterns.

Vegetational Changes

Spartina patens Community

The Spartina patens community occupied 65 - 80% of the total area on Headquarters Marsh in 1948 (Egler, personal communication). By 1976 the area had been reduced to 7%. Miller and Egler's (1950) observations on belting patterns were qualitative, but earlier reports substantiate their conclusions that Spartina patens and Juncus gerardi were the dominant species on the Wequetequock-Pawcatuck Marshes (Uhler 1932, State of Connecticut 1944, Smith 1946). In addition, analysis of peat cores (Niering et al., 1976) has shown that areas covered by forb panne communities in 1976 were dominated by Spartina patens until approximately 30 years ago.

The marked increase in the frequency of stunted Spartina alterniflora and Plantago maritima and a decrease in the frequency of Atriplex patula variety hastata and Salicornia europaea in the Spartina patens and Juncus gerardi communities may be indicative of significant changes in the physical environment on Headquarters Marsh.

Triglochin maritima and Plantago maritima occupy large expanses of Headquarters Marsh that were once Spartina patens communities. These species are often indicative of an environmental disturbance. The high concentration of Spartina patens and Juncus gerardi in the forb community on Headquarters may be residual and reflect the shifting belt patterns on this marsh.

Miller and Egler (1950) predicted that the Spartina patens community between the mosquito ditches would change into stands of another type of vegetation as a result of rectangular pools of standing water retained between the ditches after high tide. The forb pannes present on the marsh in 1948 were generally larger than 10^2 M and rectangular. The large number of forb pannes is an unusual feature on New England marshes. Blum (1968) reported only 2.9% of the Barnstable Marsh was covered by pannes and this figure included both forb and stunted Spartina alterniflora pannes. O'Connor and Orville (1972) do not list a forb association in their survey of Long Island marshes. The only forb mentioned was Salicornia europaea which occupied .3% of all Long Island marshes.

Lower Brucker was mowed by farmers until the 1940's when mowing became impossible due to changes in tidal patterns after the hurricane of 1938 (Gross 1966). Spartina patens, Distichlis spicata, and Juncus gerardi but not stunted Spartina alterniflora were used for mulch and fodder. Thus, even though Lower Brucker was predominantly stunted Spartina alterniflora in 1976 it is likely that this area contained extensive stands of Spartina patens until recently.

In addition, the number of species characteristic of dryer habitats and strong freshwater influence increased. Unlike 1948, when the community occupied large expanses in the middle of the marsh, the Spartina patens community of 1976 was restricted, primarily, to a narrow belt along the upland. It is more likely to receive seeds from the upland than areas of the belt located in the middle of the marsh.

Juncus gerardi Community

A sequence of photographs dating from 1932 - 1976 reveals changes in the belting pattern of the Juncus gerardi community on the levees of Headquarters Marsh. In the 1932 photograph, a distinct and wide vegetational belt is present on the eastern levee of Headquarters. On the western levee another large patch of vegetation extends toward the upland and occupies the area which corresponds to the upper Juncus gerardi belt described by Miller and Egler (1950). It is probable that these levee communities were Juncus gerardi because Miller (1948) reported that the Juncus gerardi areas often bordered the larger estuaries and were found landward of both the bay and cove. By 1951, the size of both belts was substantially smaller and the patterns of vegetational belting on Headquarters Marsh nearly identical to those of 1976. The Juncus gerardi community on Palmer Neck Marsh seems to have remained the same size. Although there are vestigial patches of Juncus gerardi on the Headquarters levees, most of the area is a combination of Distichlis spicata, forbs, stunted Spartina alterniflora and Spartina patens. The distinct zonation usually observed between the different marsh communities has broken down and there is often no dominant species in this area.

Although the frequency of Distichlis spicata has remained constant since 1948, the percent coverage of Distichlis spicata has shifted within the community. In 1976 the species was abundant in 68% of the quadrats as opposed to 50% in 1948 and Juncus gerardi is less frequently the sole dominant in a quadrat. Limonium carolinianum, Atriplex patula, variety hastata, Aster tenuifolius, Gerardia maritima, Salicornia europaea, Spartina patens and Iva frutescens seedlings have decreased while Spartina alterniflora and Plantago maritima have increased.

A substantial portion of the upper slope of Juncus gerardi community has disappeared and has been replaced with a forb panne community. A higher concentration of Juncus gerardi here than in the forb pannes between mosquito ditches was the only evidence that the Juncus gerardi belt had existed. The belt of forb panne fringes the entire length of the marsh including the Davis Marsh and the West Palmer Neck Marshes, neither of which has been impounded. The presence of forb pannes in the latter marshes suggests that the environmental changes resulting from the impoundments are not the major factor in the disappearance of the *Juncus gerardi* community.

Panicum virgatum Community

The position of the *Panicum virgatum* belt on Headquarters Marsh appears stable since 1948. However, the same community on Lower Brucker and Davis Marshes is shifting landward. Miller and Egler (1950) observed that the vegetation in the *Panicum virgatum* and *Juncus gerardi* communities along the seaward margin of Lower Brucker was scanty and in some areas absent. Numerous tussocks of dead *Panicum virgatum* were present. The areas that contained the dead *Panicum virgatum* tussocks were subject to surface erosion and there were usually areas 1 - 2 meters wide eroded below the *Panicum virgatum*. This phenomenon was also observed on Palmer Neck Marsh (Miller and Egler 1950) where *Distichlis spicata* was invading areas that had been subject to erosion. Miller and Egler (1950) concluded that as the *Panicum virgatum* community disappeared, *Triglochin maritima* and *Plantago maritima* would gradually become dominant. In 1948, no extensive forb panne community existed seaward of the *Panicum virgatum* community. In 1976, large areas of the *Panicum virgatum* and *Juncus gerardi* communities on Lower Brucker had been replaced by a forb or *Distichlis spicata* community as Miller and Egler (1950) had suggested.

Miller and Egler (1950) concluded that the "erosion" of these upper belts resulted from excessive mowing. However, a rise in sea level seems more probable. Large areas at the head of Davis Marsh which contained upland tree species 40 years ago now support a mixture of several shrubs and *Panicum virgatum*. The vegetation has been affected by a rise in sea level and is becoming part of the Wequetequock-Pawcatuck Tidal Marsh complex. The large forb panne is also evident seaward of the *Panicum virgatum* belt.

Causes of Vegetational Changes

It seems there is a general trend toward wetter conditions on northeastern marshes which may reflect a rise in sea level. The disappearance of the *Spartina patens* community on large portions of the marsh, the replacement of upper slope *Juncus gerardi* and *Panicum virgatum* communities by forb panne communities, and the declining frequency of several forbs within the *Juncus gerardi* belt tends to support evidence for trends toward increased inundation, higher soil moisture and higher salinity on the Wequetequock-Pawcatuck Marshes.

A reduction in the importance of *Spartina patens* on the marshes of Nassau and Suffolk Counties, New York, was also reported by the Nassau and Suffolk Regional Planning Board in 1972. A survey of 23 Long Island marshes in 1938 (Taylor 1939) revealed that *Spartina patens* was the dominant species and that *Juncus gerardi* was the second most abundant species. By 1972, *Spartina patens* composed only 16% of the total vegetation on Long Island marshes and *Juncus gerardi* covered only .3% of the marsh area. *Spartina alterniflora* was four times as extensive as *Spartina patens* representing 58% of the total marsh vegetation. Thus the relative amount of *Spartina alterniflora* (Short) has increased since 1938 while *Spartina patens* and *Juncus gerardi* decreased. The 1972 report concluded that changes in the vegetation were probably related to human destruction, because when a marsh is filled in, a larger proportion of high marsh vegetation is destroyed than low marsh vegetation. The same types of vegetation changes that were observed on the Long Island marshes are happening on the Wequetequock-Pawcatuck Marshes where no filling has occurred. Consequently, sea level rise may be a significant factor in zonation changes on both marshes.

Dowhan (1972) reports that in almost all areas of the Fire Island Marshes, Fire Island National Park, Patchague, New York, Spartina alterniflora tends to be moving landward into the Spartina patens zone. On Headquarters it is the Spartina patens, Juncus gerardi, and Panicum virgatum belts which are moving landward as opposed to the Spartina alterniflora belt. This migration is documented by photographs taken in both 1948 and 1976. Harrison (1975) has also noted a change from Spartina patens to Distichlis spicata on several of her study sites in Connecticut. Adams (1963) suggested that a reverse succession might be occurring on east coast marshes as coastal subsidence continued to be more rapid than marsh aggradation.

Effects of Increased Inundation on Plants

Artificial wetting experiments (Blum 1968) demonstrate that the protective mat beneath Spartina patens disintegrates as conditions become more moist. As the mat disintegrates the Spartina patens community becomes more vulnerable to invasion by seedlings of other species. Although mixed communities with two or three dominant species are not common on New England salt marshes, large portions of Headquarters have this type of community structure. Approximately 40.4% of Palmer Neck Marsh, 38% of Davis and 5.9% of Lower Brucker Marsh are covered by communities with two or more dominant species.

Clark and Hannon (1971) and Silander (1976) concluded that interspecific competition may have a profound effect on the distribution and zonation of species on salt marshes. Other studies on wetland and intertidal ecosystems also stress the importance of interspecific competition in the zonation of plant communities (Buttery and Lambert 1965, Dayton 1971, Dayton 1975). Interspecific competition may play a larger role where a dominant species such as Spartina patens is placed under physiological stress and its competitive ability reduced.

The amount of Spartina alterniflora in the Spartina patens community of Headquarters has doubled since 1948. In addition, 10% of Headquarters Marsh contains Spartina alterniflora/Spartina patens community. Because both the forb panne and stunted Spartina alterniflora communities contain substantial amounts of Spartina patens, it is likely that some of the communities represent transition stages from pure Spartina patens communities to those which are better adapted to wetter conditions and lower O_2 concentrations.

Vegetation types are correlated with the amount of soil oxygen available. Soil oxygen content increases as one progresses from pioneer communities into higher marsh communities (Chapman 1974). Numerous studies indicate that as soil becomes saturated the concentration of oxygen decreases rapidly and the rate at which oxygen diffuses through the soil decreases (Evans and Scott 1955, Takai et al. 1963, Turner and Partick 1968, Brereton 1972, Ponnamperuma 1972, Chapman 1974, and Woodfin 1976).

Stunted Spartina alterniflora is usually located on poorly drained portions of marshes with the lowest available oxygen (Teal and Kanwisher 1961, and Woodfin 1976). The soil under Spartina patens had an oxygen diffusion rate that was intermediate to that under Spartina alterniflora, which is flushed daily, and stunted Spartina alterniflora.

A dieback of Spartina patens community on the Wequetequock-Pawcatuck Marshes occurred in the late 1940's. The dieback was the result of water logging after a mosquito ditch became clogged. The water stood between several mosquito ditches until midsummer and as it evaporated it presumably created very high salinities. Although Miller and Egler (1950) attributed the loss of Spartina patens to salinity alone, it seems possible that low oxygen concentration may have also been a contributing factor. It seems probable that as inundation periods increase, the oxygen concentration in the soil of the Wequetequock-Pawcatuck Marshes may be decreasing and contributing to the reduction of some species.

Rozema and Blum (1977) observed that Juncus gerardi could withstand high salinities but died when subjected to long periods of inundation as a result of anaerobisis. A negative correlation between waterlogged soils with low oxygen concentrations and Salicornia europaea establishment (Brereton 1971) and survival of Atriplex patula (Rozema 1975) has also been noted.

Goodman and Williams (1960) studied a dieback of Spartina townsendii, a hybrid of Spartina alterniflora and Spartina maritima, as a result of waterlogging. They found no evidence that anaerobisis was the direct factor and suggested that the dieback might be the result of a toxic reduced ion. Although sulfide was not proven to be the ion involved, it was suspected. The stunting of Spartina alterniflora is related to the amount of hydrogen sulfide in the soil (Gardner 1973 , Nickerson personal communication). As oxygen decreases, the amount of hydrogen sulfide tends to increase. An increased flooding period coupled with a decrease in fresh water runoff after the impoundments were built may be contributing to higher levels of hydrogen sulfide and lower oxygen concentrations. It seems likely that Spartina patens is more sensitive than Spartina alterniflora to hydrogen sulfide and that it is this ion that is causing the reduction in the community's coverage. Large decreases of Salicornia europaea and Salicornia bigelovii may also be related to increased inundation.

Wiehe (1935) discovered that Salicornia europaea seedlings had a survival rate of 25% when located in a neap tide zone as opposed to 65% in the spring tide zone. In the former, the seedlings were inundated every 12 hours, whereas in the latter, inundation occurred only once every 1 - 15 days. Daily tides tend to drag the seedlings from their anchorage in the mud. Once the seedlings are established, there is tolerance to daily submergence, but there is a critical period when daily submergence lowers the survival rate. If longer inundation is occurring on the marsh, the decrease in Salicornia europaea may be directly correlated with less favorable conditions for seedling establishment.

Increased inundation may also be resulting in higher salinities on the marsh. Bourdeau and Adams (1956) found the salinity to be lowest under the Spartina patens community. Increasing the salinity may have given more salt tolerant species such as Spartina alterniflora and Distichlis spicata a competitive advantage. Iva frutescens seedlings, usually found in dryer, less saline conditions, have decreased since 1948 as has Limonium carolinianum. The latter has lower germination rates in highly saline conditions.

Causes of Increased Wetness

Mosquito Ditching

Miller and Egler (1950) suggested that mosquito ditching would permanently alter the vegetation on Headquarters. They believed two types of vegetation changes could occur: an increase in Iva frutescens stands and an increase in the number of pannes on the marsh.

In 1948, there were large stands of Iva frutescens between some mosquito ditches and Miller and Egler were concerned that this species would continue to spread over the marsh proper. By 1976, the large stands of Iva frutescens had disappeared and no distinct pattern of Iva frutescens colonization could be determined for other portions of the marsh. Iva frutescens occurs in dense stands along some ditches and is absent from large expanses of marsh. This pattern was also observed on the Fire Island Marshes in New York (Dowhan 1972). Whether or not the Iva frutescens invasion after mosquito ditching is permanent varies from marsh to marsh.

Miller and Egler (1950) also expressed concern over the possible damming effects of bank spoils and suggested that there would be an increase in the number of pannes on the Wequetequock-Pawcatuck Marshes.

In 1976, an extensive number of rectangular pannes existed between the ditches on these marshes. Dowhan (personal communication) has observed the same type of pannes on the Fire Island Salt Marshes in New York. He attributed the pannes to spoils which caused small impoundments.

Shisler (1973) also suggested that if the spoils from ditch excavation are placed along the edge of the ditch, the rate of water percolation and lateral water movement on the marsh might be affected, because compaction along the ditch edges might cause a damming effect and hold water between the ditches.

Most of the work done on the effects of marsh drainage and subsequent compaction and subsidence deals with deep drainage practices used in agriculture. The changes in the structure of the peat are a result of oxidation, settlement and shrinkage (Wier 1950, Stephens and Spier 1969, Zaidema 1975, Egglesman 1975, W. H. Van der Molen 1975). Subsidence varied between 1 - 30 cm within the first ten years after drainage and was a direct result of lowering the water table. As subsidence occurs, there is a decrease in the macropore space of the peat and the permeability decreases (Egglesman 1975). Thus, the marsh eventually becomes wetter. Mosquito ditches are not designed to lower the water table and consequently their effects on marsh soil are probably less than deep drainage. However, the effects on the hydrology of a marsh would depend on many factors including the depth of the ditches, and height of the water table.

The two papers which dealt with this topic came to different conclusions about the effects of ditching. Taylor (1939) dug pits on several marshes and concluded that the water table was unaffected by ditching and consequently one could expect little change in the vegetation. Bourne and Cottam (1950) concluded that the peat subsidence they observed was the consequence of a lowering of the water table. On Fire Island Marsh, New York, lowering of the water table was restricted to the first three meters adjacent to the ditch. The largest changes in both salinity and water table were within the first meter of the ditch. Dowhan (personal communication) concluded that the compaction may have been the result of increased mineral sedimentation resulting from more sediment-laden water flowing through the ditches as opposed to oxidation of the peat after spoils were discarded. The effects of mosquito ditching on a marsh's hydrology and consequently its vegetation are influenced by tidal regime, wind direction, wave action, substrate and the dominant type of vegetation on the marsh. Thus the effects of ditching must be evaluated for each individual marsh.

The panne areas between the mosquito ditches on Headquarters Marsh are probably not the direct result of the mosquito ditching, although the ditching may be aggravating the environmental conditions which favor this type of vegetation. The ditch bottoms are in peat not the basement sediment. Consequently it is unlikely that the water table was lowered substantially and subsidence of the peat is probably minimal. Harrison (1975) predicted that compaction on the Wequetequock-Pawcatuck Marshes would be small because of the sandiness and shallow depth of the sediments.

An increased tidal amplitude may have been initiated by the breach in the tombolo. Thus, by 1948 the high marsh may have been inundated more frequently and because the peat was perpetually saturated the water did not percolate as rapidly through the soil. Slight compaction along the ditch edges may have further slowed lateral percolation and caused the water between the ditches observed by Miller and Egler (1950). It is likely that the longer inundation periods had already begun to affect the distribution of the Spartina patens in 1948, but because of a time lag between environmental disturbance and change the effects may not have been noticeable.

If the spit had not broken and wave dynamics changed, it is likely that the ditches may have served to make the marsh dryer. Several studies indicate that ditching has this effect. Smith (1907) noted an increase in the lushness of Spartina patens after ditching on a New Jersey marsh. Britton et al. (1915) studied a marsh in East Haven, Connecticut. Initially, there was a drying phase and the area covered by Spartina patens increased by 29% between 1912 and 1915. The Spartina patens moved into areas formerly occupied by Distichlis spicata which is associated with wetter areas on marshes. Unfortunately, no follow up study was made, but the study by Britton et al. (1915) demonstrated that changes after ditching may be rapid. The preliminary report of marsh inspections in Connecticut (1944) indicated that a drying trend occurred on the Wequetequock-Pawcatuck Marshes after ditching. Spartina patens extended into areas formerly occupied by Spartina alterniflora and Distichlis spicata. Panicum virgatum was also reported to be extending into areas occupied by Spartina patens.

It is difficult to determine whether the large percentage of Spartina patens on the marshes prior to the 1940's was the result of man's tamperings with the tidal marsh since colonial days or was natural.

The presence of numerous colonial ditches on the Wequetequock-Pawcatuck Marshes strongly suggested that the farmers were draining the marshes to produce favorable conditions for Spartina patens and Juncus gerardi, both of which were used as mulch and fodder. It is probable that low sedimentation rates have always created wet spots on the Wequetequock-Pawcatuck Marshes. Peat cores (Niering et al. 1976) reveal that a portion of Headquarters Marsh containing stunted Spartina alterniflora stands in 1976 had this association long before mosquito ditches were introduced. Farmers may have drained this area to improve grazing conditions.

Portions of Davis Marsh have never supported stands of Spartina patens (John W. Davis personal communication). The western section of the marsh contained a panne covered by scum prior to mosquito ditching. After the area was mosquito ditched, stunted Spartina alterniflora began to colonize the panne. There are roots of trees protruding into the small colonial channel on Davis Marsh, 30 cm down. This suggests that the area has been changing from an upland vegetation into a salt marsh. It is possible that the vegetation of Davis Marsh was more influenced by freshwater influxes in the early 1700's. The colonial ditches drained the marsh, but in addition they also decreased the amount of fresh water running onto Lower Davis. As the sea level continued to rise, the increase in wetness and in salinity may have made it difficult for either fresh or salt water species to survive.

This may explain the large algal panne noted by the farmers. Yet it seems certain that some of the drainage alteration resulted in more favorable, thus dryer, mowing conditions.

Impoundments and Sedimentation Rates

Five of the six tidal creeks entering the Wequetequock-Pawcatuck Marshes were impounded between 1948 and 1968. Some local residents and ecologists familiar with the area feel that the impoundments are impeding upland sediment from reaching the marsh (Niering personal communication). While I agree that any sediment which was carried by these tidal creeks onto the marsh surface has effectively been halted, the amount of sediment contributed by these tidal creeks was probably negligible in the growth of the Wequetequock-Pawcatuck tidal marshes. The total drainage area onto the marsh from these creeks is approximately 1.5 sq. miles. In addition, the streams are so small and the topography of the area so flat that the stream flow and velocity of the creeks are probably too slow to pick up significant amounts of sediment. Because these streams originate in swampy areas, erosion as a result of runoff is probably minimal.

In addition, Eastern Connecticut is in an area where most of the glacial till has already been eroded away. Chapman (1974) and Ellis (1962) observed that the rocky upland of New England, which is predominatly granite, results in less silt being available for sedimentation. Only near the Connecticut River, where pleistocene lacustrine deposits are actively being eroded, is the amount of silt available for marshes abundant.

It is likely that the major source of upland sediment is the Pawcatuck River which empties into Little Narragansett Bay. The river has a drainage basin of $303M^2$ (U.S. Geological Survey 1976). Data on sediment discharge from the Pawcatuck River (tons/day) has been taken sporadically. No sediment discharge readings were made at the Pawcatuck station and data is for the Wood River Station near Arcadia, Rhode Island, between the years 1964-1973. The sediment load of this river is low, varying between 1 ton per day and 3-4 tons per day during the spring, as opposed to the Connecticut River near New Haven, which discharges 3300 tons of sediment per day (U.S. Geological Survey 1976). It is probable that sedimentation rates have always been low on the Wequetequock-Pawcatuck Marshes and that changes in sedimentation rates are not major factors in vegetation changes.

The impoundments reduced the sources of freshwater by changing both runoff and percolation patterns. The fresh water flow from the unimpounded creeks would tend to push the salt wedge seaward. A decrease in the freshwater flow would increase mixing of water in Little Narragansett Bay and increase the salinity. Consequently, the estuary became more saline further landward and allowed plants such as Spartina alterniflora and Distichlis spicata to move into areas previously occupied by Spartina patens, Juncus gerardi and sedges, which are maintained by freshwater influxes. This change in salinity has undoubtedly contributed to changes in the types of plants and zonation patterns in the marsh.

Rise in Sea Level

Submergence of the Connecticut coastline occurred at a rate of 2.6 mm per year between 1940-1972 (Hicks and Crosby 1974). A study of Connecticut tidal marshes by Harrison (1975) indicated that all the marshes studied except the Wequetequock-Pawcatuck Marshes, were able to aggrade more rapidly than sea level rose. The sedimentation rate of the Wequetequock-Pawcatuck Marshes is 2 mm per year. Thus, submergence should be 6 mm over a decade. Harrison (1975) reported that the Wequetequock-Pawcatuck Marshes submerged 8 mm between 1963-1974. During this time period, sea level rose in Connecticut at an abnormal rate of 1 cm per year and is probably responsible for increased submergence. This rapid rise in sea level may be related to an 18.6 year lunar nodal cycle (Kaye and Stucky 1973). It is probable that zonation changes are related to sea level change.

Effects of Hurricane of 1938

Prior to the 1938 hurricane, the Pawcatuck River flowed into Little Narragansett Bay, which was protected from both Fisher Island Sound and Block Island Sound by the Napatree Tombolo and had only one opening to Fisher Island Sound, to the west of the marshes. Any sediment being carried into the bay would be channeled toward the Wequetequock-Pawcatuck Marshes due to the Coriolis effect and deposited. In addition, a large amount of fresh water was introduced to the bay. Some of the sediment was washed out to the sound via the opening on the west. However, with minimal wave and current action the majority of the sediment probably settled out prior to being carried to sea.

Overwash during the hurricane of 1938 caused several breaks in the tombolo. One was repaired immediately by the town of Watch Hill. However, the break on the western end of the tombolo was never repaired. The resultant sand island, Sandy Point, has drifted approximately a mile toward the Connecticut coast between 1938 and 1976. The break has caused several alterations which might be contributing to the vegetational changes observed on Headquarters Marsh. Tidal deltas have developed near the breach in the tombolo and at the mouth of the Pawcatuck River. The deltas changed the pattern of water flow and velocity and may have increased the amount of incoming sediment available to the Wequetequock-Pawcatuck Marshes. Yet other changes occurred which would tend to negate the effect of increased sediment. The tidal delta forming in the tombolo breach tended to move more sediment into the bay. As Little Narragansett filled in, its volume became smaller and the excess water was probably displaced landward. This increased the tidal amplitude and probably pushed both the high and low tide levels to higher points on the marsh.

In addition, after the breach, the influence of water movement in Block Island Sound on water movement within Little Narragansett Bay increased. This factor also increased tidal amplitude and wave action. The fetch in Little Narragansett Bay is still quite short so little bank erosion is occurring. Yet, if the tidal amplitude has increased even slightly, the water would regularly reach parts of the marsh which were previously inundated only under spring tide and storm conditions. The fact that the middle portions of Headquarters and

Lower Brucker Marshes were always inundated by the high tides during the summer of 1976 seems to support this hypothesis.

The energy of the waves which might not have been sufficient to erode banks may have caused surface erosion, which may in part explain the disappearance of large levees along the edge of Headquarters. It is probable that the change in tidal patterns observed by the farmers on Lower Brucker in the 1940's was due to increased tidal amplitude which caused areas not regularly covered by water to become wetter. One would not need to decrease the amount of sediment load in order to create the submergence phenomenon observed by Harrison (1975). In essence, as one increases the surface erosion the marsh is being drowned. As Sandy Point drifts further toward the Connecticut shore, it is probable that tidal amplitude and surface erosion will increase and consequently the submergence will become more pronounced. The presence of the impoundments might aggravate surface erosion because the energy of the water cannot be dissipated over as large an area as before. Instead, the water hits the impoundments and sits on the front marshes. This may be causing the extensive erosion noticed in front of some impoundments.

In addition, there may be some leakage of sediment from the Pawcatuck River into Block Island Sound through the Breach. This means that some of the potential upland sediment may be lost directly into the Sound before reaching the Wequetequock-Pawcatuck Marshes. The low rate of sedimentation on Aster Marsh in England was the result of the position of the marsh in relation to the silt supply (Chapman

1974). The high rate at which the sea has been rising between 1963-1974 has likely aggravated the increase in tidal amplitude.

There must have been a dramatic increase in the salinity of the bay when the tombolo broke open, and more salt water from Block Island and Fisher Island Sound mixed with the bay water. Salinity increased further after the impoundments were constructed. Increased salinity may be an important factor in zonation changes.

The differences in the vegetation on the eastern and western portions of the Wequetequock-Pawcatuck Marshes may be attributed to the position of the breaks in the tombolo. The breach in the tombolo occurred directly opposite Barn Island. When the breach was small the effects of increased tidal amplitude probably centered on the eastern portions of the Wequetequock-Pawcatuck Marshes. This may explain the extensive erosion in the Panicum virgatum community observed by Miller and Egler in 1948.

Thus, the farmers were forced to abandon mowing on Lower Brucker in the early 1940's. It is likely vegetational changes in Lower Brucker proceeded more rapidly than on Headquarters Marsh. Even in 1976, the eastern portions of the Wequetequock-Pawcatuck marsh complex are wetter than the western portions.

Some vegetation changes may be the result of rise in sea level. The rapid rise in sea level during the last decade may be accelerating this change and may account for changes in the Juncus gerardi community on West Palmer Neck Marsh. However, I feel that the breach in the Napatree Spit accelerated vegetational changes which were destined to occur as sea level continued to rise. This may explain the large proportion of Lower Brucker covered by stunted *Spartina alterniflora* stands.

Miller and Egler (1950) did their study only ten years after the break occurred and it is likely that changes due to the breach and rise in sea level were not apparent on Headquarters. In addition, the mean high tide was considerably lower when Miller and Egler (1950) examined the marsh, the 18.6 lunar node cycle being at its low point in 1949. Consequently, one would expect the salt water wedge to be pushed seaward and more high marsh communities to be present. Second, the sea level was not rising at the anamolous rate it has been in the last decade which would tend to push low marsh plants onto higher portions of the marsh. As Sandy Point drifted further from Napatree Tombolo, and rate of sea level rise increased, hydrological and vegetational changes in Headquarters were probably accelerated. In addition, the effects of the impoundments on salinity were probably not apparent because they had just been constructed in 1948.

SUMMARY

Numerous vegetational changes have occurred on Headquarters Marsh since the 1948 study by Miller and Egler. The position of several communities has shifted. The upper slope Juncus gerardi community has disappeared and has been replaced by a forb panne community. A substantial portion of the lower slope Juncus gerardi community has been supplanted by a mosaic of forbs, Distichlis spicata and Spartina alterniflora. The percent area covered by the Spartina patens community has decreased and photographs reveal that this community has migrated several meters landward. Extensive forb panne communities occupy areas between the mosquito ditches on both Headquarters and Palmer Neck Marshes, which were previously Spartina patens communities. On Lower Brucker Marsh, areas believed to have been predominately Spartina patens now contain stunted Spartina alterniflora. The Panicum virgatum and Juncus gerardi communities of Lower Brucker, Davis, and West Palmer Neck Marshes are eroding and have been replaced with forb and Distichlis spicata communities.

The community structure of various communities is also changing. The amount of Spartina alterniflora in the Spartina patens community has doubled. The percent coverage of Distichlis spicata, Spartina alterniflora, and Plantago maritima has increased dramatically whereas Iva frutescens, Limonium carolinianum, Atriplex patula variety hastata, and Gerardia maritima have decreased. The percent coverage of Salicornia europaea and Salicornia bigelovii have decreased in all communities except the Spartina alterniflora community. A trend

toward wetter conditions on the marsh appears to be the major factor contributing to the shift in community zonation and species distribution. Several hypotheses were suggested for this increased wetness. Sea level has been rising continuously since the end of glaciation. In addition the sea level has been rising at an abnormally rapid rate of 1 cm per year in the last decade. This anomalous rate may be the result of an 18.6 year lunar node cycle. In addition the water dynamics in Little Narragansett Bay probably changed dramatically after the Napatree Spit was broken into two pieces by the 1938 hurricane. Wave amplitude was increased as a result of greater influence by the water movement in Block Island Sound. As tidal deltas formed near the breaches, Little Narragansett Bay began to fill with sediment more rapidly, decreasing the volume of the bay and displacing water landward. Tidal amplitude was probably increased as a consequence of both these factors. Even a slight increase in the tidal amplitude would result in both the high and low tides moving landward. This resulted in the more frequent inundation of parts of the marsh which were never previously inundated regularly and probably resulted in increased surface erosion. Some upland sediment may be leaking through the break in the spit.

After the break in Napatree tombolo occurred, the salinity in the bay increased dramatically. Salinity became higher after the construction of five impoundments between 1948-1968. As the amount of fresh water flow into the bay decreased, mixing of fresh water and bay water increased, and consequently the bay became more saline. The soil salinity on the marsh would also tend to increase. This allowed species such as Distichlis spicata, Spartina alterniflora, and forbs to move landward. Slight compaction along mosquito ditch edges, which slows down lateral percolation on the marsh, may also be contributing to increased wetness and zonation changes.

LITERATURE CITED

Adams, D. A. 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. Ecol. Monogr. 44:445-456.

Bourdeau, P. F. and D. A. Adams. 1956. Factors in vegetational zonation of salt marshes near Southport, North Carolina. Bull. Ecol. Soc. Amer. 37:68.

Bishop, James S. 1963. Memo Connecticut State Board of Fisheries and Game. Hartford, Connecticut.

Bishop, James S. 1971. Interdepartmental memo. Connecticut State Board of Fisheries and Game. Barn Island Wildlife Management Area.

Bloom, Arthur L. and Charles W. Ellis, Jr. 1965. Post Glacial Staigraphy and Morphology of Coastal Connecticut. State Geological and Natural Survey of Connecticut Guidebook #1.

Blum, J. L. 1968. Salt marsh Spartinas and associated algae. Ecol. Monogr. 38:200-221.

Botsford, R. C. 1930. Mosquito control in Connecticut 1930. Connecticut Agricultural Experiment Station Report. 54:67-72.

Bourne, W. S. and C. Cottam. 1950. Some biological effects of ditching tidewater marshes. Research Report #19. Fish and Wildlife Service, U.S. Department of the Interior.

Brereton, A. J. 1971. The structure of the species populations in the initial stages of salt marsh succession. J. of Ecology 59:2.

Britton, W. E.; B. H. Walden and P. O. Buttrick. 1915. Changes in the vegetation of salt marshes resulting from ditching. Report of the Connecticut Agricultural Experiment Station. New Haven, Ct. pp. 172-79.

Bromley, S. W. 1935. The original forest types of southern New England. Ecol. Monographs 5:61-89.

Brumbauch, Joseph J. 1965. Climate of Connecticut. State Geological and Natural History Survey of Connecticut. Bulletin 99. 215 pp.

Buckman, Harry O. and Hyle C. Brady. 1969. The Nature and Properties of Soils. 7th edition. McMillan Company. New York, NY.

Buttery, B. R. and J. M. Lambert. 1965. Competition between Glyceria maxima and Phragmites communis in the region of Surlington Broad. I. The competition mechanism. J. Ecol. 53:163-81.

Chapman, V. J. 1938. Studies in salt marsh ecology. Sections I - III. Journal of Ecology 26:144-179.

Chapman, V. J. 1939. Studies in salt marsh ecology. Sections IV - V. Journal of Ecology 27:160-201.

Chapman, V. J. 1941. Studies in salt marsh ecology. Section VIII. Journal of Ecology 29:69-82.

Chapman, V. J. 1974. Salt Marshes and Salt Deserts of the World. 2nd edition. Cramer Lehre.

Clark, L. D. and N. J. Hannon. 1971. The Mangrove Swamp and salt marsh communities of the Sidney District. IV. The significance of species interactions. J. Ecol. 59:535-553.

Connecticut State Board of Fisheries and Game. 1944. Preliminary Report on the Barn Island Project. Stonington, Connecticut; Hartford, Connecticut.

Conrad, H. S. 1924. Second survey of the vegetation of Long Island salt marsh. Ecology 5:379-388.

Conrad, H. S. 1935. The plant associations of Long Island. American Midland Naturalist 16:433-516.

Conrad, H. S. and G. C. Galligar. 1929. Third survey of a Long Island salt marsh. Ecology 10:326-36.

Crandall, Katharine B. 1975. The Fine Old Town of Stonington. The Book and Tackle Shop. Watch Hill, Rhode Island. 151 pp.

Day, G. M. 1953. The Indian as an ecological factor in the northeastern forest. Ecol. 34:329-346.

Dayton, P. K. 1971. Competition, disturbance and community organization: the provision and subsequent utilization of space in a rocky intertidal community. Ecol. Monogr. 351-389.

Dayton, P. K. 1975. Experimental evaluation of ecological dominance in a rocky intertidal algal community. Ecol. Monogr. 45:135-59.

Davis, Charles A. 1910. Salt marsh formation near Boston and its significance. Econ. Geology 5:623-39.

Dowhan, Joseph J. 1972. Preliminary report on the ecology of salt marshes and effects of mosquito control in Fire Island National Seashore. Progress report on Fire Island National Seashore salt marsh survey. 100 pp.

Egglesman, R. 1975. Physical effects of drainage in peat soils of the temperate zone and their forecasting. In Hydrology of marsh ridden areas. Proceedings of the Mirisk Symposium, June 1972. The UNESCO Press. IAHS - Paris. pp. 69-76.

Ellis, C. W. 1962. Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut. Connecticut State Geological and Nat. History Survey Bull. 94. 89 pp.

Emery, K. O. and Uchupi, E. 1972. Western North Atlantic Ocean: topography, rocks, structure, water life, and sediments. Tulsa, Okla., American Assoc. Petrol. Geol. 532 pp.

Evans, D. D. and A. D. Scott. 1955. A polygraphic method of measuring dissolved oxygen in saturated soils. Soil Sci. Society Amer. Proc. 19:12-16.

Fernald, Merritt Lyndon. 1950. Grays Manual of Botany. 8th edition. American Book Company. New York. 1632 pp.

Gardner, L. R. 1973. The effect of hydrological factors on pore water chemistry of intertidal marsh sediments. Southeastern Geol. 15: 17-28.

Gleason, Henry A. and Arthur Cronquist. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Van Nostrand Reinhold Company. New York. 810 pp.

Goldsmith, Richard and H. R. Dixson. 1968. Bedrock geology of eastern Connecticut. From Guidebook for Field Trips in Connectucut. New England Intercollegiate Geological Conference 60th annual meeting. New Haven, CT. October 25-27, 1968. State Geological and Natural History.

Good, R. E. 1965. Salt marsh vegetation, Cape May, New Jersey. Bull. N. J. Acad. Sci. 10(1):1-11.

Goodman, P. J. 1960. Investigations into "die-back" in Spartina townsendii agg II. J. Ecology 48:711-724.

Goodman, P. J. and W. J. Williams. 1961. Investigations into die-back in Spartina townsendii agg III. J. Ecol. 49:391-98.

Gross, A. C. 1966. Vegetation of the Brucker Marsh and the Barn Island Natural Area, Stonington, CT. Unpublished masters thesis, Connecticut College, New London.

Harrison, Ellen Z. 1975. Sedimentation rates, shoreline modification and vegetation changes on tidal marshes along the coast of Connecticut. Unpublished masters thesis, Cornell University, Ithaca, NY. 107 pp.

Hicks, S. D. 1972. On the classification and trends of long period sea level series. Shore and Beach 40(1):20-23.

Hicks, S. D. and J. E. Crosby. 1974. Trends and variability in mean sea level, 1893-1972. Nat. Oc. and Atmos. Admin. Tech. Memo. Nat. Oc. Survey 13. Rockville, MD.

Hill, David E. and Arthur E. Shearin. 1970. Tidal marshes of Connecticut and Rhode Island. Connecticut Agricultural Experiment Station. New Haven, CT. Bulletin 709.

Johnson, D. W. 1925. The New England-Acadian Shoreline. John Wiley and Sons, Inc. New York, NY. 608 pp.

Johnson, D. S. and H. H. York. 1915. The relation of plants to tide levels. Carnegie Institute of Washington. Publication #206.

Kaye, G. A. and C. W. Stucky. 1973. Nodal tidal cycle of 18.6 years. Geology 1:141-44.

Kerwin, J. A. and R. A. Pedigo. 1971. Synecology of a Virginia salt marsh. Chesapeake Science 12:125-30.

Knight, J. S. 1935. A salt marsh study. American Journal of Science 28:161-81.

Martin, Chester W. 1964. Barn Island. Conn. Woodlands 29:7-11.

Mead, R. H. and K. O. Emery. 1971. Sea level as affected by river runoff, eastern United States. Science 173:425-28.

Miller, W. R. 1948. Some aspects of waterfowl management on the Barn Island shooting area. University of Connecticut. Unpublished masters thesis. 293 pp.

Miller, W. R. and F. E. Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal marshes. Conn. Ecological Monogr. 20:143-72.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons. New York, NY.

Nichols, G. E. 1929. Vegetation of Connecticut VIII. The associations of depositing areas along the sea coast. Bull. Torrey Bot. Club 47:511-48.

Nichols, Robert L. and Alwyn F. Marston. 1939. Shoreline changes in Rhode Island produced by hurricane of September 21, 1938. Bulletin of the Geological Society of America 50:1357-70.

Niering, William A.; R. Scott Warren and Carolyn G. Weymouth. 1977. Our dynamic tidal marshes vegetation changes as revealed by peat analysis. Bulletin No. 22. The Connecticut Arboretum. Connecticut College. New London, Connecticut. 12 pp.

O'Connor, Joel S. and Orville W. Terry. 1972. The marine wetlands of Nassau and Suffolk Counties, New York. Marine Sciences Research Center. State University of New York at Stony Brook. 32 pp.

Oosting, Henry J. 1956. The Study of Plant Communities. 2nd edition. Freeman. San Francisco. 389 pp.

Ponnamperuma, F. N. 1972. In Soil Chemistry. J. Bremner and G. Chesters, ed. Dekkev. New York.

Redfield, Alfred C. 1972. Development of a New England salt marsh. Ecological Monographs 42:201-57.

Rozema, J. (1975a). The influence of salinity, inundation and germination of some halophytes and non-halophytes. Oecologia Pl. 10, 341-53.

Rozema, J. and B. Blom. 1977. Effects of salinity and inundation on the growth of Agrostis stolonifera and Juncus gerardi. J. Ecol. 65:213-22.

Sakalowsky, P. P., Jr. 1975. Beach morphology and near shore processes on a sheltered beach - the case of Napatree Beach, Rhode Island. Mar. Geol. 18:M35-M43.

Shisler, Joseph K. 1973. Pioneer plants on spoil piles associated with mosquito ditching. In proceedings of the 60th annual meeting of the New Jersey Mosquito Extermination Association. pp. 135-41.

Silander, John August. 1976. The genetic basis of the ecological amplitude of Spartina patens on the outer banks of North Carolina. Doctoral dissertation. Department of Botany. Duke University, Durham, North Carolina.

Smith, Allen F. 1946. Progress report on the Barn Island Project - Stonington, Connecticut. Memo Connecticut State Board of Fisheries and Game, Hartford, CT.

Smith, J. B. 1907. A New Jersey salt marsh and its improvement. New Jersey Agricultural Experiment Station Bulletin 207.

Spignolia, J. J. 1968. Comparative plant ecology, Jones Salt Marsh, Cold Spring Harbor, Long Island, New York. Unpublished masters thesis. Long Island University. Brookville, NY.

Steever, E. Z. 1972. Productivity and vegetation studies of a tidal salt marsh in Stonington, Connecticut: Cottrell Marsh. Masters thesis. Connecticut College, New London.

Stephens, John C. and William H. Spier. 1969. Subsidence of organic soils in the U.S.A. Studies and reports in hydrology land subsidence. Proceedings of the Tokyo Symposium. IASH/AIHI UNESCO Vol. 2.

Stonington Land Records Vol. 7. Deed John Palmer to James Noyes, Dec. 15, 1767.

Stonington Land Records Vol. 7. Deed John Palmer to James Noyes, Jan. 5, 1957. pp. 26-7.

Stonington Land Records Vol. 8. Andrew Stanton to Nathan Stanton, Dec. 7, 1776. p. 231.

Stonington Land Records Vol. 29. Nathaniel S. Babcock to Warren C. and Henry C. Randall. p. 357.

Taki, Yasuo, Tadashiro Kuyama and Takao Kamura. 1963. Microbial metabolism in the reduction process of paddy soils (part 2). Soil Science and Plant Nutrition. Vol. 9(5):10-14.

Taylor, Norman. 1938. A preliminary report on the salt marsh vegetation of Long Island, New York. New York State Museum Bulletin. 316:21-84.

Taylor, Norman. 1939. Salt tolerance of Long Island salt marsh plants. New York State Museum Circ. 42 pp.

Teal, J. M. and J. Kanwisher. 1961. Gas exchange in a Georgia salt marsh. Limnology and Oceanography 6:388-99.

Turner, F. T. and W. H. Patrick, Jr. 1968. Chemical changes in water-logged soils as a result of oxygen depletion. Trans. Int. Congr. Soil Sci. 9th. 1968. Vol. 4. pp. 53-65.

Uhler, F. M. 1932. Report on an examination of certain water fowl feeding and breeding grouds in Connecticut, August 2 to 5, 1932. Report. Connecticut State Board of Fisheries and Game.

U.S. Geological Survey. 1976. Water resources data for connecticut water year 1976. Hartford, Connecticut. 449 pp.

Van der Molen, W. H. 1975. Subsidence of peat soils after drainage. In Hydrology of marsh ridden areas. Proceedings of the Minsk Symposium, June 1972. The UNESCO Press. IAHS - Paris. p. 183.

Wedmore, Joan. 1970. A population study of the blue crab, *Callinectes sapidus* and the soft shell clam, *Mya arenaria* in the estuary of the Barn Island Management Area, Stonington Connecticut. Unpublished student paper. Eastern Connecticut State College.

Wheeler, Grace Denison. 1903. The Home of our Ancestors in Stonington Connecticut. Newcomb and Gauss. Salem Massachusetts.

Wiehe, P. O. 1935. A quantitative study of the influence of the tide upon populations of *Salicornia europaea*. Journal of Ecology 23: 323-33.

Wier, W. W. 1950. Subsidence of peatlands of the Sacramento-San Joaquin Delta, California. Hilgardia 20:37-56.

Woodfin, Frances Shannon. 1976. Soil oxygen diffusion and photosynthetic rates of *Spartina* in Connecticut salt marshes. Unpublished masters thesis. Connecticut College, New London, CT.

Zaidema, F. C. 1975. The transformation of the hydrological regime of marsh ridden areas by land reclamation and forecasting its influence on hydrometeorological conditions with reference to the Netherlands. Hydrology of marsh ridden areas. Proceedings of the Minsk Symposium. The UNESCO Press. IAHS - Paris 1975. pp. 387-413.

APPENDIX

Species list of the observed ferns and flowering plants of the Wequetequock-Pawcatuck Marshes, Stonington, Connecticut. The community in which the species is found most often is included.

PTERIDOPHYTA. VASCULAR CRYPTOGAMS.

Polypodiaceae. Fern Family.

Osmunda cinnamomea L. *Panicum virgatum* Community; rare.

Onoclea sensibilis L. Sensitive Fern. *Panicum virgatum* Community; rare.

Dryopteris thelypteris (L.) Gray. Marsh Fern. *Panicum virgatum* Community; occasional.

Dryopteris noveboracensis (L.) Gray. New York Fern. *Panicum virgatum* Community; rare.

Dryopteris spinulosa (O.F. Muell.) Watt. Spinulose Wood Fern. *Panicum virgatum* Community; rare.

SPERMATOPHYTA. SEED PLANTS.

Gymnospermae.

Pinaceae. Pine Family.

Juniperus virginiana L. Red cedar. *Panicum virgatum* Community; rare.

Angiospermae
Monotyledoneae

Zosteraceae

Zostera marina L. Eelgrass. Bay; abundant.

Ruppia maritima L. Ditchgrass. Tidal creek; rare.

Juncaginaceae. Arrowgrass Family.

Triglochin maritima L. Arrow Grass. Forb panne Community; abundant.

Gramineae. Grass Family.

Festuca rubra L. Fescue Grass. *Panicum virgatum* Community; rare.

Glyceria canadensis (Michx.) Trin. Rattlesnake Grass. Panicum virgatum Community; rare.

Distichlis spicata (L.) Greene. Spike Grass. Distichlis spicata Community; abundant.

Phragmites communis Trin. Reed. Banks of the impoundments and on spoils; rare.

Elymus virginicus L. Terrel Grass. Panicum virgatum Community; rare.

Ammophila breviligulata Fern. Dunes; abundant.

Agrostis alba L. Redtop. Panicum virgatum Community; occasional.

Spartina pectinata Link. Freshwater Cord Grass. Panicum virgatum Community; occasional.

Spartina alterniflora Loisel. Saltwater Cord Grass. Spartina alterniflora Community; abundant.

Spartina patens (Ait.) Muhl. Salt Meadow Grass. Spartina patens Community; abundant.

Pharlaris arundinaceae L. Canary Grass. Panicum virgatum Community; rare.

Hierochloe odorata (L.) Beauv. Sweetgrass. Panicum virgatum Community; rare.

Panicum virgatum L. Panicum virgatum Community; rare.

Panicum meridionale Ashe. Panicum virgatum Community; rare.

Panicum clandestinum L. Panicum virgatum Community; rare.

Panicum spp. Panicum virgatum Community; rare.

Echinochloa crusgalli (L.) Beauv. Barnyard Grass. Panicum virgatum Community; rare.

Setaria glauca (L.) Beauv. Foxtail. Panicum virgatum Community; rare.

Cyperaceae. Sedge Family.

Cyperus filicinus Vahl. Panicum virgatum Community; rare.

Cyperus strigosus (L.) Lean. Panicum virgatum Community; rare.

Eleocharis rostellata Torr. Panicum virgatum Community; rare.

Cladium mariscoides (Muhl.) Torr. Panicum virgatum Community; rare.

Scirpus americanus Pers. (American) Spartina patens Community; rare.

Scirpus acutus Muhl. Panicum virgatum Community; rare.

Carex spp. Panicum virgatum Community; rare.

Juncaceae. Rush Family.

Juncus gerardi Loisel. Juncus gerardi Community; abundant.

Juncus tenuis Willd. Panicum virgatum Community; rare.

Lilliaceae. Lilly Family.

Asparagus officinalis L. Asparagus. Panicum virgatum Community; rare.

Smilax rotundifolia L. Common Greenbriar. Panicum virgatum Community; rare.

Dicotyledoneae

Salicaceae. Willow Family.

Populus tremuloides Michx. Quaking Aspen. Panicum virgatum Community;

Myricaceae. Wax Myrtle Family.

Myrica pensylvanica Loisel. Bay Berry. Panicum virgatum Community; rare.

Comptonia peregrina (L.) Coult. Sweet Fern. Panicum virgatum Community; rare.

Fagaceae. Beech Family.

Quercus alba L. White Oak. Panicum virgatum Community; rare.

Quercus bicolor Wild. Swamp White Oak. Panicum virgatum Community; rare.

Quercus velutina Lam. Black Oak. Panicum virgatum Community; rare.

Polygonaceae. Buckwheat Family.

Rumex acetosella L. Sheep Sorrel. Panicum virgatum Community; rare.

Chenopodiaceae. Goosefoot Family.

Atriplex patula var. hastata. (L.) Gray. Juncus gerardi Community; rare.

Salicornia bigelovii Torr. Dwarf Saltwort. Forb panne Community; occasional.

Salicornia europaea L. Samphire. Forb panne community; abundant.

Sueda linearis (Ell.) Moq. Near dunes; rare.

Caryophyllaceae. Pink Family.

Spergularia canadensis (Per.) Don. Forb panne Community; rare.

Spergularia marina (L.) Griseb. Forb panne Community; rare.

Ranunculaceae. Crowfoot Family.

Thalictrum polygamum Muhl. *Panicum virgatum* Community; rare.

Rosaceae. Rose Family.

Spiraea tomentosa L. Steeple Bush. *Panicum virgatum* Community; rare.

Prunus serotina Ehrh. Black Cherry. *Panicum virgatum* Community; rare.

Potentilla anserina L. Black Cherry. *Panicum virgatum* Community; rare.

Rubus spp. L. *Panicum virgatum* Community; rare.

Rosa carolina L. *Panicum virgatum* Community; occasional.

Pyrus malus L. Apple. *Panicum virgatum* Community; rare.

Leguminosae. Pulse Family.

Trifolium pratense L. Red Clover. *Panicum virgatum* Community; rare.

Trifolium repens L. White Clover. *Panicum virgatum* Community; rare.

Lathurus maritimus Willd. Sand dunes; occasional.

Anacardiaceae. Cashew Family.

Rhus radicans L. *Panicum virgatum* Community; occasional.

Celatraceae. Staff-Tree Family.

Celastrus scandens L. Climbing Bittersweet. *Panicum virgatum* Community; rare.

Aceraceae. Maple Family.

Acer rubrum L. Red Maple. *Panicum virgatum* Community; rare.

Vitaceae. Vine Family.

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper. Panicum virgatum Community; rare.

Malvaceae. Mallow Family.

Hibiscus moscheutos L. Swamp Rose. Panicum virgatum Community; rare.

Guttiferae. St. Johnswort Family.

Hypericum perforatum L. Common St. Johnswort. Panicum virgatum Community; rare.

Hypericum virginicum L. Marsh St. Johnswort. Panicum virgatum Community; rare.

Violaceae. Violet Family.

Viola spp. L. Panicum virgatum Community; rare.

Nyssaceae. Sour Gum Family.

Nyssa sylvatica Marsh. Panicum virgatum Community; rare.

Umbelliferae. Parsley Family.

Cryptotaenia canadensis (L.) DC. (Canadian) Panicum virgatum Community; rare.

Ptilimnium capillaceum (Michx.) Kaf. Panicum virgatum Community; rare.

Coelopleurm lucidum (L.) Fern. Panicum virgatum Community; rare.

Daucus carota L. Wild Carrot. Panicum virgatum Community; rare.

Ericaceae. Heath Family.

Vaccinium corymbosum L. Highbush Blueberry. Panicum virgatum Community; rare.

Plumbaginaceae. Leadwort Family.

Limonium carolinianum (Walt.) Britt. Forb panne Community; occasional.

Convolvulaceae. Convolvulus Family.

Convolvulus sepium L. Bindweed. Panicum virgatum Community; occasional.

Cuscuta polygonorum Engelm. Dodder. Panicum virgatum Community; rare.

Labiatae. Mint Family.

Teucrium canadense L. Woodsage. Panicum virgatum Community; occasional.

Solanaceae. Nightshade Family.

Solanum dulcamara L. Nightshade. Panicum virgatum Community; rare.

Scophulariaceae. Figwort Family.

Verbascum thapsus L. Common Mullein. Panicum virgatum Community; rare.

Gerardia maritima Raf. Forb panne Community; occasional.

Plantaginaceae. Plantain Family.

Plantago maritima L. Forb panne Community; abundant.

Caprifoliaceae. Honey Suckle Family.

Lonicera spp. L. Panicum virgatum Community; rare.

Compositae. Composite Family.

Eupatorium dubium Willd. Joe Pyeweed. Panicum virgatum Community; rare.

Solidago sempervirens L. Seaside Goldenrod. Panicum virgatum Community; occasional.

Solidago elliotii Ait. Panicum virgatum Community; rare.

Solidago rugosa Ait. Panicum virgatum Community; occasional.

Solidago graminifolia (L.) Salisb. Panicum virgatum Community; rare.

Solidago tenuifolia Pursh. Panicum virgatum Community; rare.

Aster lateriflorus (L.) Porter. Panicum virgatum Community; rare.

Aster novi-belgii L. Panicum virgatum Community; rare.

Aster tenuifolius L. Panicum virgatum Community; rare.

Aster spp. L. Panicum virgatum Community; rare.

Baccharis halmmifolia L. Sea-Myrtle. Panicum virgatum Community; rare.

Iva frutescens L. Panicum virgatum Community; rare.

Ambrosia artemisilfolia L. Common Ragweed. Panicum virgatum Community; rare.

Galinsoga ciliata (Raf.) Blake. Panicum virgatum Community; rare.

Achillea millefolium L. Common Yarrow. Panicum virgatum Community; rare.

Carduus acanthoides L. Thistle. Panicum virgatum Community; rare.

Cichorium intybus L. Common Chicory. Panicum virgatum Community; rare.

Sonchus asper (L.) Hill. Panicum virgatum Community; rare.

Lactuca scariola L. Panicum virgatum Community; rare.