The Relationship of *Spartina Alterniflora* to Mean High Water

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Abstract

The relationship between *Spartina* zonation and tidal heights was determined by comparing direct tide measurement and marsh surface elevations to plant distribution at five locations on Long Island, New York. Neither species distribution nor plant vigor correlated closely with any specific tidal elevation. In some areas *Spartina alterniflora* was found growing well above the plane of mean high water. Since the observed elevation limits for *S. alterniflora* varied among the five marshes, factors other than the tide-elevation effect must contribute significantly to plant zonation. Because vegetation is not a precise indicator, it should not be used to determine the mean high water line. The upland border of the five marshes in this study also failed to coincide with any particular tidal datum. If a tidal plane is used to define a wetlands, it should be only one of several criteria and should be related to the local tide range of each area.

Introduction

That salt marshes are both ecologically and economically important to coastal areas is by now undisputed and well documented. Functions that now seem obvious are erosion control, storm buffer, sediment trap, oxidation basin for breaking down pollutants, wildlife habitat, estuarine nursery, recreation, education, and aesthetics (Green, 1972).

More recently, the indirect benefit of marsh productivity has received attention. Estimates ranging from 4.4-8.9 tons dry organic matter per acre per year in Georgia to 1.3 tons per acre in New Jersey, with 2.9 tons per acre for North Carolina, 3.0-7.0 tons per acre for Virginia, 2.0 tons per acre for Delaware (Wass and Wright, 1969), and 2.3-3.7 tons per acre for Hempstead Bay marshes (Udell *et al*, 1969) compare to 1-1.5 tons per acre average yield of wheat and one-third ton per acre production in open oceans (Teal and Teal, 1969).

Why has the emphasis shifted to productivity? Teal (1962) believes that tidal currents transport 45 percent of the primary production of a salt marsh to nearby estuarine waters. This organic material forms the base of complex food webs. Nearly two-thirds of the total commercial fishery catch in the Atlantic area are estuarine-dependent species (McHugh, 1966). Shellfish depend on marshes not only for food, but as a mechanism for removing excess turbidity and pollutants from the water. Wass and Wright (1969) estimated an average tangible benefit of $78 per year for each acre of salt marsh.

Long Island marshes, in the middle of the migration route known as the Atlantic Flyway, are especially important to waterfowl. The coastal marshes and shallow water habitats of Long Island are among the most valuable migration and wintering grounds on the Atlantic Coast (US Department of the Interior, 1955).

An important, often overlooked reason for preserving the remaining wetlands is that they are essentially nonrenewable (Hawkes, 1966). Redfield (1972) estimated that the mature marsh at Barnstable, Massachusetts required 500 to 1,000 years to develop.

Awareness of the importance of wetlands is becoming more widespread, but it is relatively new. Instituting the legal means to protect wetlands has not been quick or easy.

Table 1 shows the significant loss of coastal wetlands in Nassau and Suffolk counties between 1954 and 1968. The original data for 1954-1964 come from the US Department of the Interior wetlands inventories. The 1968 data come from the NYS Department of Environmental Conservation (EnCon). The most recent inventory lists 9,363 acres of marsh left in Nassau and 12,725 acres in Suffolk (O'Connor and Terry, 1972). While most of the loss between 1954 and 1964 occurred in Nassau County (US Dept Interior, 1970), this trend shifted between 1964 and 1971: Suffolk County lost about 4,300 acres, or 25 percent of its 1964 acreage, while Nassau lost only 130 acres--approximately 1 percent of the 1964 figure (O'Connor and Terry, 1972).

TABLE 1 *Declining Acreage of Salt Marsh Meadows, Nassau and Suffolk Counties*

	1954	*1959*	*1964*	*1968*
Nassau County	14,130	11,911	9,495	9,462
Suffolk County	20,590	19,208	17,008	12,930
TOTAL	34,720	31,119	26,503	23,392

Source: Office of Planning Services (1972).

The major reason for marsh destruction appears to be landfill for real estate, with dredging second (Office of Planning Services, 1972). Mt. Sinai Harbor alone lost 140 acres, or 60 percent of its marshes, to continued harbor dredging (Oceanographic Committee, Nassau-Suffolk Regional Planning Board, 1966).

Ownership is an important factor: privately owned wetlands are more vulnerable to destruction than are public wetlands. According to the Regional Marine Resources Council (1973), 96 percent of Nassau's remaining tidal marshes is owned by some level of government, while in Suffolk, 34 percent to 47 percent remains in private hands. The Office of Planning Services (OPS) (1972) estimated that 46 percent, or approximately 5,000 acres, in Suffolk and slightly over 2 percent, or 228 acres, in Nassau are under private ownership. Close to one-half of the publicly owned marshes belong to town and village governments (OPS, 1972). Table 2 shows a detailed breakdown of ownership.

TABLE 2 *Wetlands Ownership in Nassau and Suffolk Counties*

	Nassau		*Suffolk*	
Ownership	*Acres*	*Percentage*	*Acres*	*Percentage*
Federal			1,018	8
State	1,124	12	1,527	12
Municipal	7,865	84	4,200	33
Private	187	2	4,326	34
Unknown	187	2	1,654	13
TOTAL	9,363	100	12,725	100

Source: O'Connor and Terry (1972).

Attempts at Land-Use Regulation and Problems in Defining Wetlands

Public awareness that salt marshes are both irreplaceable and rapidly disappearing has led to the development of protective devices at various government levels. Governmental acquisition is perhaps the most effective and permanent means of protection, but lack of funds, coupled with increasing real estate costs, makes this impractical on a large scale.

Land-use regulation to protect natural resources has become a powerful legal tool in wetlands preservation. Zoning, used most often on a local level, is one method of imposing restrictions. Cluster, agricultural, and floodplain zoning have all been used for wetlands preservation (see Appendix B: Wetlands Preservation at the Local Level).

Requiring permits to alter wetlands is another form of land-use regulation now used extensively at all government levels. The Rivers and Harbors Act of 1899, administered by the US Army Corps of Engineers, requires permits for dredging, filling, and construction in navigable waters of the United States. Originally designed to control activities affecting navigation, this act, modified by the Fish and Wildlife Coordination Act of 1958, now requires the Corps of Engineers to consult the US Fish and Wildlife Service and the state administrator of wildlife resources regarding possible adverse affects on such resources (Commission on Marine Science, Engineering and Resources, 1969).

Many coastal states have recently enacted wetlands legislation to supplement the federal permit requirements. (New York State passed a Tidal Wetlands Act in 1973.) The land area covered by these laws is more extensive and regulation is more restrictive than under federal jurisdiction (see Appendix A: State Wetlands Legislation). On a local level, most Nassau and Suffolk towns require permits for dredging and filling (see Appendix B).

Most problems in administering these laws stem from the common belief that land-use regulation is contrary to the principle of private ownership. Navigation, health, and public welfare are generally accepted as valid goals of regulation, while conservation and aesthetics are still questioned. Determining the extent of control, establishing equality among landowners, and potential loss of property value are difficulties inherent in any such restrictive legislation (Comm. Mar. Sci., Eng. and Res., 1969).

A major problem in implementing wetlands legislation is establishing boundary lines. Legally, "no one knows what they are or where they are" (Hawkes, 1966). Definitions vary greatly in state laws and even more in local laws. Vagueness, all-inclusiveness, ambiguous terminology, and difficulty in delineating boundaries combine to weaken the power of wetlands legislation.

Concerning this problem, Hawkes (1966) summarized some criteria used for defining wetlands: 1) presence of underlying peat; 2) position of land-water interface; 3) tidal elevations; 4) vegetative zonation; 5) level of nutrient production; and 6) soil salinity. After discussing at length the inadequacies in wetlands definitions, Wass and Wright (1969) suggested including the areas between mean higher high water (the mean of the higher of the two daily high tides) and mean lower low water (the mean of the lower of the two daily low tides) as determined by survey or, in undisturbed areas, by vegetation plus any contiguous areas "deemed necessary to the stability of wetlands and the security of their biota." The difficulty and expense of extensive survey, the uncertainty in using vegetation, and the ambiguity of contiguous zones are evident flaws in their definition.

A related problem is ascertaining the boundary of private ownership. Garretson (1968) emphasized that because of "the uncertainty as to the extent of a state's power to regulate the use of privately owned tidelands on grounds other than navigation, the question of title becomes of great importance." If, for example, under current regulatory laws an appeals court considered a restriction a compensable taking, the extent of ownership would determine the amount of compensation due.

Historically, under English common law all lands below the "ordinary high water mark" were under the dominion of the king (Shalowitz, 1962). With independence, the states retained ownership of the tidelands, to be held in trust for their people (Comm. Mar. Sci., Eng. and Res., 1969). After much legal controversy, the courts generally accepted the borderline dividing upland from tideland as the US Coast and Geodetic Survey definition of mean high water (Shalowitz, 1962).

Rhode Island, Connecticut, New York, New Jersey, North Carolina, and South Carolina continue to claim title to the land extending up to mean high water. Massachusetts, Maine, New Hampshire, Delaware, Pennsylvania, Virginia, and Georgia have partially relinquished this right, permitting the upland owner to hold land down to the low-water mark, subject to the rights of navigation commerce and fishing (Garretson, 1968).

Although New York State claims ownership to mean high water, on Long Island some townships hold title to the tidelands within their boundaries under colonial patents granted prior to statehood. For instance, the Dongan patents, issued in the 1680s, delegated to the trustees of several towns on Long Island the preservation of marshes, beaches, harbors, inlets, creeks, etc., for the public good (Taormina, 1973). In an important case challenging the Town of Southampton's right to restrict wetlands development, Judge William Geiler determined that by virtue of the Dongan patents the town did own the tidelands, and that the boundary line between private and town ownership, through precendents set in other tidelands cases, was the mean high water line.*

* Dolphin Lane Associates, Ltd. *v.* Town of Southampton, 1971.

The Difficulties in Determining MHW

Not only has mean high water (MHW) been used to determine riparian ownership, but also to define the limits of regulatory jurisdiction. A prime example is the Corps of Engineers' regulatory power in navigable waters, which extends to MHW. Several states have additional legislation regarding structures placed in navigable waters, and some recent wetlands legislation defines the upper limit of a "wetland" as a specific elevation above MHW.

There are two questions to consider before using this tidal datum in wetlands preservation: 1) can MHW be accurately determined by zones of vegetation, and 2) does the land below the horizontal intersection of MHW include all of the low marsh, *Spartina alterniflora* (salt marsh cordgrass) zone, or is there substantial growth above this plane?

Using a tidal datum as a boundary line has several shortcomings. The terminology describing the tidal planes is not standardized. "High-water line," "high-water mark," and "line at ordinary high water" may all refer to the plane of MHW or may vary considerably in elevation, depending on interpretation. In Maine the "high-water mark," defined as the line which the tide usually reaches at high water (Parks, 1967), is not necessarily equivalent to MHW--the average of all the high waters over a 19-year period.

While such an inconsistency is contrived by man, others result from natural processes. Tidal datums "are not unambiguous, time invariant lines" (Comm. Mar. Sci., Eng. and Res., 1969). Where the slope of the floodplain is irregular, the tidal boundary line may show extreme lateral sinuosity (Lynch, 1969). Erosion, accretion, and rise in sea level mean further irregularities.

Measuring the intersection of a tidal plane on a land surface may be possible, but, in terms of time and money, it is highly impractical (Garretson, 1968). The accurate determination of a tidal datum requires measurement within its immediate vicinity (Hawkes, 1966). According to the US Coast and Geodetic Survey definition, values must be derived from 19 years of observations or corrected to long-term mean values (Marmer, 1951). Hawkes (1966) described finding mean high tide in a salt marsh as "an attempt to plot an altitudinal variant on to an essentially flat surface which can easily be distorted even by the weight of a transit and the man operating it." Accuracy is extremely important: a difference of only 0.1 feet in elevation could mean several hundred feet of land lost or gained (Garretson, 1968).

A method not involving survey techniques is using vegetation zones to determine MHW. Salt marshes, although rich in productivity, are low in species diversity. The few species tolerant of the alternating periods of submergence and exposure are distributed in relation to the amount of tidal inundation. One such species, *Spartina alterniflora*, characteristically grows nearest the water's edge, where flooding is greatest. This growth is often referred to as the low marsh. Further inland the high marsh consists of *Spartina patens* (salt meadow hay), usually directly above the *S. alterniflora* zone, and two other species, *Distichlis spicata* (spike grass) and *Juncus gerardi* (black grass), nearer the upland border. Other species occur commonly, but not as abundantly.

Attempts have been made to correlate species distribution with tidal datums. In the State of Washington the "mean high tide line" is the vegetation line where land can no longer support agriculture (Comm. Mar. Sci., Eng. and Res., 1969). In the case of Dolphin Lane Associates *v.* Town of Southampton, Judge William Geiler ruled that MHW could be determined as the line where *S. alterniflora* and

S. patens intermix. Because of this ruling, the town decided to use multispectral aerial photography, which highlights different plant species, to determine the extent of town-owned wetlands (Incantalupo, 1973).

The Southampton case is not the only one equating the *S. alterniflora* zone with land below MHW. According to the Office of Planning Services (OPS) (1972), New York State's claim of ownership up to MHW "definitely includes the salt-marsh intertidal zone of *S. alterniflora*." Green (1972) reported that the Corps of Engineers' jurisdiction up to MHW includes the *S. alterniflora* marsh.

This implies that public ownership encompasses the *S. alterniflora* zone and that this area is is under the protection of navigable waters legislation. Hawkes (1966) warned against such assumptions because "a surveyed mean high tide in Rhode Island frequently falls near the outer edge of the salt marsh." Thus, most of the marsh could be outside the protected area.

General literature on salt marshes supports the idea that *S. alterniflora* grows in the intertidal zone up to MHW (Green, 1972; Spagnoli, 1971; Wass and Wright, 1969; OPS, 1972; O'Connor and Terry, 1972). A superficial survey of basic research on salt marshes substantiates this generalization. Miller and Egler (1950), Bourn and Cottam (1950), Reed (1947), and Taylor (1938) all noted that the *S. alterniflora* zone is flooded twice daily at every high tide. Redfield (1972), working at Barnstable, Massachusetts, characterized *S. alterniflora* as the exclusive intertidal higher plant, growing throughout two-thirds of the tidal range, from 3 feet above mean low water (MLW) to MHW. Conard (1935) reported the elevation range of *S. alterniflora* at Cold Spring Harbor, Long Island at 5 to 7 feet, where MHW equaled 7 feet. Chapman (1960) divided salt marshes into upper and lower sections, with the line of demarcation at MHW.

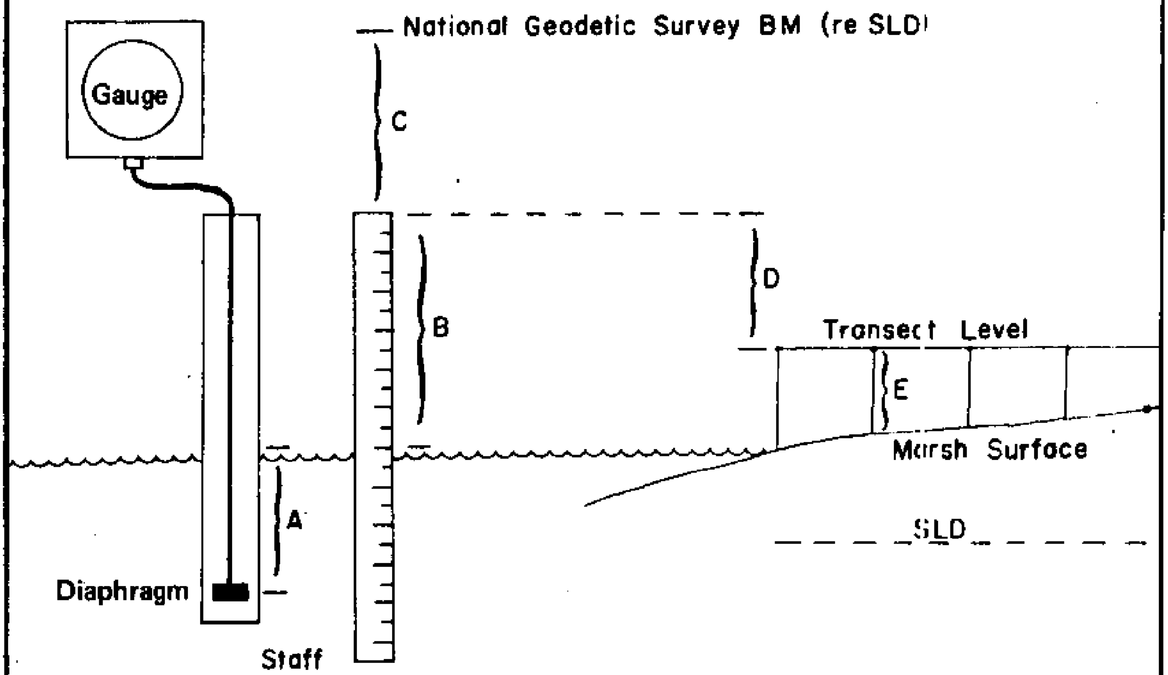
But there are important qualifications and substantial inconsistencies. The upper limit of the intertidal zone flooded at every high tide does not coincide with MHW. The area up to MHW may not be all-inclusive of *S. alterniflora* or all-exclusive of other species. Ganong (1903) described the *Spartina stricta* association in the Bay of Fundy as a belt from just above to below ordinary high tide. Reed (1947) claimed *S. alterniflora* is "best developed" between MLW and MHW. Marsh (1969) stated that *S. alterniflora* becomes "less abundant" above MHW, and Johnson and York (1915) found *S. alterniflora* growing "exactly between mean low water and mean high water" without stating the upper limit of growth as MHW. Additionally, these studies show inconsistencies in the elevation ranges of several plant species in relation to tidal heights.

The dissension over the specific causes of plant zonation adds further doubt as to how precisely MHW actually sets an upper limit to *S. alterniflora* growth. Although the tide-elevation relationship is generally considered the primary controlling factor, Chapman (1940) listed other influential factors including water table, drainage, aeration, and salinity. Hinde (1954) mentioned aeration, salinity, and substrate in addition to the tides. Miller and Egler (1950 contended that past catastrophic events and man-made alterations are partially responsible for the condition of a marsh. Harshberger (1909), Johnson and York (1915), Penfound and Hathaway (1938), and Taylor (1938) found that vegetation correlated with salinity.

Such controversy leads one to suspect that several factors combined influence zonation. The effects of any one factor such as tide-elevation may be highly modified by other conditions such as salinity or type of substrate.

Using the upper limit of the *S. alterniflora* zone to indicate the line of MHW (or determining any tidal datum using position of vegetation) requires a precise and consistent correlation between the two. Such a correlation, although often referred to in the literature, is not actually supported. The actual methods of determining tidal data and locating them as a specific line on a marsh were often inadequate to support such a consistent correlation. Generalizations on other marshes cannot be made from results obtained in one specific location. The vague descriptions of MHW as the upper limit, the divergent opinions over causes of zonation, and inconsistencies among previous studies suggest the uncertainty of using MHW as a precise borderline.

FIGURE 1 *How to Determine Tidal and Marsh Surface Elevations*



A = gauge reading

B = staff reading

A + B = measure point (MP) [a constant]

MP - A = distance from top of staff to water level for any gauge recording

BM (re SLD) - C = top of staff (re SLD)

top of staff - D = transect level (re SLD)

transect level - E = marsh surface elevation (re SLD)

Fieldwork Methods

The five salt marshes studied here were chosen on the basis of location, tidal range, characteristic vegetation, available information, and accessibility. I did original tide calculations in only three of the areas, as recent tidal data on the two other locations were available.

In the three marshes where I needed tidal information, Bristol continuous recording tide gauges were installed and operated over a three-month period. The gauge records the height of the water column above a pressure-sensitive diaphragm. Water pressure on the inflated diaphragm, connected by an airtight tube to the gauge, moves a stylus which marks the rise and fall of the tide on a rotating chart.

James Kuntz, tidal specialist for the Corps of Engineers, New York District Office, helped install and operate the tide gauges. Leveling was done with a Craftsman transit under the direction of Robert Adler, civil engineer.

A staff graduated in tenths of feet, and long enough to include the maximum range of the tide, was secured near the gauge. Simultaneous measurements of the distance from the top of this staff to the water level and of the height of the water column recorded by the gauge could then detect errors in the tide record, because the sum of the gauge reading and the staff reading should yield a constant--the measure point. A change in the measure point over a period of time would indicate a malfunction such as leakage. Charts were replaced and the measure point checked at least once a week.

The top of the staff was later leveled to the nearest National Geodetic Survey bench mark to obtain a reference to sea level datum (SLD). Subtracting any height on the gauge chart from the measure point indicated the distance from the top of the staff to the water level for that gauge reading. Subtracting this distance from the elevation of the top of the staff (re SLD) gave the height of the water level with respect to SLD (Fig. 1). Thus, any gauge reading could be expressed as an elevation with respect to SLD.

Because the more important variations in tide-producing forces have a period of approximately 19 years, the US Coast and Geodetic Survey defines mean high water as "the average height of high waters over a 19-year period." Values derived from a short series of observations may vary considerably from mean values and must be corrected to long-term records. (Marmer [1951] gives the complex calculations used to arrive at corrected MHW.)

For this study, the short-term or observed values for MHW, MLW, half-tide level (HTL), and mean range (Mn) were computed directly from gauge recordings. The observed records were corrected to long-term observations, using simultaneous comparisons to primary stations at either Montauk, New York, or Bridgeport, Connecticut, or Sandy Hook, New Jersey for the 1941-1959 period.

An approximate value of mean spring high water (SpHW) was calculated for those areas having a nearby National Ocean Survey tide station with a comparable mean range and a given spring range by the formula:

$$\text{SpHW} = \text{HTL}_1 + \tfrac{1}{2}\,\frac{\text{spring range}}{\text{mean range}} \times \text{Mn}_1$$

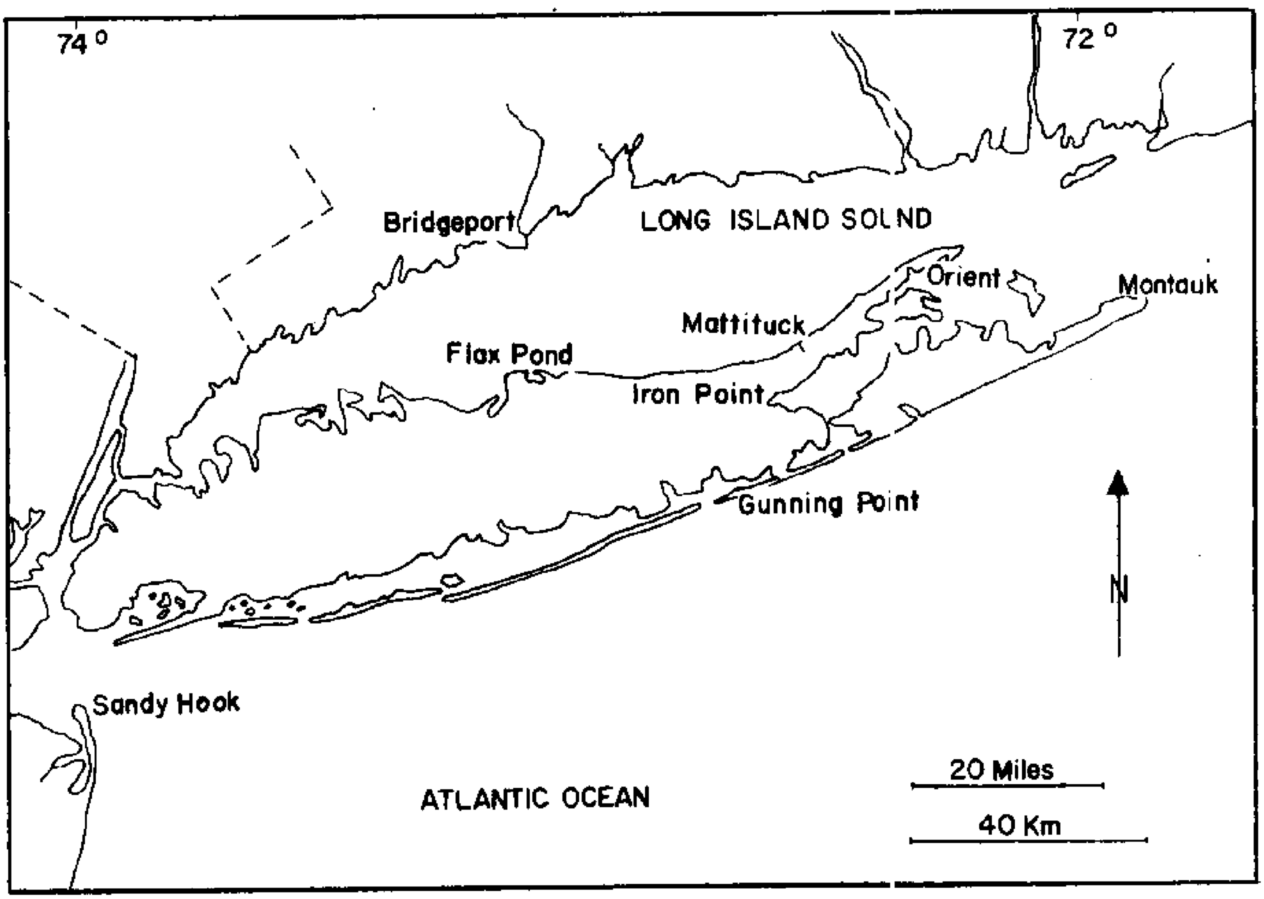
(Marmer, 1951). For the observed mean SpHW, HTL_1 was the observed half-tide level and Mn_1 the observed mean range from the gauge record. I calculated the ratio of spring range to mean range from the National Ocean Survey 1973 Tide Tables (US Dept Commerce, 1972) values for the nearby station. The long-term SpHW was derived by substituting the corrected values of HTL_1 and Mn_1 previously obtained by simultaneous comparison to a primary tide station. SpHW represents the mean of high waters of spring tides occurring within a day or two after the moon is new or full (Marmer, 1951).

I took weekly salinity readings at several stations in each area, using an American Optical Corporation refractometer to detect any large differences in salinity among the marshes.

I used two methods to determine marsh surface elevation. Line transects from the marsh-water edge to the upland using a string and a line level to maintain a constant elevation gave a measure of the overall contour of the marsh. At 1-meter intervals I recorded the distance from the marsh surface to the string along with the type of vegetation, height, percent cover, and notes on plant vigor, such as color and flowering condition. To obtain the elevation of the string in reference to SLD, I leveled the string to the top of the staff using the transit. Knowing the height of the staff in relation to gauge recordings, I could apply any tidal datum to the marsh surface (Fig. 1). Two transects, selected on the basis of characteristic zonation and proximity to creeks and ditches, were completed at each marsh.

The second means of determining marsh surface elevation involved using the transit to obtain several point elevations in the various vegetation zones, which could then be used to detect any errors in the transect elevation. In addition, transit elevations include areas not directly along the transect as well as upland zones where the transect method was impossible.

FIGURE 2 *Locations of Study Areas and National Ocean Survey Tide Stations Used for Simultaneous Comparisons*



Results

Figure 2 shows Flax Pond, Mattituck Inlet, Orient Point, Iron Point, Gunning Point, and the primary tide stations used in simultaneous comparisons. Table 3 summarizes the results of the tide records for each area. Tidal datums refer to elevation in feet above or below SLD, except for Flax Pond, where the values represent height in feet above the corrected plane of MLW designated as the 0 level.

is designated "observed MHW." Thus, an elevation for *S. alterniflora* of 0.8 feet above MHW (0.5 feet above observed MHW) means that this species was found 0.8 feet above the corrected MHW and 0.5 feet above the observed MHW, where the difference in the two datums is 0.3 feet.

Both MHW datums are included because the corrected value of MHW is the 19-year mean, which has legal significance, whereas the vegetation

TABLE 3 *Summary of Tidal Datums (Feet re SLD)*

	Observed Values					*Corrected Values*				
Location	*MHW*	*MLW*	*HTL*	*Mn (feet)*	*SpHW*	*MHW*	*MLW*	*HTL*	*Mn (feet)*	*SpHW*
Mattituck 41°01'N;72°33'W	3.00	-2.17	0.42	5.17	3.40	2.76	-2.34	0.21	5.10	3.15
Iron Point 40°55'N;72°37'W	1.81	-0.97	0.42	2.78	2.07	1.48	-1.23	0.13	2.72	1.74
Orient Point 41°08'N;72°19'W	1.72	-0.55	0.59	2.27	1.95	1.40	-0.84	0.28	2.24	1.62
Gunning Point 40°47'N;72°41W	1.61	0.20	0.91	1.41		1.14	-0.26	0.44	1.40	
Flax Pond* 40°58'N;73°09'W	5.16	0.14	2.70	5.02	5.59	4.73	0.00	2.36	4.73	5.08

* Elevations for Flax Pond are in feet above MLW.

At all five areas the observed means are greater than the corrected values. The difference between observed MHW and corrected MHW ranges from 0.24 feet at Mattituck to 0.47 feet at Gunning Point. Table 4 shows the difference between the two planes of MHW for each area.

In subsequent discussions of the relation of tidal datums to species distribution, I considered both the corrected plane of MHW and the observed plane in relation to species distribution. All elevations referring to vegetation are given in feet above or below both datums. The elevation in reference to the corrected MHW appears first as the height above or below "MHW." Neither "corrected" nor "long-term" precedes the term "MHW." In parentheses is the same elevation given as a height above or below the observed MHW. This

on the marsh may more closely reflect the short-term value of MHW.

Salinity differences between the marshes are negligible. From the three areas sampled, mean values from open water stations were:

Orient Point - 23.8 + 1.45 °/₀₀ (6 samples)
Iron Point - 23.9 + 0.38 (10 samples)
Mattituck - 24.6 + 1.75 (10 samples)

TABLE 4 *Differences Between Observed and Corrected Planes of MHW*

Location	*Observed MHW*	*Corrected MHW*	*Difference*
Mattituck	3.00ft (reSLD	2.76ft (reSLD)	0.24 feet
Iron Pt.	1.81	1.48	0.33
Orient Pt.	1.72	1.40	0.32
Gunning Pt.	1.61	1.14	0.47
Flax Pond	5.16ft (reMLW	4.73ft (reMLW)	0.43

Analysis of variance for these three areas showed no significant difference between the means. At Iron Point, however, paired comparisons between Reeves Bay and the Peconic River on the opposite side of the marsh differed significantly at the 0.05 level.

Since data were already available, I took no salinity recordings at either Flax Pond or Gunning Point. At Flax Pond several transitions from fresh to salt water have occurred with the opening and closing of the inlet. At present, normal salinity is about 26‰ (Woodwell and Pecan, 1973). Data from the Corps of Engineers' study at Gunning Point indicated an average salinity of 26‰ (Suszkowski, 1973).

Mattituck Inlet

Mattituck Inlet (41°01'N;72°33'W) is on the northeastern shore of Long Island. Ownership of the marsh there is unknown. The study area, on the eastern side of the inlet, is flooded with water from Long Island Sound. Over 90 percent of the 15-acre area (excluding filled portions) is *Spartina alterniflora*, most of which is under 50 cm in height. Other species, including *Spartina patens* (salt meadow hay), *Distichlis spicata* (spike grass), *Juncus gerardi* (black grass), *Salicornia europea* and *Salicornia virginica* (saltwort), *Aster tenuifolius* (salt marsh aster), *Limonium nashii* (sea lavender), and *Solidago sempervirens* (seaside goldenrod) are common in the marsh. *Iva frutescens* (marsh elder), *Baccharis halmifolia* (groundsel), and *Phragmites communis* (reed) predominate in the bordering upland. One main creek drains the marsh; mosquito ditching is minor.

Man's impact is conspicuous in the filled areas along the shoreline and the extensive erosion of the marsh edge caused by successive dredging of the inlet. Presently, a four-foot escarpment forms the marsh-water border.

The tide gauge, placed on a dock on the western side of the inlet, about 200 feet from the study area, ran from August 24, 1973 through December 14, 1973. Gauge readings totaled 152 high waters and 147 low waters. The unequal number of high and low waters was due to breaks in the tide record. The gauge was leveled to bench mark BM B374 (1956) on the inlet's west jetty, about one-half mile away from the gauge.

Long-term values of MHW, HTL, MLW, and Mn were based on 63-day comparisons to National Ocean Survey's Bridgeport station (US Dept Commerce, 1974). Corrected values for the tidal datums were lower than the short-term record. The corrected value of MHW at 2.76 feet (re SLD) was 0.24 feet below the observed MHW at 3.00 feet (re SLD).

To compute SpHW, I used the predicted mean range and spring range for Mattituck Inlet (US Dept Commerce, 1972) to obtain a corrected spring value of 3.15 feet (re SLD) and an observed SpHW of 3.40 feet (re SLD), 0.4 feet above their respective planes of MHW.

Mattituck has a large tidal amplitude. The mean range is slightly over 5 feet. The tidal data obtained in this study were similar to National Ocean Survey observations at Mattituck Inlet from 4/69 to 10/70:

MHW - 2.99 feet (re SLD)
HTL - 0.44
MLW - -2.11
Mn - 5.10 feet (US Dept Commerce, 1971*b*).

Figure 3 shows the Mattituck Inlet area and the location of the two transects, where the results were similar. Transect 1, shown graphically in Figure 4, extended 165 meters inland from the marsh edge to the shrub border.

Tall *S. alterniflora* (1 meter high) grows in a narrow belt along the marsh edge from 1.6 feet below MHW (1.35 feet below observed MHW) to 0.15 feet below MHW (0.4 feet below observed MHW). The height of the grass decreases near MHW as the marsh surface becomes level. A conspicuous rise in elevation, probably the

FIGURE 3 *Mattituck Inlet*

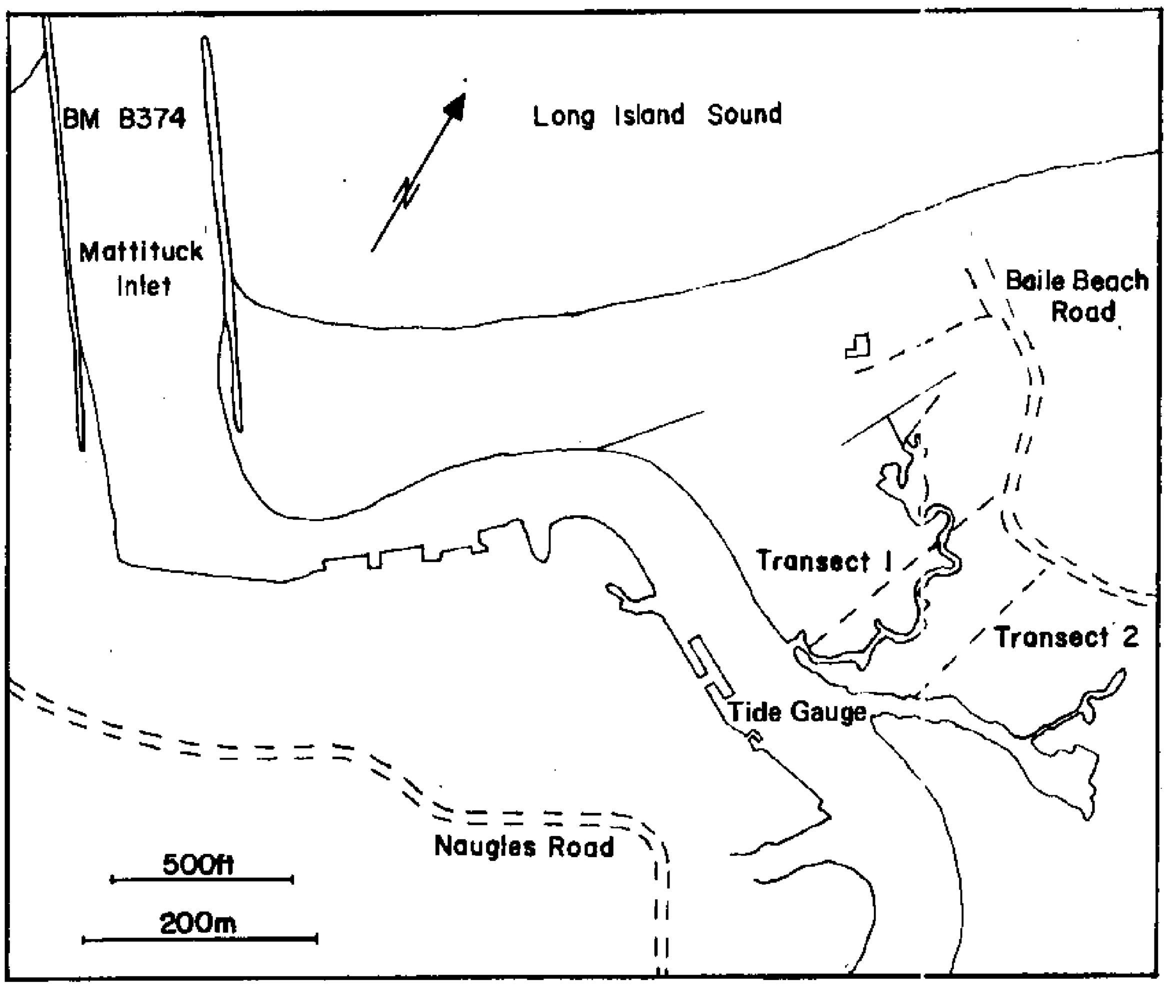
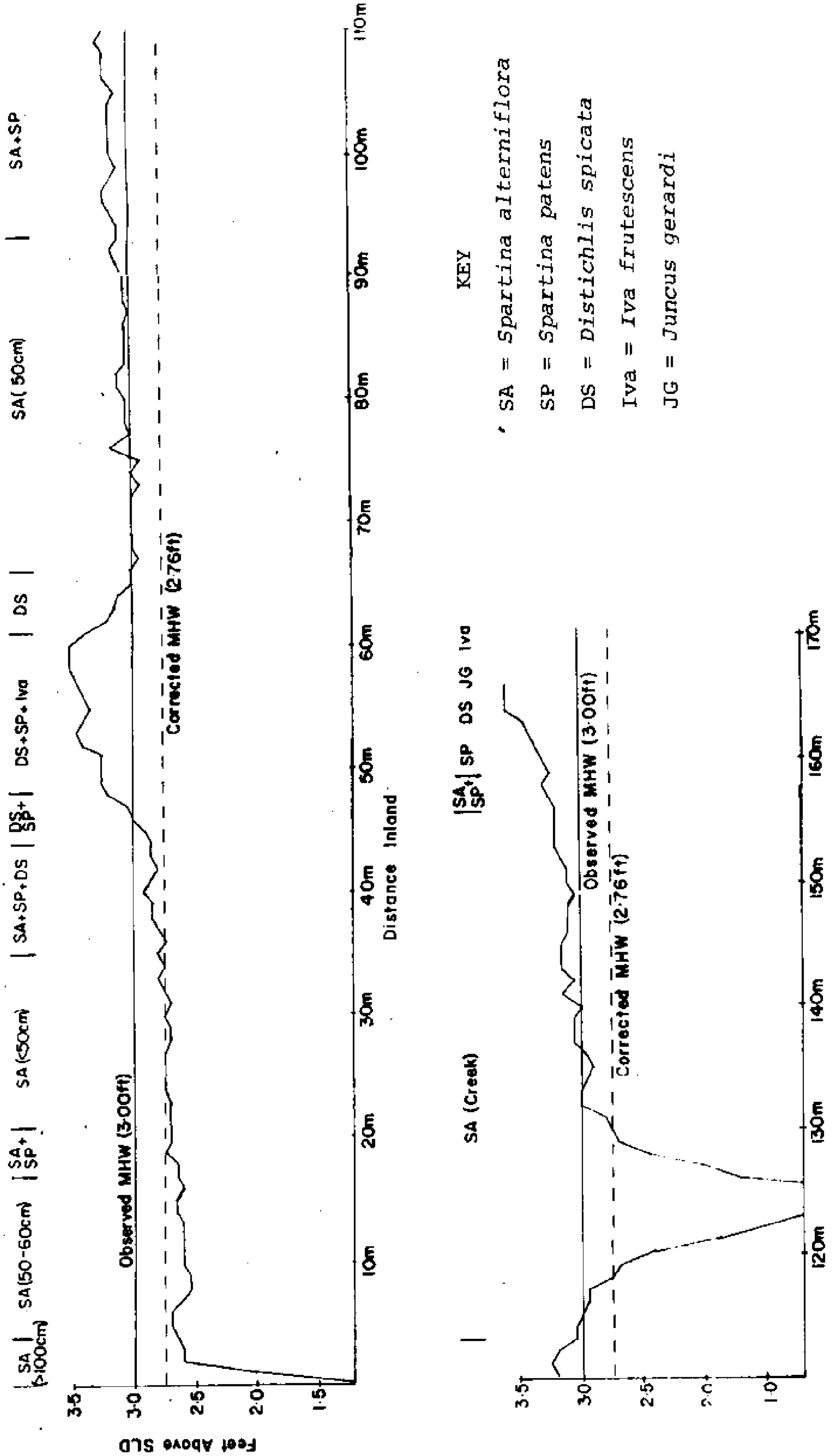


FIGURE 4 *Mattituck Inlet, Transect 1*



result of nearby filling, interrupts the transect. Although high marsh species, including *S. patens*, *D. spicata*, *A. tenuifolius*, *S. sempervirens*, and *I. frutescens*, dominate, single plants of tall, flowering *S. alterniflora* are scattered throughout this region.

Nearly 120 meters from the marsh edge, the transect crosses the main creek. There is a renewed growth of tall *S. alterniflora* along either bank. Beyond this, *S. alterniflora* declines in vigor, and 160 meters inland the high marsh begins at 0.5 feet above MHW (0.25 feet above observed MHW); *S. patens* dominates, followed by *D. spicata* and *J. gerardi* at 0.85 above MHW (0.6 feet above observed MHW). The narrow high marsh zone ends abruptly in a shrub growth consisting mostly of *I. frutescens* and *B. halmifolia*. Here, the surface slopes rapidly upward toward the road.

No consistent relationship between species distribution and absolute elevation is apparent. Elevation ranges of different species overlap. Zones of mixed *S. alterniflora/S. patens* are present 20 meters inland, at 0.05 feet below MHW (0.3 feet below observed MHW), at 0.35 feet above MHW (0.1 feet above observed MHW), and at 0.45 feet above MHW (0.2 feet above observed MHW) near the high marsh border. There are also zones of short *S. alterniflora* at successively higher elevations, from 0.05 feet below MHW (0.3 feet below observed MHW) nearest the marsh edge to 0.25 feet above MHW (the level of observed MHW) further inland to 0.35 feet above MHW (0.1 feet above observed MHW) beyond the creek. Rapid changes in elevation are often accompanied by a change in vegetation, but a transition to any one particular species does not always occur at the same elevation. Thus, the tide-elevation effect may be modified by distance from the water source or may operate relative to the surrounding marsh elevation rather than on an absolute basis.

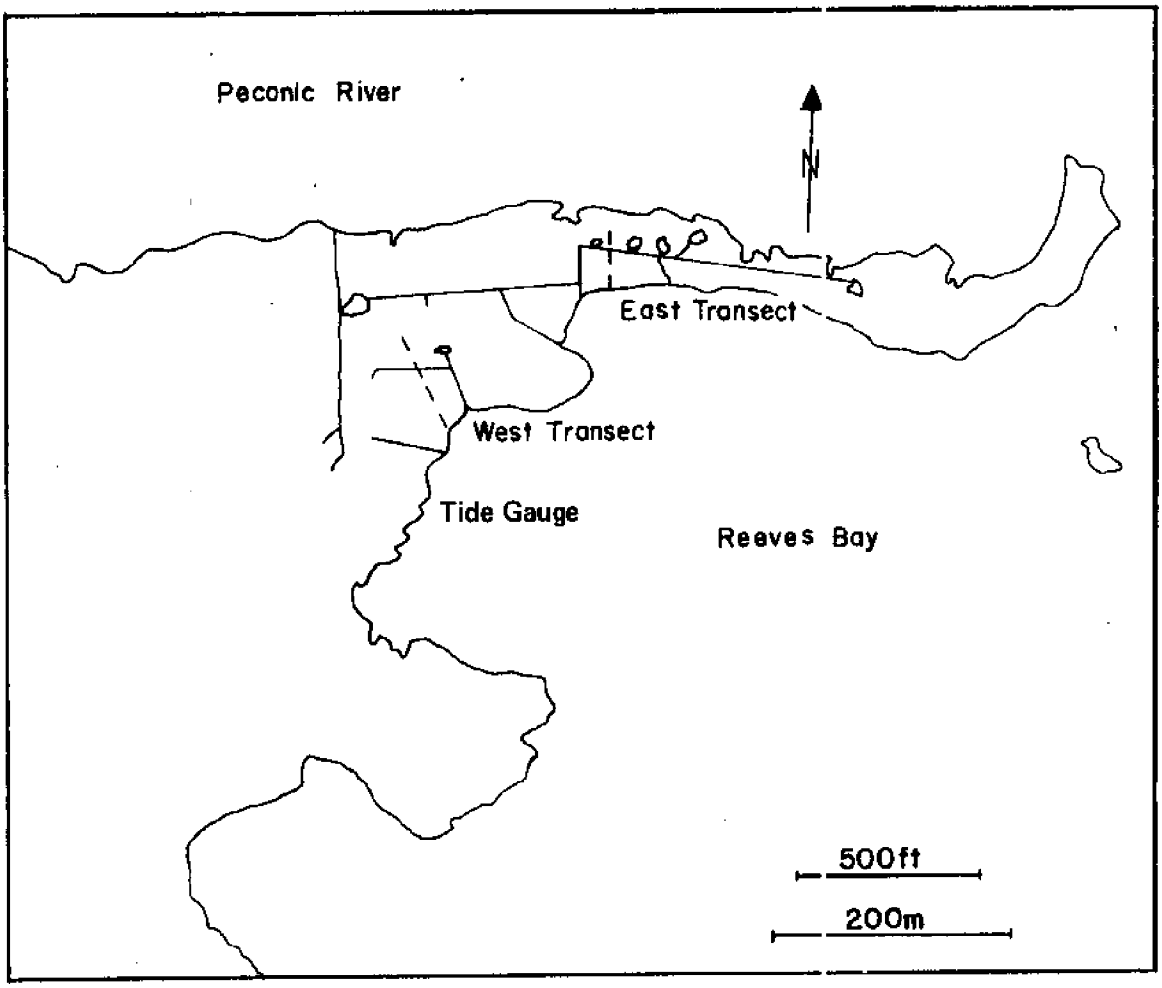
Since the elevation zone of one species is variable, the relationship between a species and a constant elevation such as MHW also varies. Except for the first 30 meters and the creek banks, most of the marsh is above the corrected MHW of 2.76 feet (re SLD). The exact location of the MHW plane on the marsh surface is difficult to determine, because as the marsh surface reaches the elevation of the corrected MHW it becomes very level. The corrected MHW, however, intersects at several points within a zone of short *S. alterniflora*. Where the final transition to high marsh occurs, the surface is 0.8 feet above the corrected MHW datum.

The observed plane of MHW at 3.00 feet (re SLD) is above the first 45 meters of marsh surface including zones of tall-to-short *S. alterniflora*, mixed *S. alterniflora/S. patens*, and some *D. spicata*. Behind the elevated region a zone of short *S. alterniflora* resumes at the same level as the observed MHW. As the marsh surface rises 0.1 to 0.2 feet above this, *S. patens* again appears. Toward the upland border the transition to high marsh is 0.6 feet above the observed MHW. Zones of the tall *S. alterniflora* are below both planes of MHW, but most of the marsh surface, including substantial amounts of short *S. alterniflora*, is above these two planes.

Iron Point

Iron Point (40°55'N;73°37'W) is a narrow strip of land extending eastward between the Peconic River and Reeves Bay, about two miles east of Riverhead, New York (Fig. 5). The area is privately owned. The 20-acre marsh is 50 percent *S. alterniflora; S. patens* and *D. spicata* are the next most abundant species. Both *Suaeda maritima* (sea blite) and *A. tenuifolius* are more common than in the four other study areas. Salt marsh pools surrounded by dense stands of *S. alterniflora* are numerous, and several mosquito ditches drain the marsh. Landfill has destroyed the western portion of Iron Point, forming an abrupt end to the

FIGURE 5 *Iron Point*



vegetation growth. Iron Point is particularly interesting because it is close to a densely populated area (and therefore exposed to much pollution) and it is adjacent to the fresh-water Peconic River.

The tide gauge was installed in Reeves Bay (Fig. 5), giving a short-term record from September 21, 1973 through December 14, 1973 of 150 high waters and 144 low waters. The gauge was leveled to BM G336 on State Highway 24, 0.75 miles away from the gauge.

Correction to long-term records at National Ocean Survey's Montauk station (US Dept Commerce, 1974) for 56 days' comparisons indicate that the observed MHW of 1.81 feet (re SLD) was 0.33 feet above the corrected MHW at 1.48 feet (re SLD).

SpHW, computed from the ratio of spring range to mean range from National Ocean Survey predictions for South Jamesport in the Great Peconic Bay (US Dept Commerce, 1972), is 2.07 feet (re SLD) for the observed period and 1.74 feet (re SLD) for the long-term period. Both are 0.26 feet above their respective planes of MHW.

Tidal datums given for the South Jamesport station are comparable to data obtained from gauge records at Iron Point:

MHW - 1.56 feet (re SLD)
HTL - 0.24
MLW - -1.14
Mn - 2.70 feet (US Dept Commerce, 1969*a*).

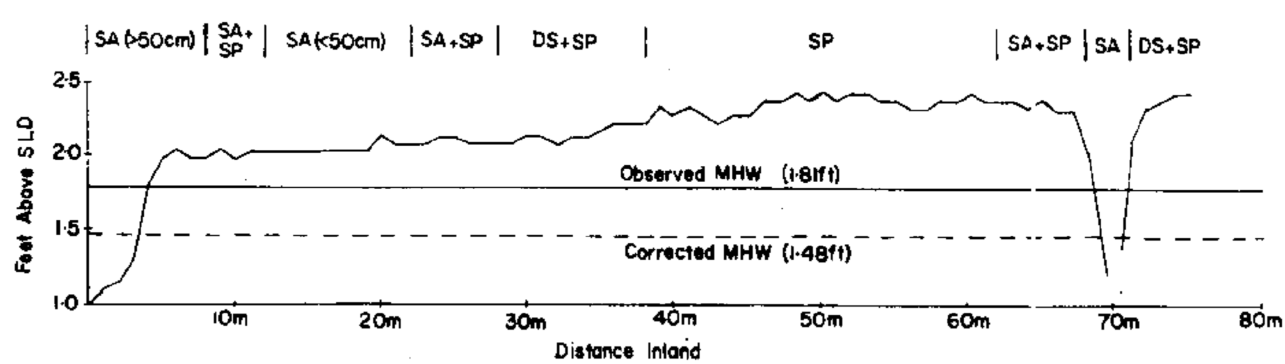
Figure 5 shows the locations of the transects. The west transect (Fig. 6), nearest the gauge, extends 75 meters inland through an exclusively *S. alterniflora* zone, a mixed *S. alterniflora/S. patens* zone, and a *S. patens/D. spicata* high marsh. The east transect, 60 meters long, is mostly mixed *S. alterniflora/S. patens*. Neither transect includes upland, since the elevation declines toward the opposite shore of Iron Point.

S. alterniflora grows to heights exceeding 1 meter in a narrow belt along the marsh-bay edge beginning at 0.8 feet below MHW (1.1 feet below observed MHW) on the east transect and 0.5 feet below MHW (0.8 feet below observed MHW) on the west. This vigorous growth declines in height to 60-70 cm as the marsh becomes level. There is a flat 10-meter zone of short *S. alterniflora* (40-50 cm) at 0.6 feet above MHW (0.3 feet above observed MHW) on the west transect.

While the east transect lacks this typical short *S. alterniflora* zone, from 8 meters to 45 meters inland it contains an extensive ecotone of flowering *S. alterniflora* (60-70 cm) mixed with a dense growth of *S. patens*. This mixed zone begins at 0.3 feet above MHW (approximately the level of observed MHW) and reaches a height of 0.6 feet above MHW (0.3 feet above observed MHW).

Along the west transect the transition to high marsh occurs at 0.6 feet above MHW (0.3 feet

FIGURE 6 *Iron Point, West Transect*



above observed MHW). There is no difference in elevation from the mixed zone. A mosquito ditch supporting a vigorous stand of *S. alterniflora* interrupts the high marsh, which resumes growth at the same elevation on the opposite side of the ditch. Along the east transect the transition to high marsh immediately follows a ditch at an elevation of 0.45 feet above MHW (0.15 feet above observed MHW).

Elevations surveyed with the transit correspond to the transect results (Table 5). The highest elevation of 2.90 feet above MHW was along the *S. patens/Phragmites* border.

Almost the entire marsh surface is above the corrected MHW. Along both transects this plane intersects the marsh in the middle of the tall *S. alterniflora* zone. Most of the high marsh is nearly one foot above this datum.

The observed plane of MHW intersects the marsh near the beginning of the mixed zone on the east transect and, on the west transect, at the point where *S. alterniflora* starts decreasing in height from over 1 meter to 70-80 cm. Thus, at two locations within the same marsh, the observed MHW has quite a different relationship to vegetation. The zone of short *S. alterniflora*, stands of *S. alterniflora* 60-80 cm high, and the transition to high marsh are all above this datum.

TABLE 5 *Elevations Determined With Transit at Iron Point*

Vegetation	*Relation to MHW*	*Relation to Observed MHW*
Tall *S. alterniflora*	0.26 ft below	0.59 ft below
	0.15 ft above	0.18 ft below
Short *S. alterniflora*	0.74 ft above	0.41 ft above
S. patens	0.50 ft above	0.17 ft above
	0.60 ft above	0.27 ft above
	0.75 ft above	0.42 ft above
	2.90 ft above	2.57 ft above
S. patens/D. spicata	0.94 ft above	0.61 ft above

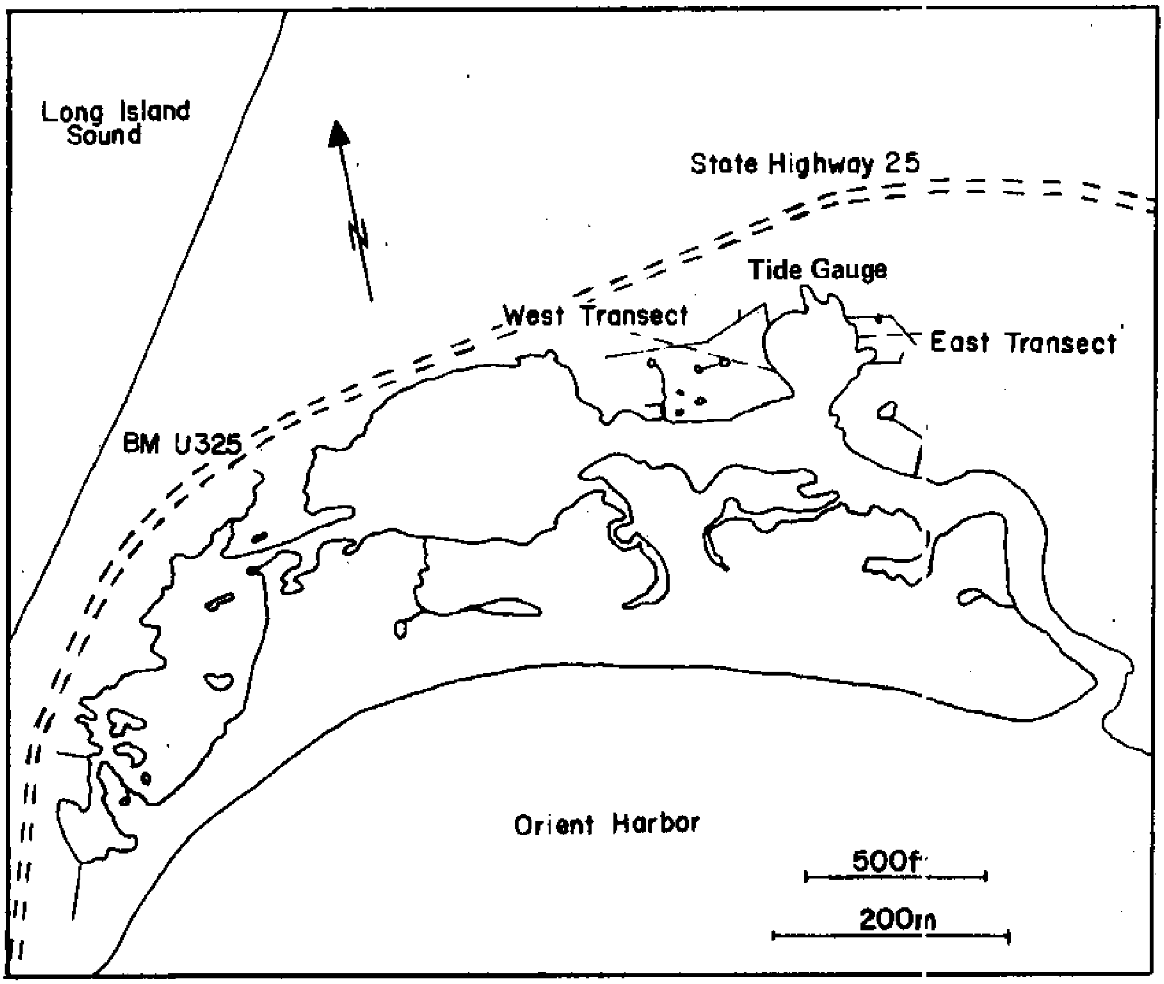
Orient Point

The Orient marsh (41°08.5'N;72°19'W) is a privately owned tract of land approximately four miles west of Orient Point. Water from Orient Harbor on Gardiner's Bay enters and floods the marsh. Only a small portion of the 50-acre marsh and water complex was studied. This area adjoins the upland border, a shrub zone separating the marsh and State Highway 25 (Fig. 7). The marsh is predominantly *S. alterniflora*. Both the Mattituck and Orient marshes have a very narrow belt of high marsh. Mosquito ditches supplement a complex natural drainage system.

The tide gauge, installed in a lagoon near the upland border, measured the fluctuation of water within the marsh. The short-term record from August 24, 1973 through December 14, 1973 showed 155 high waters and 141 low waters. BM U3?5 on State Highway 25, 0.5 miles from the gauge, was used as a reference elevation.

The long-term datums were computed from 53 days' comparisons to Montauk (US Dept Commerce, 1974). The corrected MHW is 1.40 feet (re SLD), 0.32 feet lower than the observed MHW of 1.72 feet (re SLD).

FIGURE 7 *Orient Point*



The values for mean range and spring range at Orient Harbor (US Dept Commerce, 1972) were used to calculate SpHW. The corrected SpHW at 1.62 feet (re SLD) and the observed SpHW at 1.95 feet (re SLD) are both approximately 0.2 feet above their respective planes of MHW.

Comparisons of the tide record to stations in the vicinity indicate that the 2.24 feet tidal amplitude within the marsh is only slightly less than that of nearby open waters (Table 6).

TABLE 6 *Datums at Tide Stations Near Orient (Feet re SLD)*

Location	*MHW*	*HTL*	*MLW*	*Mn(Feet)*
Orient Harbor	1.62	0.37	-0.88	2.50
Plum Gut Harbor	1.52	0.22	-1.08	2.60
Greenport Harbor	1.34	0.14	-1.06	2.40

Source: US Dept Commerce (1969 *b,c,d*).

The two transects were located to include as much high marsh as possible. On the west transect (Fig. 8), tall *S. alterniflora* begins at 0.8 feet below MHW (1.1 feet below observed MHW), mixes with *S. patens* by 0.4 feet above MHW (0.1 feet above observed MHW), and ends as the elevation rises another 0.1 feet. The emergent zone of tall *S. alterniflora* on the marsh edge of the east transit is also narrow and ends at the same elevation as on the west transect.

Beyond the narrow zone of *S. patens* on the west transect, short *S. alterniflora* (30 cm) grows at 0.6 feet above MHW (0.3 feet above observed MHW) and extends for 15 meters until the transect crosses a salt pan in which the *S. alterniflora* grows taller and the elevation drops to the level of MHW (0.3 feet below observed MHW). Along with this depression the transect includes a permanent pool surrounded by *S. alterniflora* over 1 meter in height.

A ditch with its usual vigorous growth of *S. alterniflora* interrupts both transects. Beyond each ditch the high marsh begins. On the east transect this occurs at 0.65 feet above MHW (0.35 feet above observed MHW), while on the west transect the transition to high marsh is 0.9 feet above MHW (0.6 feet above observed MHW). Single plants of *S. alterniflora*, often higher than 60 cm and flowering, are scattered throughout the latter high marsh. Along both transects the shrub border is nearly 0.9 feet above MHW (0.6 feet above observed MHW).

Surveyed elevations corroborate the transect results (Fig. 9). From State Highway 25, more than 10 feet above either plane of MHW, the elevation declines rapidly toward the marsh surface. There is a 0.65 foot vertical rise from the high marsh-shrub border to 1 foot within the shrub growth, indicating the steep slope of this area. East of the gauge, the elevation in the dense stand of *Phragmites* is lower than most of the high marsh and less than 0.1 feet above *S. alterniflora*.

FIGURE 8 *Orient Point, West Transect*

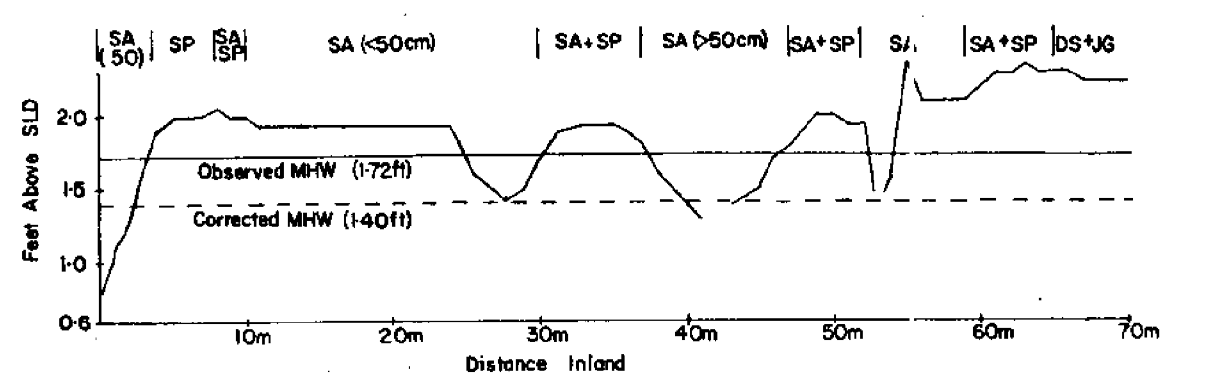
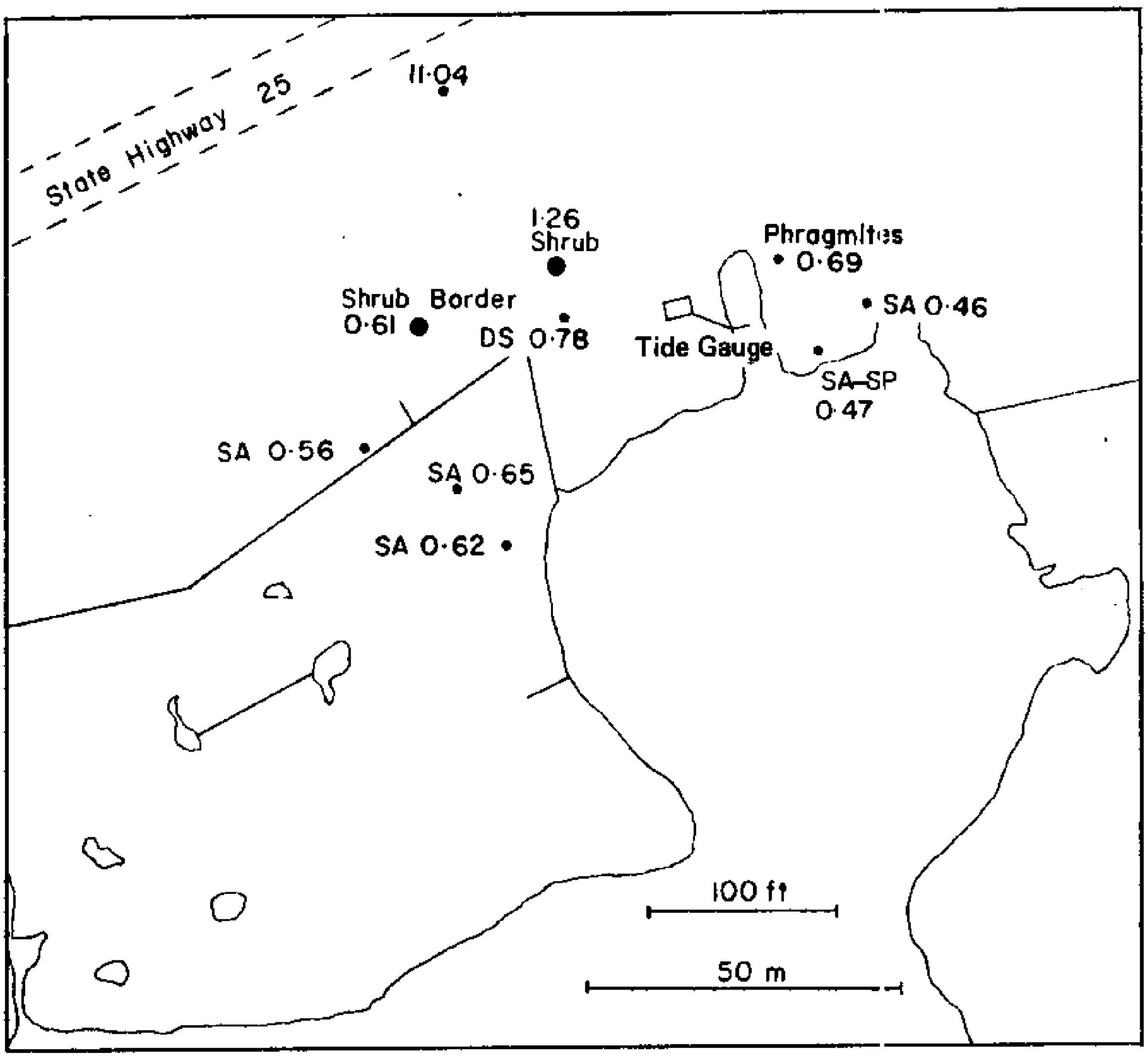


FIGURE 9 *Orient: Elevations of Marsh Surface as Determined by Transit*



This last finding emphasizes the fact that elevation cannot be the sole consideration in species distribution. At Orient, as in other areas, species elevations overlap. Zones of a single species occur at different elevations. The strip of *S. patens* near the marsh edge is 0.3-0.4 feet below the high marsh *S. patens* zone. The corrected MHW, intersecting the marsh in the middle of the tall *S. alterniflora*, 3 meters from the marsh edge, bears little relationship to vegetation. The high marsh ranges between 0.7 and 0.9 feet above the MHW plane.

Most of the marsh surface is also above the observed MHW, which intersects the marsh slightly below the upper limit of tall *S. alterniflora*. Short *S. alterniflora* is 0.2-0.3 feet above observed MHW; the high marsh is 0.4-0.6 feet above observed MHW.

Flax Pond

Flax Pond (40°58'N; 73°09'W) is located in the Village of Old Field, on the north shore of Long Island (Fig. 10). The marsh is jointly owned by State University of New York at Stony Brook and the New York State Department of Environmental Conservation (EnCon) for research purposes. Since 1971, Brookhaven National Laboratory has operated a continuously recording tide gauge in the central channel of the marsh, in conjunction with an extensive study on nutrient exchange in salt marsh ecosystems. I included Flax Pond in this study because of the large volume of available information, large tidal range, and particularly vigorous growth of *S. alterniflora*.

The marsh is 60 percent *S. alterniflora*, much of which exceeds 1 meter in height. *D. spicata* and *S. patens* form the marginal high marsh areas. (Woodwell and Pecan [1973] give a complete list of plant species.) Water enters and exits Flax Pond through a narrow channel stabilized by two jetties. There is a two-hour lag in low tide between Flax Pond and Long Island Sound, mainly because the channel bottom is higher than most low tides in the Sound. Consequently, the tide in the marsh floods for four hours and ebbs for eight hours (Woodwell and Pecan, 1973).

Tidal datums were computed from 12 months of records (not continuous) from March 1972 to October 1973. Gauge readings gave the water level on a graduated tide staff. Measurements, originally in meters, were converted to feet. The data were not leveled to SLD and all the heights of tidal datums at Flax Pond are given in feet above the corrected MLW, designated as the 0 level (Fig. 11).

The corrected mean range at Flax Pond is 4.73 feet--substantially less than the mean range of 6.60 feet for the nearby Port Jefferson Harbor Entrance station (US Dept Commerce, 1972). The restricted opening to Flax Pond probably accounts for the smaller tidal amplitude.

Using 56 days of comparisons to Bridgeport for the months of September and October 1973 (US Dept Commerce, 1974), I obtained a corrected MHW of 4.73 feet (re MLW). This is 0.43 feet lower than the observed MHW of 5.16 feet (re MLW). I used the ratio of mean range to spring range at Port Jefferson (US Dept Commerce, 1972), giving a corrected SpHW of 5.08 feet (re MLW) and an observed SpHW of 5.59 feet (re MLW).

The results of both transects, one west and one east of the channel bridge, are given in Figure 11. The unstable substrate made it impossible to obtain the lower limit of *S. alterniflora* growth, although I estimated it at about 3 feet below MHW.

The *S. alterniflora* zone at Flax Pond has the most luxuriant growth of all areas included in this study. On the west transect the surface elevation increases rapidly from the

FIGURE 10 *Flax Pond*

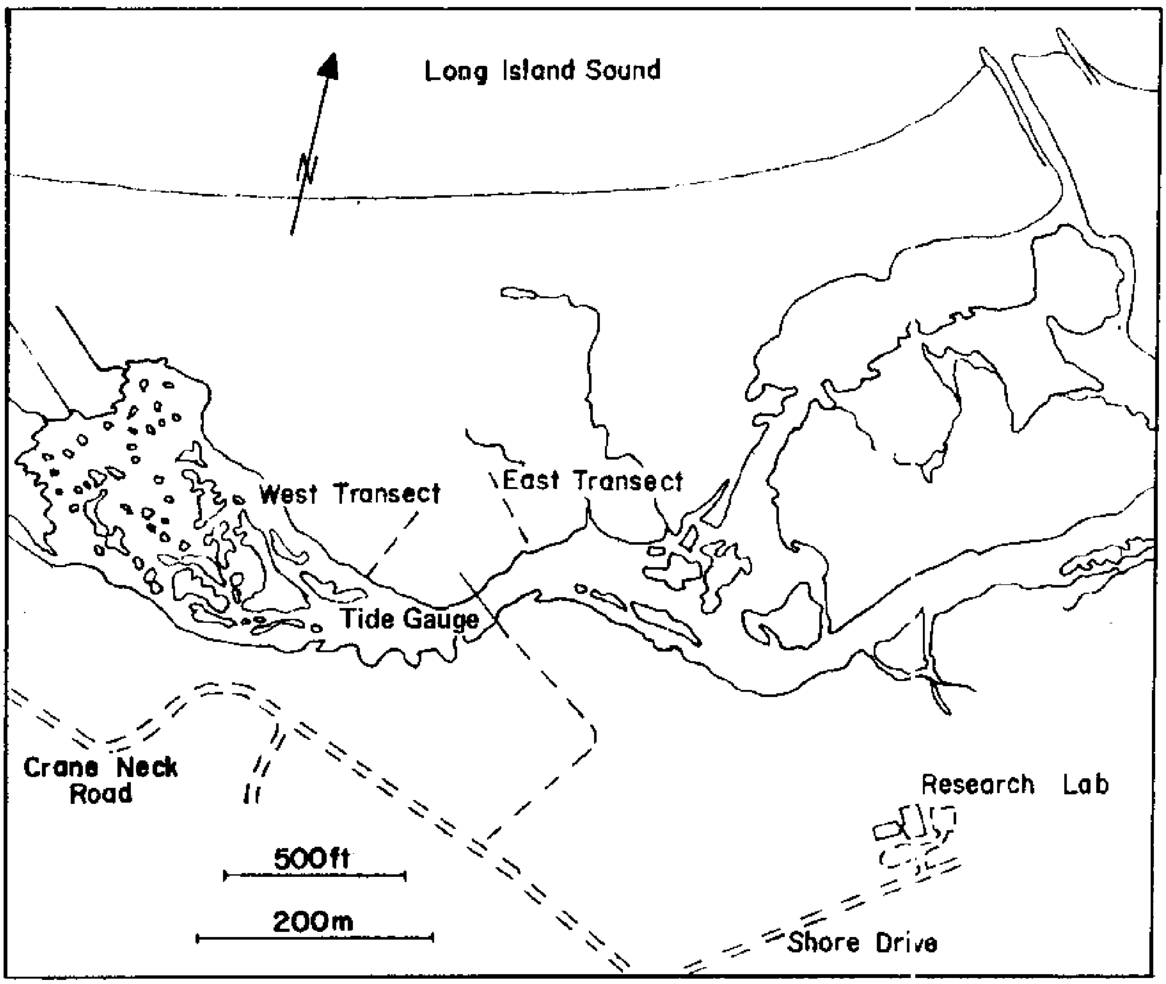
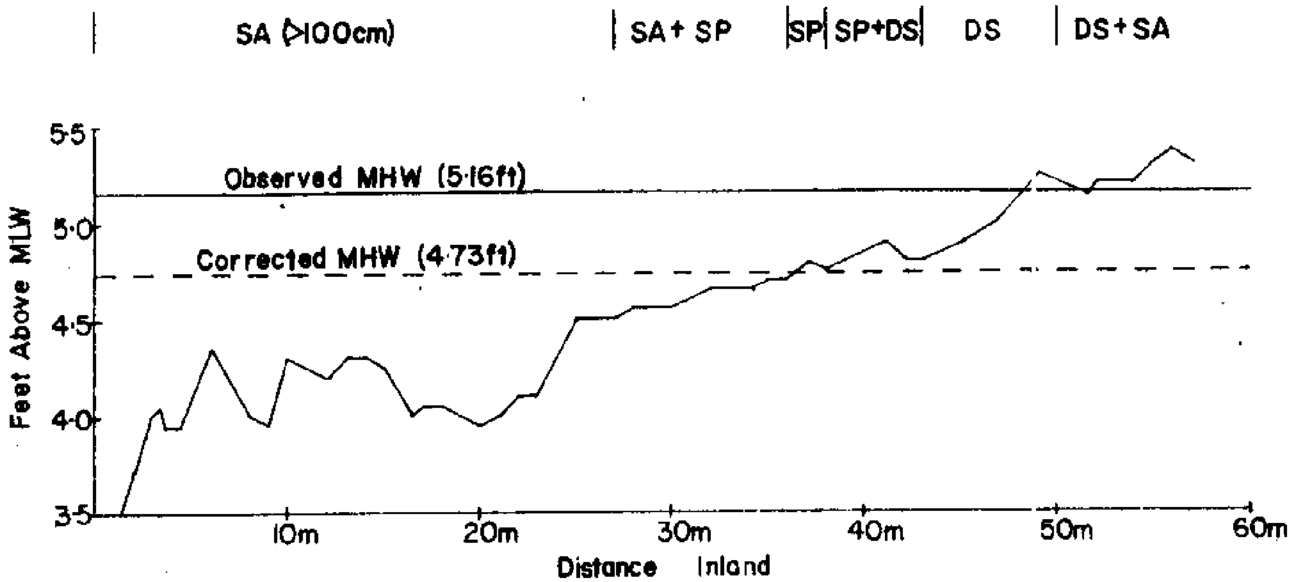
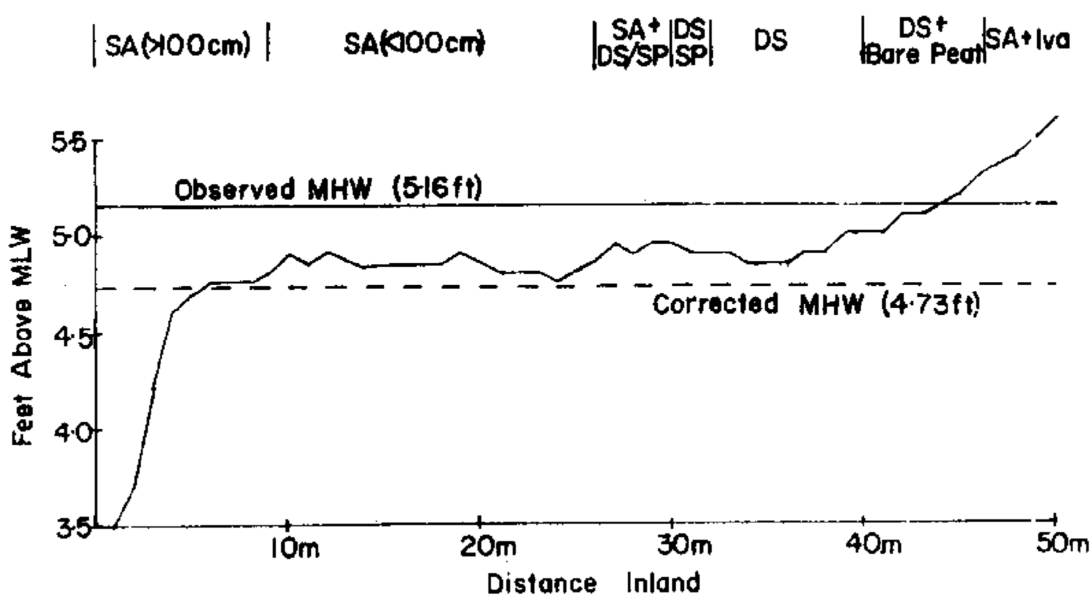


FIGURE 11 *Flax Pond, East and West Transects*





marsh edge, leveling at approximately the elevation of MHW (0.4 feet below observed MHW). The tall *S. alterniflora* zone extends 9 meters inland, ending as the marsh surface rises 0.15 feet above MHW (0.25 feet below observed MHW) and the height of the grass decreases to 50-70 cm. Twenty-five meters inland, there is a 4-meter transition zone of mixed *S. alterniflora/S. patens/D. spicata* at 0.25 feet above MHW (0.15 feet below observed MHW). Beyond this is the *D. spicata* high marsh.

Along the east transect, tall *S. alterniflora* extends 25 meters inland, ending in a mixed *S. alterniflora/S. patens* growth 0.25 feet below MHW (0.65 feet below observed MHW). In this ecotone, *S. alterniflora* is dominant to 0.1 feet below MHW (0.5 feet below observed MHW). Towards the upland border, zones of pure *S. patens*, mixed *S. patens/D. spicata*, and pure *D. spicata* occur at successively higher levels.

Beyond this typical high marsh is a zone peculiar to Flax Pond, in which the *D. spicata* is sparse, patches devoid of vegetation are numerous, and *Salicornia virginica* is prevalent in many places. Most unusual is the presence of an anomalous zone of tall, flowering *S. alterniflora* directly above this depauperate region. On the west transect this renewed growth forms a narrow belt from 0.65 feet above MHW (0.25 feet above observed MHW) to 0.9 feet above MHW (0.5 feet above observed MHW) and separates the marsh from the shrub zone. While less pronounced on the east transect, tall, flowering plants are scattered along the shrub border as high as 0.6 feet above MHW (0.2 feet above observed MHW).

The corrected MHW on the west transect marks the decrease in height of *S. alterniflora*. The short *S. alterniflora* zone is only 0.1-0.2 feet above the corrected MHW.

Most of the marsh surface is below the observed MHW. In both transects the intersection of this plane and the marsh surface occurs only toward the end of the high marsh. This is in contrast to the other four locations, where most of the marsh surface is above both planes. At Flax Pond, excluding the anomalous *S. alterniflora*, the observed MHW includes all of the *S. alterniflora* and most of the high marsh, and the corrected MHW includes all of the tall *S. alterniflora* and some transitional high marsh area.

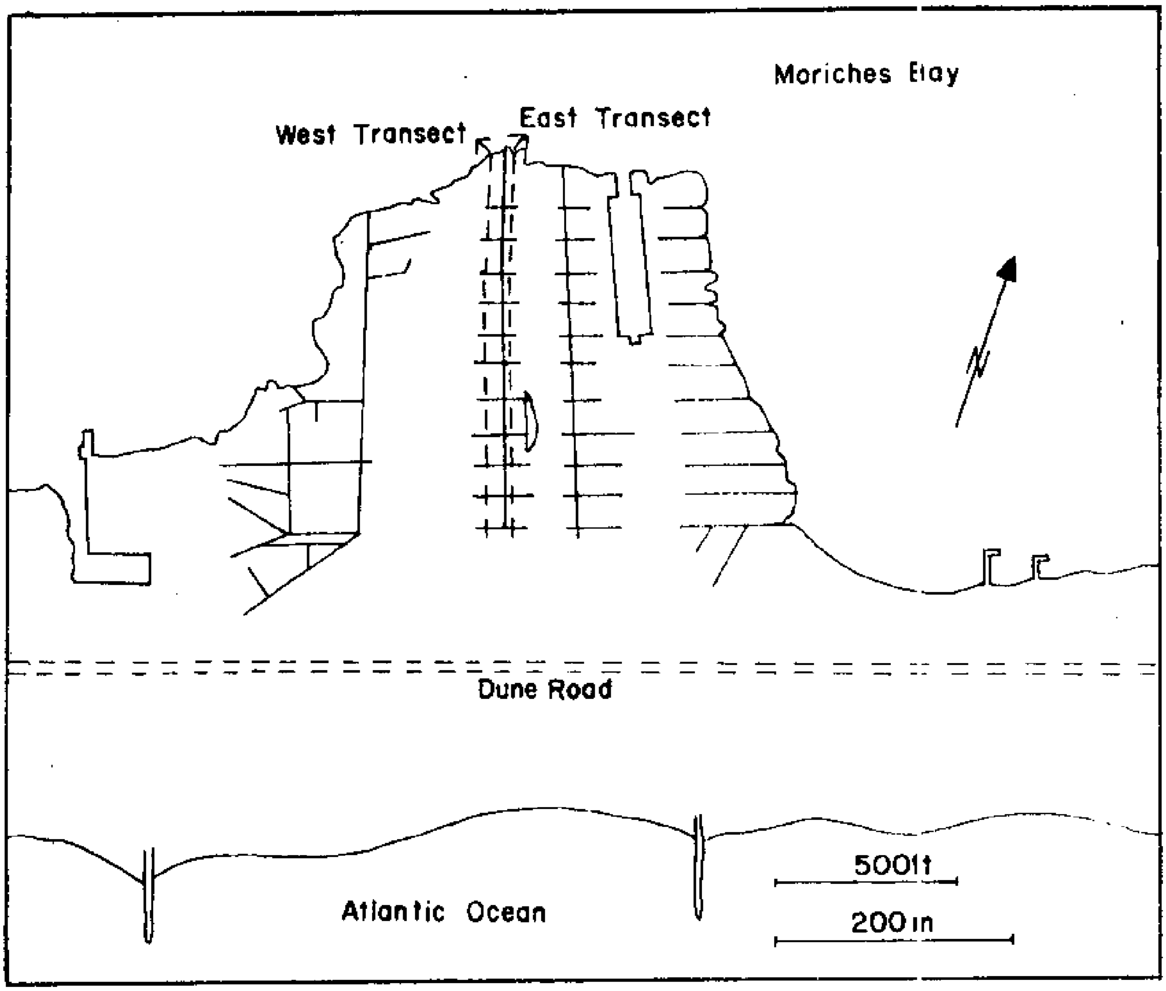
Gunning Point

Gunning Point (40°47'N; 72°41'W), on the bay side of Westhampton Beach, is about three miles east of Moriches Inlet. Approximately 50 percent of the privately owned marsh is *S. alterniflora*, with *S. patens* the next most abundant species. *Salicornia europea* is prevalent, often occurring in extensive salt pans devoid of other vegetation. There is no *D. spicata* zone or shrub zone. A dense stand of *Phragmites* separates the marsh from Dune Road. The narrow strip of marsh is flanked by fill along both sides, and mosquito ditching is extensive (Fig. 12).

Gunning Point is a south shore marsh with small tidal amplitude. The vegetation shows distinctive zonation patterns, and the high marsh area is substantial. In addition, as part of a comprehensive study of the area, the US Army Corps of Engineers recently computed tidal datums and surveyed marsh-surface elevations.

The short-term tide record, running from May through October 1973, showed 280 high waters and 279 low waters. Corrections for long-term means were made from 261 days of comparisons to Sandy Hook. The corrected MHW is 1.14 feet (re SLD). This is 0.47 feet below the observed MHW of 1.6 feet (re SLD) (Suszkowski, 1973). Of the five locations in this study, Gunning Point shows the largest difference between the two datums.

FIGURE 12 *Gunning Point*



Tidal datums at Gunning Point are similar to those of Eastport, Moriches Bay, where MHW is 1.17 feet (re SLD) and the mean range is 1.2 feet (US Dept Commerce, 1969*e*). Other areas in Moriches Bay (Potunk Point and Mastic Beach) have a range of only 0.5 feet (US Dept Commerce, 1972). SpHW could not be computed because the spring range for the Eastport station was not given.

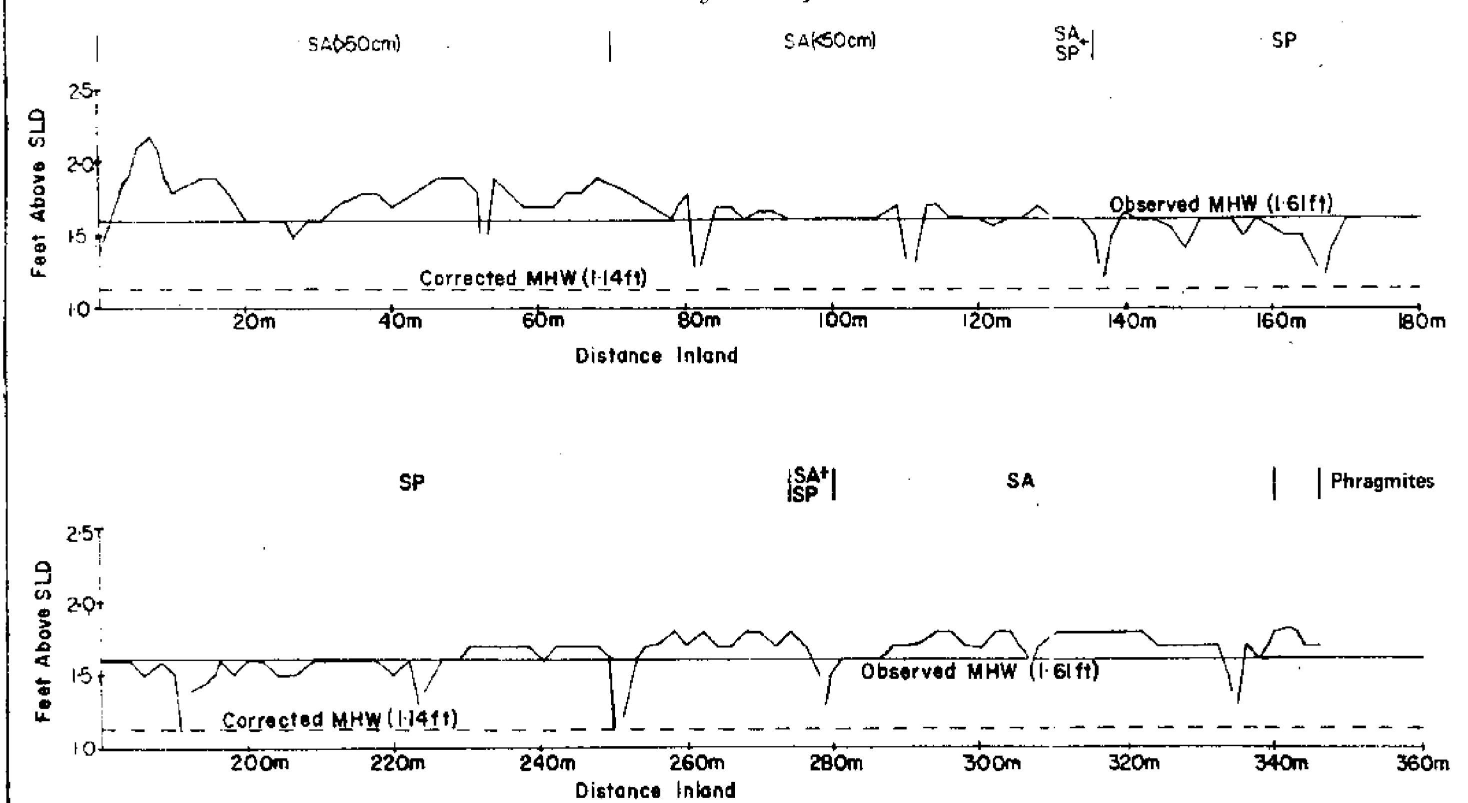
Two transects, one 10 meters west and one 5 meters east of the main drainage ditch, extend 340 meters inland from Moriches Bay. They have similar vegetation zones and elevations (see Fig. 13 for data on east transect).

Along both transects *S. alterniflora* begins growing at 0.15 feet above MHW (0.3 feet below observed MHW). The primary zone of *S. alterniflora* extends 120-125 meters inland. Within this region, plants range from 70-80 cm high nearest the bay to 40 cm or less further inland. The usual elevational sequence is reversed; the short *S. alterniflora*, most of which is 0.45 feet above MHW (the level of observed MHW), is 0.2-0.3 feet below the taller growth.

The transition to high marsh is abrupt and forms a strongly demarcated borderline. There is no corresponding change in elevation. *S. patens* grows at the same elevation as does the short *S. alterniflora*. The *S. patens* is commonly stunted or dying out in extensive pans between mosquito ditches. Occurrence of these pans is not specific to any one elevation but seems to depend upon the relative elevation of the surrounding marsh. Further inland, as the surface rises another 0.1-0.2 feet, so that it is 0.6 feet above MHW (0.15 feet above observed MHW), the *S. patens* becomes more vigorous.

Perhaps the most interesting aspect of the Gunning Point marsh is the secondary zone of *S. alterniflora* beyond the *S. patens* high marsh. Again, there is a distinct borderline with no marked change in elevation. Most of

FIGURE 13 *Gunning Point, East Transect*



this zone is 0.6 feet above MHW (0.15 feet above observed MHW).

Elevations surveyed by the Corps of Engineers support the transect results. Most marsh elevations are between 0.35 feet above MHW (0.1 feet below observed MHW) and 0.65 feet above MHW (0.2 feet above observed MHW) and do not correspond to any particular type of vegetation. The *Phragmites* zone along the marsh border is about 1.5 feet above MHW (1 foot above observed MHW). Fifty feet from the start of this growth, the elevation rises 1 foot, and at Dune Road the elevation is only about 6 feet above MHW (Suszkowski, 1973).

The corrected MHW, below the entire marsh surface, shows little relationship to vegetation zones. Furthermore, the overlap in elevations of *S. alterniflora* and *S. patens* is so great that it is hard to define any specific elevation separating them. Both short *S. alterniflora* and *S. patens* grow at approximately the MHW level, and taller *S. alterniflora* (70 cm) grows as much as 0.6 feet above this plane on the berm near the marsh edge.

Comparison of Results With Other Research

The results of previous research, the possible influence of factors other than the tide, and certain technical characteristics of tidal measurements must be considered in evaluating the correlation between vegetation and a tidal datum.

It is widely accepted that the primary factor controlling the distribution of salt marsh vegetation is the relationship between the tide and the marsh surface elevation. My findings support the general concept that species are distributed according to elevation. *S. alterniflora* usually occurs at lower elevations than do high marsh species. What remains unanswered is the extent to which tide levels control zonation and the consistency of the relation between a specific tide-elevation (such as the intersection of MHW) on the marsh and vegetation.

Comparing plant distribution in several North Carolina marshes, Adams (1963) concluded that species occur primarily in response to tide-elevation influences. He hypothesized that for every marsh, each species occurs within a narrow elevation range, which has a specific relationship to the tide in that area. Despite a lack of data to support this hypothesis, Adams still claimed that some species have a constant tide-elevation relationship.

Several studies on the tide-elevation factor were conducted at Cold Spring Harbor, New York. The assumption that MHW is the upper limit of *S. alterniflora* seems to originate mainly from these investigations. But variations in the results of different reports shed doubt on the validity of this assumption. Measuring the tide with a graduated stake, Johnson and York (1915) found *S. alterniflora* growing between levels of 1.5 and 6.5 feet above MLW. The tide range at Cold Spring Harbor is 7.63 feet (Chapman, 1940). This places MHW 7.63 feet above MLW, 1 foot above Johnson and York's estimate of the upper margin of *S. alterniflora*.

Chapman (1940) separated the marsh into upper and lower divisions, based on the relative periods of submergence and exposure, at 7.75 feet above MLW. This elevation, 0.1 feet above MHW, corresponds to a change in species composition.

At the same location, Conard (1935) reported that *S. alterniflora* grows between the 5- and 7-foot levels (no reference elevation given) where MHW is 7 feet. Not only is the upper limit at MHW different from the previous values, but the 2-foot range of growth is only one-half of Johnson and York's 1915 estimate.

Elevations reported for high marsh species in these studies are as variable as those for *S. alterniflora*. Johnson and York (1915) found *S. patens* and *D. spicata* between 6.5 feet and 8 feet above MLW. This extends 1 foot in elevation below MHW. Conard (1935) found *D. spicata* from 7 to 8 feet and *S. patens* from 7.5 to 8 feet. Both are above his 7-foot level of MHW.

Although these reported elevations imply that the zones of *S. alterniflora* and high marsh are mutually exclusive, Johnson and York (1915) found *S. alterniflora* as high as 7.5 feet above MLW, and Conard (1935) found *S. patens* growing as low as 5.5 feet. This suggests that factors other than tide-elevation influence vegetation--an important consideration when attempting to equate the upper limit of a species with one particular elevation.

Other investigations also show substantial overlap between *S. alterniflora* and other species. At Mispillion, in Delaware, Bourn and Cottam (1950) reported a vertical range of 1.88-2.93 feet for *S. alterniflora* and 2.58-3.32 feet for *S. patens*. This indicates that at 0.4 feet, either species can occur. Although Adams (1963) found species occurring within narrow elevation limits, *S. alterniflora* did extend into the range of *S. patens* and *D. spicata*.

My findings show that, excluding mixed zones (where species must occur at the same elevation), even monospecific zones overlap. At Gunning Point, the highest elevation of *S. alterniflora* is 0.7 feet above the lowest elevation of *S. patens*. A zone of *S. alterniflora* at Flax Pond occurs above the *S. patens* and *D. spicata* high marsh.

Still other findings suggest that the tide relationship is not solely responsible for species distribution. Chapman (1940) found *S. alterniflora* more tolerant of submergence further south in its geographical range. Mosquito ditching altered the elevations of species in Mispillion, Delaware (Bourn and Cottam, 1950). Jackson (1952) found that throughout a single marsh, zones of one species may occur at different elevations; this is apparent at Mattituck and Orient, where zones of one species occur at higher elevations further inland than zones of the same species near the marsh edge.

Measuring other factors that influence plant distribution was beyond the scope of this project. Salinity measurements were only intended to detect any major difference among the marshes--not to describe the effects of salinity within a marsh.

There is little agreement over the influence exerted by other factors like salinity. In North Carolina, Reed (1947) found a decreasing gradient in salt concentration from *S. alterniflora* to higher levels, and concluded that salinity was partly responsible for species distribution. Both Chapman (1940) and Adams (1963) found no constant differences in salinity among plant communities.

Such factors as aeration, drainage, soil characteristics, and nutrient concentration may all influence species distribution or growth form. The occurrence of tall *S. alterniflora* along ditches and creeks may be due to good drainage. Chapman (1940) believed that drainage was not responsible for its presence in these areas, but could considerably affect the height and vigor of the plants.

The variations in height of *S. alterniflora* are often striking. At Mattituck, plants of this species range from 20 cm to 150 cm high. There are several theories on the cause of such variation. The short *S. alterniflora* may be a genetic subspecies (Merrill, 1902), or it may be stunted by environmental factors (Mooring *et al.*, 1971). In addition to the drainage factor, high nutrient concentrations along creeks and near the low tide line may be responsible for increased vigor (Marsh, 1969). Adams (1963) wrote that *S. alterniflora* has a high iron requirement which is best satisfied where flooding is greatest. Taylor (1938) reported that salinity influences height.

This growth variation is important because it suggests a relationship to tidal planes and, therefore, may possibly be used to indicate a borderline. In the case of Dolphin Lane Associates, Ltd. *v.* Town of Southampton (1971), an expert witness testified that the area where *S. alterniflora* is lush and almost entirely in blossom is congruent with the area flooded at every high tide. If this were true generally, all areas with tall *S. alterniflora* would definitely be below the elevation of MHW.

My observations indicate that this is not true. *S. alterniflora* does seem to grow best at lower elevations, near the marsh edge or along creeks and ditches. Most of the taller growth is below the observed MHW at all the locations, but only at Flax Pond and Mattituck is most of this zone included below the corrected MHW. Even at Flax Pond, flowering *S. alterniflora* grows over 1 meter tall along the upland border, more than 0.5 feet above either plane of MHW.

A difficulty in using vigor to indicate a borderline is deciding how tall is the "tall" form of *S. alterniflora*. Height differences are relative in each marsh. At Flax Pond, tall *S. alterniflora* grows up to 2 meters, while at Gunning Point the tallest plants are only 1 meter high. Mixed *S. alterniflora/ S. patens* zones often exhibit increased vigor over surrounding monospecific zones. Although the taller form usually blossoms, flowering is a poor criterion for determining the tall form because some of the shortest plants also flower.

Plant zonation is complex; this alone makes vegetation a nebulous indicator of a tidal datum. To evaluate any correlation between MHW and vegetation, however, one must also consider certain characteristics of the tidal phenomena.

Any tidal datum is an artificial construct designed to describe a characteristic of the tide in a specific area. Mean high water is simply an average height of all the high waters over a given period. The value of high water varies greatly, and, as with any mean, extremes affect its value. I found individual high waters at Mattituck differing by as much as 5.9 feet.

It would be incorrect to assign a precise physical value to such a mean, e.g., the line that the tide usually reaches, or the zone covered twice a day by the tide. Describing the *S. alterniflora* zone as "intertidal," "flooded each day," or "extending to the high-water mark" cannot be interpreted as meaning that the upper limit of *S. alterniflora* is MHW. For instance, of the 707 high tides at Boston in 1968, only 316 were predicted to reach or exceed the level of MHW (Redfield, 1972). Thus, less than one-half of the high tides there actually reached the line of mean high water.

Determining a tidal datum incurs further difficulties. Monthly and even yearly high waters are subject to periodic and nonperiodic variation. Monthly averages of high waters from Atlantic City, Los Angeles, and Pensacola for two years (1946-47) varied from a few hundredths of a foot to 0.8 feet (Marmer, 1951). In my study the minimum variation in a monthly average was 0.1 feet at Orient, and the maximum was 0.6 feet at Iron Point.

Because of such variations, short-term mean values are corrected to a tide station where observations over a 19-year period have been recorded. According to Marmer (1951), a corrected datum from one month's observation is generally within 0.1 feet of a well-determined value.

Using a 19-year average, however, introduces the problem of variations in relative sea level over this extended period. On the east coast of North America, two factors--a worldwide trend in sea level rise and coastal subsidence--have contributed to the change in the value of mean sea level. Since 1930 the apparent rise in sea level in the New York area determined from tide gauge records has averaged 3.5 mm per year (Meade and Emery, 1971).

This increase is obvious in the observed tide gauge records for the National Ocean Survey station at Montauk. Observed values of HTL (half-tide level, which approximates mean sea level) were 4.51 feet for 1924-42; 4.74 feet for 1941-59; and 4.84 feet for 1951-69 (US Dept Commerce, 1974). The accepted 19-year value of HTL used for comparisons to short-term records is presently 4.68 feet.

Sea level rise probably accounts for the fact that observed values of MHW are conspicuously higher than the corrected values. Other factors may also contribute to this difference. Some of it may be periodic, resulting from astronomical cycles. The opening and maintenance of Moriches Inlet surely have influenced the tides at Gunning Point. Dredging the boat channel could have affected the tidal amplitude at Mattituck. The National Ocean Survey tide predictions for MHW at Mattituck Inlet showed an increase from 5.0 feet in 1972 (US Dept Commerce, 1971*a*) to 5.2 feet in 1973 (US Dept Commerce, 1972).

Corrected MHW

The corrected MHW, approximating a 19-year average, is important in legal matters because it is the accepted definition of MHW. The vegetation, however, probably more closely reflects the recent tidal phenomena. For instance, the abnormally high value of MHW at Gunning Point over the 1973 growing season may have caused the depauperate growth of *S. patens*. Unfortunately, few long-term studies have been conducted to determine how rapidly vegetation reacts to such phenomena. Harrison and Bloom (1974) reported that over a 10-year period the ecotone of *S. alterniflora* and *S. patens* in Connecticut marshes did not reflect changes in sea level.

At Mattituck all of the tall *S. alterniflora* is below the corrected MHW. Intersection of this datum with the marsh surface coincides with a mixed *S. alterniflora/S. patens* zone. Orient is similar to Iron Point: only the first 3 meters of marsh are below the corrected MHW. At both marshes, this plane intersects within the tall *S. alterniflora* growth. At Flax Pond, the corrected MHW coincides with the upper border of tall *S. alterniflora* on one transect and at the transition from *S. alterniflora* to *S. patens* on the other. At Gunning Point the entire marsh surface is above the corrected plane of MHW.

Observed MHW

Excluding the filled area, at Mattituck the observed MHW coincides with the lower margin of a short *S. alterniflora* zone, but nearer the marsh edge, zones of both *S. patens* and short *S. alterniflora* occur beneath this plane. At Orient, the observed MHW marks the upper limit of the tall *S. alterniflora*. Observed MHW intersects the marsh at Iron Point within a mixed zone on one transect and at the point where *S. alterniflora* decreases in height on the other. At Flax Pond, observed MHW intersects the marsh in the middle of the high marsh region, and at Gunning Point, this plane is level with much of the marsh surface, intersecting the marsh surface in several apparently random spots.

Each marsh is unique in terms of tidal influence, water source, formation, and human intervention, so that some modification of the tide-elevation effect is to be expected. The very narrow zone of tall *S. alterniflora* at Mattituck, for example, may be the result of mechanical removal of part of the marsh edge during dredging. Limited water exchange through the narrow outlet at Flax Pond may reduce nutrient loss and perhaps account for the high vigor there. Either the inequality of flood and ebb intervals or the large tidal amplitude at Flax Pond could also influence vegetation vitality and zonation. Gunning Point, located on a barrier beach, is probably subject to the effects of storm overwash and beach erosion.

Establishing an Upland Margin

There is a final question important in legal definitions of wetlands: What relationship, if any, exists between the upland margin of the marsh and the tide? At this border, definition by vegetation creates problems. Typical plants along the upland region include *I. frutescens*, *Phragmites*, *B. halmifolia*, and *Typha* spp. (cattails). But some of these plants are not restricted to growth along the salt marsh border.

Because these plants can grow elsewhere, their upper elevation limits have little meaning. More significant is their lowest elevation (i.e., where they first appear). At Cold Spring Harbor, Johnson and York (1915) found

I. frutescens 0.1 feet below MHW. This is only 1 foot above the zone of *S. alterniflora*. At Mattituck, the beginning of the shrub zone is 0.9 feet above the corrected MHW and 0.6 feet above the observed MHW. One point along the shrub-high marsh border at Orient is 0.6 feet above the corrected MHW and 0.3 feet above the observed MHW. This elevation is lower than some of the *D. spicata*, *S. patens*, and even *S. alterniflora* at Orient.

Phragmites at Orient begins growing at 0.7 feet above the corrected MHW and 0.3 feet above the observed MHW. The border between *S. patens* and *Phragmites* at Iron Point is almost 3 feet above either plane of MHW. Corps of Engineers survey data at Gunning Point indicate that the lower edge of the *Phragmites* zone is about 1.7 feet above the corrected MHW and 1.1 feet above the observed MHW (Suszkowski, 1973).

Rather than define the upland margin using species whose distribution is variable, it might be better to describe the marsh border, where applicable, in terms of a change in growth form from grasses to woody shrubs and to define a specific distance inland from this border as a contiguous buffer zone.

Another way of establishing an upper margin is to estimate an elevation that would include most of the highest tides. Redfield (1972) reported that flooding by only one percent of the tides for two hours affects vegetation. This indicates that such a margin must include even extreme tides. Table 7 shows the elevation reached by the highest tide observed over the three-month period for the three locations where I ran tide gauges. Storm tides could go considerably higher.

Several states currently define such an upper margin in terms of an elevation above MHW. In Delaware, a wetland includes all the land up to 2 feet above the local MHW.[1]

Perhaps the most defensible use of a tidal datum in defining the upper margin of a marsh is expressing that datum as a proportion of the local tide range. Virginia uses such a method: wetlands extend to "an elevation above the mean low water equal to the factor 1.5 times the mean tide range at the site."[2] This compensates for varying tide ranges. Applying Virginia's 1.5 factor would make the upper border at Gunning Point 0.7 feet above MHW, while at Mattituck it would be 2.5 feet above MHW. This elevation would be above most of the marsh surface at Gunning Point and well within the shrub growth at Mattituck.

Determining an optimal range factor or height above MHW requires a thorough study of predicted tides. Table 7 includes the height of the extreme observed tide above MHW and its proportion of the tide range, and it gives an

[1] Delaware Code c.66, Section 6603.

[2] Virginia Code, Section 62.1-13.2.

TABLE 7 *Highest Tides Recorded Over Three Months' Observation Period*

Location	*Date*	*Height (re SLD)*	*Height Above MHW*		*Proportion of Tide Range**	
			Corrected	*Observed*	*Corrected*	*Observed*
Mattituck	12/9	5.43	2.67	2.43	1.52	1.47
Iron Point	12/9	4.23	2.75	2.42	2.01	1.87
Orient Point	12/9	3.87	2.47	2.15	2.10	1.95

* Calculated as the height of the tide above MLW divided by the tide range.

idea of what only three months of observations indicated.

Although a tidal datum provides an exact borderline, it should be used with extreme caution in defining wetlands. For conservation purposes, a definition should include all of the wetlands, but should also uphold the right of private ownership. A definition of wetlands that also applies to large amounts of land other than wetlands jeopardizes the private owner's rights and weakens the effect of the legislation.

Conclusions and Recommendations

Vegetation cannot be used to indicate the line of MHW on the marsh surface. Neither species distribution nor plant vigor exhibits a consistent relation to the corrected MHW or the observed MHW. The upper margin of *S. alterniflora* cannot be equated with either plane of MHW.

Therefore, I do not recommend using the *S. alterniflora/S. patens* ecotone as the boundary between public and private ownership or as the upper limit of jurisdiction in navigable waters. The transition from *S. alterniflora* to high marsh could occur below the line of MHW, reducing the area of publicly owned wetlands. But more likely, the line of MHW on the marsh surface would be below the ecotone, resulting in an injustice to the private owner.

Much of the *S. alterniflora* growth in the five marshes studied was above both corrected and observed MHW; therefore, we should not assume that most of the *S. alterniflora* marsh is under the protection of public ownership or navigable waters.

It is apparent from this study that other factors modify the tide-elevation influence. The combined effects of salinity, substrate, tide, and so on are unique in each salt marsh. The tide-elevation factor may influence vegetation more in connection with slight changes in marsh topography than as an absolute species-elevation relationship. Thus, an area surrounded by higher surfaces may support vegetation usually found at lower elevations.

Because a tidal datum offers a distinct and indisputable border, it can strengthen the definition of wetlands used in legislation. Choosing a tidal height indicative of the upper margin of the marsh, however, presents problems akin to those of using vegetation as an indicator of MHW. The shrub zone does not appear to correspond to a specific elevation in relation to the tide. A tidal datum of a certain number of feet above MHW or a height proportional to the local tide range is only an estimate based upon the expected amount of tidal inundation.

For this reason a tidal datum, if used in a wetlands definition, should be only one of a number of criteria. The primary basis for determining the presence of a wetland might be a much-reduced number of plant species like *S. alterniflora*, *S. patens*, *D. spicata*, *J. gerardi*, and *Salicornia* spp. Second, salt marsh peat at the surface level could be proof of a wetland. As a last recourse, an upland border could be defined as a height above mean low water equal to a predetermined factor times the local tide range. This need only be used for areas where the other criteria are inadequate to define the wetland.

I recommend that a wetlands definition include all tidal wetlands and still protect the private owner from unjust restriction on lands other than wetlands. State wetlands legislation should also be coordinated, and local laws should be made uniform.

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Appendix A: State Wetlands Legislation

Recognizing that salt marshes are "in jeopardy of despoilation by persons unmindful of the economic and aesthetic consequences of such spoilation" (1), several coastal states have enacted regulatory legislation "to preserve and protect the productive public and private wetlands and to prevent their despoilation and destruction" (2). Basically these laws prohibit any unauthorized alteration of coastal wetlands. The extent of restriction, process and standards of review, provision for compensation, and definition of wetlands differ among the states. A brief summary of some of the Atlantic coastal states' wetlands legislation highlights these differences and may provide a basis for comparison and evaluation of wetlands laws.

In 1963 Massachusetts became the first state to enact legislation regulating the use of coastal wetlands by imposing conditions on removing, filling, or dredging of material in any "bank, flat, marsh, meadow, or swamp bordering on coastal waters" (3). Neither the exercise of eminent domain nor compensation was provided for; municipalities still retained the right to exercise their own regulatory authority.

Subsequent Massachusetts legislation, enacted in 1965, gave the commissioner of natural resources the power to "adopt, amend, modify, or repeal orders regulating, restricting, or prohibiting dredging, filling, removing, or otherwise altering, or polluting, coastal wetlands" (4). This law does provide for compensation and taking by eminent domain when an appeals court finds a restrictive order to be an unreasonable exercise of police power (5).

In 1965 Rhode Island established a program for wetlands protection, authorizing the director of the Department of Natural Resources to "designate coastal wetlands or parts thereof, the ecology of which shall not be disturbed and the use of which shall be restricted to those uses compatible with the public policy [preserving the purity and integrity of wetlands] of this state" (6). When a superior court finds a restriction causes an owner to suffer damages, the owner may recover compensation paid either from funds appropriated specifically to carry out this act or from a recreation and conservation land acquisition fund (7).

Both Maine and New Hampshire enacted dredging and filling laws in 1967. Maine requires a permit, approved by both a Wetlands Control Board and the affected municipality, to conduct such activities. An owner may appeal a permit denial or restrictive condition to determine if the regulation deprives him of the lawful use of his property, but no provision is made for compensation or the exercise of eminent domain (8). New Hampshire's original excavation and dredging law has undergone several amendments since its inception. As in Maine, the state requires permits to excavate, remove, fill, or dredge "any bank, flat, marsh, or swamp in and adjacent to any waters of the state" (9). The reviewing body is the Water Resources Board. If, upon appeal, a superior court determines that a regulation constitutes an unjust taking, the state may draw upon special funds to purchase the land or interest therein (10).

In 1969 Connecticut became one of the first states to enact a comprehensive wetlands bill requiring an inventory of all wetlands (including freshwater wetlands) within the state. After a wetland is designated by the commissioner of environmental protection and a subsequent public hearing on such designation, permits are required to conduct any regulated activity in that area. Regulated activities include: draining, dredging, excavation, or removal of any material; dumping, filling, or depositing any material; and erecting structures, pilings, or obstructions. If a higher court should find a regulation unreasonable, it may award damages or rescind the restriction (11).

Modeled after Connecticut's bill, New Jersey's 1970 Wetlands Act regulates similar activities and initiated a two-year inventory of the state's wetlands (12). Previously, the Board of Commerce and Navigation reviewed and usually approved all plans for waterfront development (13). The 1970 act does not allow for taking or for compensation. Instead, if a superior court determines the restrictions are equivalent to taking, it waives the regulation (14).

Florida, faced with rapid, expanding development, has dealt with the problem of wetlands loss with a series of restrictive acts regarding the sale or conveyance of tidelands, the establishment of bulkhead lines, and the filling or dredging of tidal lands. Permits to conduct such activities require an ecological, biological, and, when necessary, hydrographic survey undertaken at the owner's expense (15).

Virginia's wetlands legislation combines state and local control. The state Board of Marine Resources, in conjunction with the Virginia Institute of Marine Science, maintains a continuing inventory of the state's wetlands. The board establishes standards and policies for wetlands and adopts regulations to enforce them (16). The act authorizes municipal governments to adopt a wetlands zoning ordinance, the terms of which are set forth in the state law. Permits from local wetlands boards are necessary to conduct any activity other than those specifically permitted by the law (17). The commissioner of the Department of Conservation, Development, and Natural Resources reviews the decisions of the local boards and may, under certain circumstances, modify or repeal the order (18). The law does not provide for taking or for compensation.

Maryland's Wetlands Act of 1970 differs from the previous laws in that it divides wetlands into two categories: "state wetlands" and "private wetlands" (19). A license is required from the Board of Public Works to dredge or fill in any state wetland (20). The secretary of natural resources, in consultation with the Maryland Agricultural Commission, designates the wetlands within the state and promulgates rules and regulations for the use of private wetlands, based upon the value of each particular area. A permit is required in private wetlands to conduct all but certain activities. Among these are the right to make improvements on the land, the right to preserve access to waters adjacent to the land, the right to prevent erosion, and the right to reclaim "fast" land (21). This act represents Maryland's first substantial change in riparian ownership law in 100 years (22) and reflects the state's reluctance to obviate any right of private ownership.

With the passage in 1973 of the Delaware Wetlands Act, Delaware joined the ranks of states regulating wetlands use. While this law requires permits for alterations and orders a state wetlands inventory, its emphasis on private rights is similar to Maryland's. The declaration of policy specifically states that preservation of wetlands must be "consistent with the historic right of private ownership of lands" (23). To protect these rights, the act created the Wetlands Appeals Board, consisting of seven Delaware residents representing various interests (24). People affected by restrictions on the use of their land must first appeal to this board, and then, if unsatisfied with the decision, they may appeal to a superior court. The law provides for fee simple or lesser acquisition of the land when the court rules in favor of the owner (25).

New York State's Tidal Wetlands Act of 1973 (26) made New York the last northeastern coastal state to enact coastal wetlands legislation. Prior to this, the state had little power to protect wetlands. As elsewhere, review of Corps of Engineers dredging notices provided some control, but this extended only as far as the corps' jurisdiction--to mean high water. New York does have a law which prohibits excavation and filling in "marshes, estuaries, tidal marshes, and wetland" adjacent to, or contiguous to, navigable waters of the state (27). Unfortunately, the definition of "navigable waters" does not include those of Nassau and Suffolk counties (28).

New York's first major attempt at coastal wetlands preservation was the 1959 Long Island Wetlands Act. This act encouraged local governments to enter into cooperative agreements with the state to protect wetlands (29). Under such agreements, a municipality could dedicate a wetland to conservation and the Department of Environmental Conservation (EnCon) would aid in the development of the area and would finance one-half the cost of maintaining it (30). Since the law was enacted, the towns of Oyster Bay, Hempstead, Islip, and Brookhaven have entered into cooperative agreements with EnCon (31).

This cooperative system has several drawbacks. Agreements are subject to revision. Much of Suffolk County's wetlands are still under private ownership. The projected annual expenditure of only $15,000 also limits the act's efficacy (32).

A more permanent and more expensive approach to wetlands preservation is acquisition. The Environmental Quality Bond Act of 1972 provided $18 million from the total $1.15 billion bond issue for acquisition of tidal wetlands (33). The goal was to acquire 5,000 acres of wetlands over a three-year period, but a 10-to-15 percent inflation in real estate costs reduced this goal to 4,500 acres (34).

While acquisition may be the most effective means of preserving wetlands, lack of funds limits its scope. New York still needed a comprehensive program for all its coastal wetlands. In March 1972 the state legislature passed a wetlands bill introduced by State Senator Bernard Smith. Governor Nelson Rockefeller vetoed this bill in June 1972 on the grounds that it was restrictive to state utilities development. The Tidal Wetlands Act, drafted to meet Rockefeller's objections, was introduced by Assemblyman Peter J. Costigan and passed by the state legislature in December 1972. The governor signed this into law, effective 1 September 1973 (35).

In providing for an inventory of the state's wetlands and the regulation of their use, New York State's Tidal Wetlands Act is similar to other states' wetlands legislation. The law authorizes the commissioner of EnCon to adopt land-use regulations compatible with the public policy of preserving wetlands and with the value of each particular wetland (36). All regulated activities are prohibited without a permit (37). A significant addition is the establishment of a two-year moratorium on all wetlands alterations; this allows EnCon to conduct a thorough survey of New York's wetlands prior to designating land-use regulations (38).

The act upholds the rights of the private owner by providing for compensation when regulations are considered unjust (39), and by basing tax assessments, after the adoption of land-use regulations, upon the limitations imposed by such regulations (40).

The law does not undo previous progress in wetlands protection. Both special moratorium permits (41) and those required afterwards (42) are in addition to--not in lieu of--those required by municipalities. The cooperative program begun by the Long Island Wetlands Act is continued in a new provision for such agreements (43).

The enactment of this law gives New York the same status as its neighboring states. Variations exist among the laws, but the activities regulated are similar. Most of the laws include exemptions such as mosquito control, soil conservation, hunting, shellfishing, aquaculture, and maintenance of navigational aids. New Jersey and Delaware explicitly exclude haying and other agricultural activities from regulation (44). Virginia excludes "governmental activities" (45), and New York, after much controversy, exempted the state and its agencies from restrictions (46).

While the above differences are minor, differences in the definition of "coastal wetland" and therefore, the extent of jurisdiction, are significant. Here, one word can mean a considerable amount of land included or excluded from the law.

In Massachusetts, wetlands are simply:

> any bank, marsh, swamp, meadow, flat, or other low land subject to tidal action or coastal storm flowage and such contiguous land as the commissioner reasonably deems necessary (47).

Maine also uses a broad definition, including:

> any swamp, marsh, bog, beach, flat, or other contiguous low land above extreme low water which is subject to tidal action or normal storm flowage at any time excepting periods of maximum storm activity (48).

Rhode Island uses two criteria to define a "salt marsh": the presence of any of certain plant species (19 species); and "the occurrence and extent of salt marsh peat at the undisturbed surface." The salt marsh, together with a contiguous upland zone extending no more than 50 yards from the salt marsh border, comprise a "coastal wetland" upon which regulation is imposed (49).

Virginia, Connecticut, New Jersey, and New Hampshire supplement vegetation with tidal datums. Virginia's "wetlands" lie "between and contiguous to mean low water and an elevation above mean low water equal to the factor 1.5 times the mean tide range at the site" and support, as of 1 July 1972, a growth of at least one of 35+ plant species (50). In Connecticut a "wetland" is an area now or formerly bordering on or lying beneath tidal waters:

> whose surface is at or below an elevation of one foot above local extreme high water; and upon which may grow or be capable of growing some, but not necessarily all, of the following: [74 species including those of freshwater wetlands] (51).

This is said to include more area than any other coastal state's definition (52). New Jersey's definition is similar, except that only 19 species of plants are listed (53).

In New Hampshire, restrictions apply wherever the tide ebbs and flows to:

> all lands submerged or flowed by mean high tide as locally determined, and, in addition, to those areas which border on tidal water, such as, but not limited to banks...whose surface is at an elevation not exceeding three and one-half feet above local mean high tide and upon which grow or are capable of growing some, but not necessarily all, of the following: [19+ species] (54).

Limiting this is a statement similar to one in Rhode Island's definition:

> The occurrence and extent of saltmarsh peat at the undisturbed surface shall be evidence of the extent of jurisdiction hereunder within a saltmarsh (55).

Delaware adds to the confusion by using still another tidal datum in its definition. There, "wetlands" are those areas above mean low water, now or in this century connected to tidal waters:

> whose surface is at or below an elevation of two feet above local mean high water, and upon which may grow or is capable of growing any, but not necessarily all of the following plants: [29 species] (56).

Perhaps the most confusing definition is in Maryland's Wetlands Act of 1970. "State wetlands" refers to 'all land under the navigable waters of the State below the mean high tide, which is affected by the regular rise and fall of the tide" (57). Those lands which have been transferred by the state by valid grant, lease, or patent are considered "private wetlands." These include:

> all lands not considered "State wetlands" bordering on or lying beneath tidal waters, which are subject to regular or periodic tidal action and which support aquatic growth (58).

The law does not say what constitutes "aquatic growth" or what determines "regular and periodic tidal action." As stated, the definition suggests that the law applies only to lands below mean high water.

New York's Tidal Wetlands Act adds one more definition of "wetlands"; it is based primarily on vegetation and does not use a tidal datum. "Tidal wetlands" includes:

> a) those areas which border on or lie beneath tidal waters, such as, but not limited to, banks, bogs, salt marsh, swamps, meadows, flats or other low lands subject to tidal action, including those areas now or formerly connected to tidal waters; b) all banks, bogs, meadows, flats and tidal marsh subject to such tides and upon which grow or may grow some or any of the following: [13+ species] (59).

The definition of "tidal wetlands" published in the proposed moratorium permit procedure further extends the regulated area to include up to 300 feet landward of the marsh boundary as a buffer zone, at the discretion of EnCon's commissioner (60).

These definitions are inconsistent, often ambiguous, and, in some cases, indeterminable. Exactly how many is "some" plants? Many of the species lists contain plants that could grow in places other than a salt marsh or even land contiguous to a salt marsh. Both New Hampshire and Rhode Island laws contain a clause on salt marsh peat. Is this meant to be a required condition besides the other prerequisites? How is "extreme high water" to be determined in Connecticut and New Jersey? Why is a New Hampshire "wetland" 3.5 feet above mean high water and a Delaware "wetland" 2 feet above mean high water? Is it possible to be fair to all owners in determining the "contiguous zone"?

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Appendix B: Wetlands Preservation at the Local Level

Prior to Massachusetts' 1963 law regarding dredging and filling lands abutting on coastal waters (1), wetlands preservation was primarily a local effort. Local control continues as a means of preventing wetlands loss, but it lacks the uniformity of statewide legislation. A brief survey of the development of local preservation programs, including some of the municipal laws in Nassau and Suffolk counties concerning wetlands use, illustrates the extent of variation in both the degree of emphasis placed on wetlands and the methods used to prevent their destruction.

The establishment of local authorities responsible for natural resources was a major step toward wetlands preservation. In 1957, Massachusetts became one of the first states to pass legislation permitting the establishment of such authorities (2). The Municipal Conservation Commissions in Barnstable, Massachusetts succeeded in setting aside 3,300 acres of tidal marsh and appropriating an additional $15,000 for open space acquisition (3).

New York has similar legislation authorizing town boards to appoint a town conservation advisory council. One of the specified duties of such a council is to keep an inventory of "all open marsh lands, swamps, and all other wetlands" and to recommend "a program for ecologically suitable utilization of all such areas" (4).

As concern over destruction increased, municipalities began placing restrictions on the use of wetlands. In New York such authority derives from the Town Law together with the Municipal Home Rule Law; these give the power to preserve the general welfare of local residents. The local governments can thus enact laws and ordinances to protect wetlands (5).

One method of local regulation is using certain types of zoning restrictions to reduce the impact of development on wetlands. This has not always proved successful. Wetlands zoning in Connecticut was invalidated by a 1964 court decision that the zoning ordinance was an unlawful restriction on land use (6). In New York, legislation passed in 1956 allows municipalities to adopt floodplain zoning (7) like the Town of East Hampton's and the Village of Lloyd Harbor's, which require minimum fill elevations for residences built in the tidal floodplain (8). Cluster zoning on upland portions of shorefront property is another type of zoning useful in wetlands management. This permits an owner full use of his property, while the wetlands remain undeveloped (9).

Along with instituting zoning restrictions, municipalities can also enact ordinances regulating the alteration of wetlands. These can include a dredge and fill ordinance, a marine law, or a specific wetlands ordinance. Most towns in Nassau and Suffolk have such ordinances which, although variously worded, are similar in scope and intent.

Many of the town ordinances were originally designed to regulate activities within the town's waterways and have since been modified to include wetlands. In 1966 Babylon became the first town on Long Island to establish a dredging ordinance (10). Brookhaven developed a comprehensive marine law in 1967 and established a Board of Waterways and Natural Resources to oversee activities within the coastal zone (11). The Town of Hempstead declared a public policy of preserving the town's wetlands in 1968 (12). Other towns soon followed suit.

The intent of these laws is to provide for the "protection, preservation, proper maintenance, and use of [the town's] wetlands" (13), thereby preventing "unreasonable erosion of soil, increased turbidity, the loss of fish and aquatic wildlife, and the destruction of natural habitat" (14). In all such laws, the justification for regulation is that the watercourses and wetlands are essential to the health, safety, economy, and general welfare of the town's residents.

Basically these laws require permits for removal (of soil), filling, dredging, depositing, dumping, discharging, and construction in the private or public wetlands and watercourses of the town. At least one person from the town conservation advisory council, the town board, the town trustees, the planning board, or the board of waterways reviews the permit applications. The board or boards may: issue the permit if the proposed activity does not adversely affect watercourses, wetlands, and adjacent land; impose conditions on the manner and extent of such activities; or deny the permit.

A few of the laws, such as Islip's "Coastal and Interior Wetlands of the Town of Islip," provide for condemnation when limitations restrict use unlawfully (15). This law encourages private owners to grant the town conservation easements by explicitly allowing for real estate valuation based on imposed limitations (16). East Hampton's "Flood Control and Wetlands Preservation Ordinance" also mentions acquisition as a consideration, should denial of a permit deprive an owner of the lawful use of his property (17).

East Hampton's ordinance prohibits outright all activities altering wetlands. Should a property owner wish to make some alteration, he must apply directly to the Board of Appeals. If the board finds that the limitations imposed by the ordinance deprive the owner of the use of his property, it may either grant a "special permit" or refer the matter to the town board to consider acquisition (18). In this way the owner must prove that restriction is equivalent to a taking before obtaining a permit.

The Town of Hempstead has a different system of wetlands protection: it has laws requiring permits for dredging and construction in the town's waterways (19). The laws do not specifically pertain to wetlands, but as they apply to the town's watercourses and adjacent upland, wetlands can be included in these laws. Because the town owns most of its wetlands, such inclusion is superfluous.

Instead, Hempstead passed an ordinance dedicating all town-owned tidal wetlands and underwater lands to recreation and conservation (20). The intent of the law is most eloquently stated:

> to forever guarantee to the people of the Town of Hempstead the sanctity of such natural resources for their benefit and enjoyment and for the benefit and enjoyment of generations yet unborn" (21).

Lesser differences among these town laws pertain to penalties for violation, application procedures, fees, reviewing bodies, and exemptions from regulations. Usually mentioned in the last category are shellfishing, hunting, aquaculture, and mosquito control, but both the towns of Smithtown and Shelter Island explicitly exclude themselves from regulation (22).

A more important difference among the various laws is that of definition. A wetland ends where jurisdiction ends, and so the amount of land designated "wetlands" is significant. Of the ordinances discussed here, none uses a tidal datum or specific elevation in defining a wetland. Islip's and East Hampton's definitions include an extensive list of plants, while Shelter Island mentions only two species, *Spartina alterniflora* and *S. patens* (23). Huntington, Smithtown, and Brookhaven laws lack any reference to vegetation (24). Ambiguous terms such as "generally covered," "normally," "some," and "capable of growing," and undefined lay terms like "thatch meadow," "salt meadow," "bogs," and "swamps" are common.

The towns of Islip and East Hampton have separate definitions for a tidal marsh and wetlands. "Wetlands" is the more general term: in Islip these include lands covered by normal or peak lunar tides (25); in East Hampton, "wetlands" refers to those lands now or formerly connected to tidal waters and upon which 13+ species grow or may grow (26). In both laws, a "tidal marsh" is inundated by tidal waters, exhibits salt marsh peat at its surface, and supports growth of certain plant species (27). Restrictions apply equally to "wetlands" and "tidal marsh."

Definitions of "upland," often delineating the landward boundary of the marsh, are also inconsistent. In Smithtown, "upland" is land above the mean high water mark (28). In Brookhaven and Huntington, regardless of the local tide range, "upland" is land above the National Geodetic Survey 5-foot contour above SLD (sea level) (29). With a tide range of almost 6 feet on the north shore, this would place upland about 2 feet above mean high water. Where the range is only 1 foot along portions of southern Long Island, the 5-foot contour would lie approximately 4.5 feet above mean high water. In both Islip and East Hampton, "upland" is land either above peak lunar tides or above the landward edge of the tidal marsh (30).

Variation among governmental units as small as a township means that over a larger area such as the Nassau-Suffolk region, some wetlands are more vulnerable to destruction than others. Failure to coordinate conservation efforts results in less than optimal use of resources (31). In addition, restrictions placed on property owner in each town are unequal.

The inconsistencies among the towns can be overcome. One method, suggested by Peter L. Johnson of Open Space Institute, is to develop a model municipal wetlands ordinance which all the towns would agree upon and adopt (32). The result would be a uniform wetlands preservation program and equality for all property owners. There is a comparable system in Virginia: local municipalities adopt a prescribed wetlands zoning ordinance and Virginia's Department of Conservation, Development, and Natural Resources acts as a coordinating and reviewing body (33). Such a uniform, prescribed ordinance could be required in New York State by amendment to the present wetlands legislation.

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