Chapter 3

NEW JERSEY CASE STUDY

by

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INTRODUCTION

We applied the same method developed for Charleston to the area around Tuckerton, New Jersey. We gathered data on the vegetation at various elevations within the marsh, and then developed a composite transect representing an average profile of the area. Using this information and estimates of the sediment provided by nearby marshes, we then estimated the shifts in wetland communities and net loss of marsh acreage associated with three possible scenarios of sea level rise for the year 2075: the current sea level trend and worldwide rises in sea level of 66 and 138 centimeters (cm) (2.2 and 4.5 ft) by 2075, which would imply rises of 87 and 159 cm (2.9 and 5.2 ft) around South Central New Jersey, allowing for local effects. While emphasizing site-specific data, the results presented in this study provide some interesting contrasts with higher tidal range areas, which should prove useful in studies of other wetlands in microtidal settings.

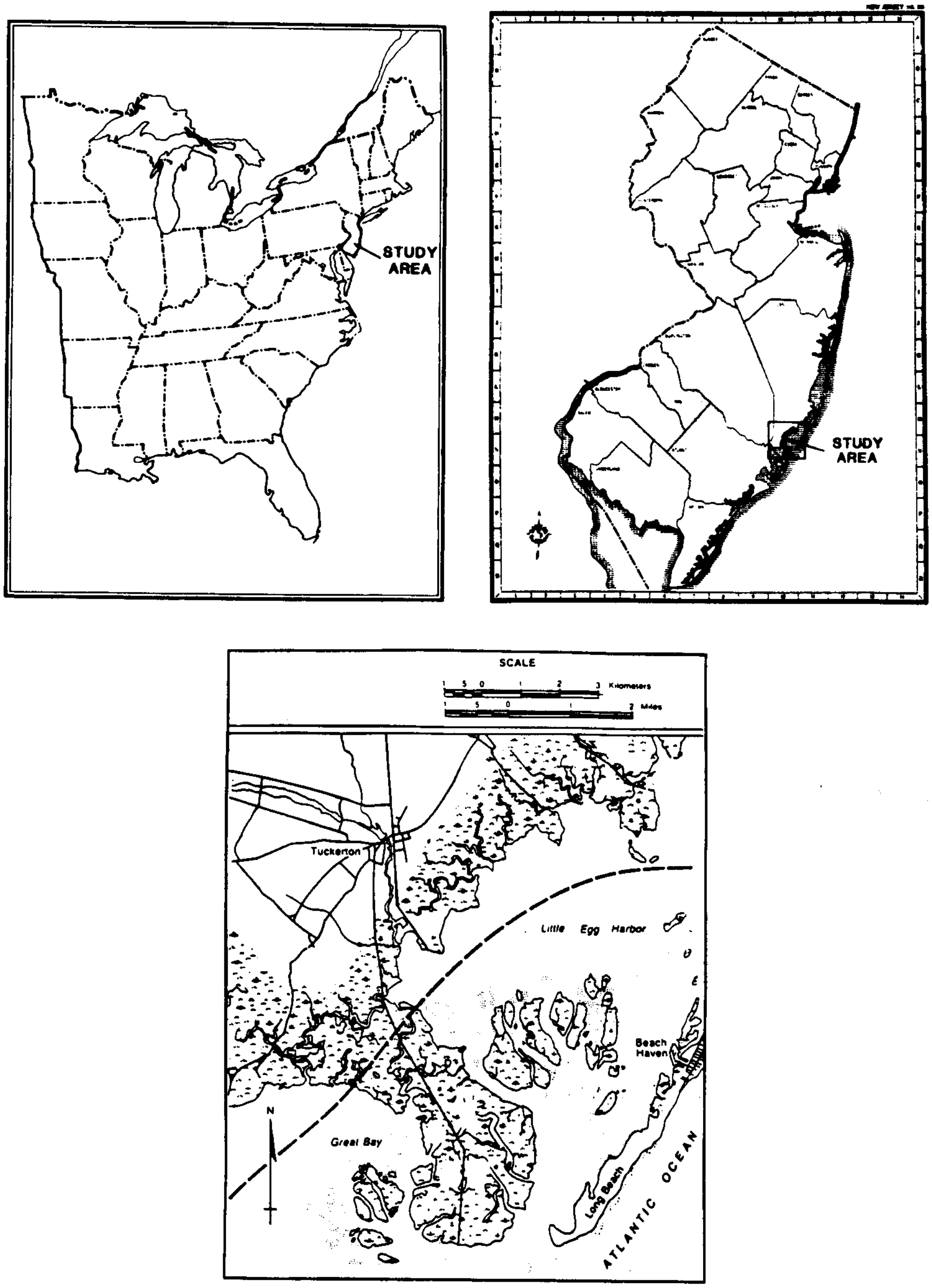
Numerous researchers have surveyed the distribution of plants and species diversity within intertidal salt marshes throughout the United States (Teal 1958; Wilson 1962; Good 1965; Stroud and Cooper 1968; Reimold et al. 1975; Turner 1976; and Nixon 1982). It was not the intent of this study, or of the Charleston study, to provide a detailed species inventory or a refined model of marsh zonation and primary productivity. Rather, our concern was to develop some applicable relationships between the predominant marsh species and corresponding intertidal elevations. Our field surveys were site-specific for the Tuckerton/Little Egg Harbor area but can be applied generally to other microtidal marsh environments by normalizing absolute elevations for the local tide range.

CHARACTERISTICS OF THE STUDY AREA

The study area encompasses the town of Tuckerton, Little Egg Harbor Inlet, and Long Beach Island, New Jersey (Figure 34). To facilitate our analysis, me chose boundaries to coincide with the U.S. Geological Survey (USGS) topographic map of Tuckerton. The total area covered is 14,000 hectares (34,700 acres).

Major elements of the study area are the mainland surrounding Tuckerton (northwest portion of the quadrangle); the barrier lagoons of Great Bay (southwest portion) and Little Egg Harbor (northeast portion); and the barrier spits of Long Beach Island, Little Egg Inlet, Beach Haven Inlet, and the Atlantic Ocean in the southeast portion.

FIGURE 3-1
THE SOUTH CENTRAL NEW JERSEY STUDY AREA



The Inlet and Barrier Lagoon Systems

Extensive marsh fringes the mainland adjacent to Tuckerton-in some areas, exceeding one mile across. A peninsular marsh, referred to locally as the Great Bay Boulevard marsh, bisects Great Bay and Little Egg Harbor lagoons. Based on its geomorphic configuration, the marsh has most likely formed on part of the flood-tidal delta for the Little Egg and Beach Haven Inlets system. Flood-tidal deltas or landward shoals are common depositional features of microtidal barrier lagoon systems (Hayes and Kana, 1976).

The inlet within the study area is unusual compared to many microtidal inlets because of its large throat width between adjacent barrier beaches. It is locally referred to as two inlets-Beach Haven to the north, which flushes Little Egg Harbor lagoon, and Little Egg Inlet to the south, which flushes Great Bay. However, for all intents and purposes, the two form one system over 3,000 m (10,000 ft. wide, and there appears to be essentially free exchange of waters between Great Bay and Little Egg Harbor.

Great Bay Boulevard marsh is probably the largest and one of the only untouched marshes in New Jersey.[1] The marsh adjacent to Tuckerton has been altered by numerous mosquito ditches that crisscross it every 50-100 m (165-330 ft). Long Beach Island, across Little Egg Harbor lagoon, is developed and essentially devoid of fringing marsh, except for the southern tip, which is part of Brigantine National Wildlife Refuge.

Tides and Wetlands

In contrast to the Charleston, South Carolina, study area, the Tuckerton/Little Egg Harbor area is typical of a microtidal barrier lagoon system. Little Egg Harbor and Great Bay are lagoons enclosed by barrier islands that have formed within the past several thousand years after the last deglaciation. Microtidal barrier islands, such as Long Beach Island, are generally separated by widely spaced tidal inlets, which provide the principal flow between the lagoon and the ocean (Hayes 1979). Tidal deltas typically form seaward and landward of the inlet as sediments become trapped in low-velocity zones. Of primary interest here is the landward deposit, or "flood-tidal delta," which derives its name from the tidal currents that supply most of the sediment (Hayes 1972). The flood-tidal delta of which Great Bay Boulevard marsh forms a portion is exposed to higher tides because of its proximity to the inlet. Lagoon tidal range drops quickly away from the inlet because of the relatively large volume of water in the basin with respect to the volume that can flow through the inlet over one tidal cycle. Therefore, in microtidal settings, tidal range close to the inlet will almost equal the ocean tidal range but in remote parts of the lagoon, it will be much less.

Tidal Frequencies and Coastal Habitats

As in the Charleston area, six discrete Habitats are found in the Tuckerton study area. They are distinguished by their elevation in relation to sea level and, thus, by how often they are flooded:

- *highland* - flooded rarely
- *transition wetlands* - flooding may range from biweekly to annually
- *high marshes* - flooding may range from daily to biweekly
- *low marshes* - flooded once or twice daily up to one-half of the time
- *tidal 17ats* - flooded about half of the day
- *open water* - flooded more than half of the day

The distribution of coastal wetlands within the New Jersey study area is balanced for tides occurring twice each day. Because of the lunar cycle and other astronomic or climatic events, higher tides than average occur periodically. Spring tides occur approximately fortnightly in conjunction with the new and full moons. The statistical average of these, referred to as mean high water spring (MHWS), has an elevation of 69 cm (2.25 ft) above local man sea level (MSL) in Little Egg Inlet (U.S. Department of Commerce 1985). Less frequent tidal inundation occurs at even higher elevations at least several times each year.

The frequency of this flooding controls the kinds of plant species that can survive in an area. Unlike the intertidal areas of the southeastern United States, the salt marshes of New Jersey are predominantly high marsh. High marsh has been reported to be over seven times more common than low marsh in the state (Spinner 1969). From the standpoint of primary productivity (organic accumulation per square meter), certain high marshes appear to be as productive as low marshes (Nixon 1982). However, the export of produced organic matter is low from high marsh, indicating its productivity values are less important than those of low marsh.

The marsh wetlands in south-central New Jersey are generally divided into *transition zones.* The most extensive of these zones occurs between (1) the upland and normal monthly tide level, *high marsh,* which receives meekly flooding, and (2) the *low marsh,* which tolerates daily flooding. Near local MSL, prolonged inundation inhibits plant growth and the marsh gives way to intertidal sand and mud flats. The most sheltered areas (with the least wave action) contain the muddiest sediments (Hayes and Kana 1976). The upper limit of salt-tolerant plants appears to be at about the 5.0 ft (about 1.5 m) contour shown on USGS topographic maps. This is an important elevation because it represents the lower limit of human development that could occur without altering existing wetlands. The zone below this elevation (delineated on the basis of vegetation types) is a *critical area,* subject to strict Coastal Zone Management laws of New Jersey.

The pannes, potholes, and depressions within the marsh are unique habitats and have been investigated in certain East Coast marshes (Redfield 1972). The lack of emergent vegetation has been credited to a lack of favorable sediment characteristics (Redfield 1972). The low circulation, depth, and exposure to temperature or salinity extremes may also be factors preventing marsh colonization of the areas once the topographic features are formed.

Mosquito ditches affect the ecology of the East Coast marshes, although there is inadequate information on how extreme these effects may be (Daiber 1974). In the New Jersey sites, ditches increase the flushing of the high marsh and may be enhancing the growth of certain species. More important, substantial low marsh composed of tall *S. alternifbra* is created along the edges of the ditches. Spoil from the ditches is uncommon, but where it occurs, it provides elevation for the growth of *Iva frutescens* and other high-marsh transitional species. The depth and sediment characteristics of the ditches limit growth of seagrass or tall *S. alterniflora.*

Roads and house lots also affect local marsh ecology. The raised elevations of the roads increase the abundance of high-marsh transitional species, many of which are the dominant roadside vegetation (e.g., *Panicum species and Phragmites communis).* The lots are covered with material that prevents marsh growth. Sediments from the sand and gravel also enter the nearby marsh and probably influence vegetative growth.

DATA GATHERING AND ANALYSIS

Before me could model how the rising sew under the three scenarios would affect the coastal wetlands of south central New Jersey, w needed to determine the types, elevation, and productivity of the plant species currently in the marshes. However, as in the Charleston study, there is little data on the elevation range that contains most of the coastal wetlands in New Jersey. For this reason, me surveyed a series of sixteen field transacts across representative marshes and tidal flats rear tuckerton.

Data Collection and Analysis

Each transect was a sample cross section of an area of the marsh. It began at a benchmark located on high ground near a marsh's boundary, and ended at a tidal creek or mud flat, or after covering 300 m (1,000 ft)-whichever came first. The New Jersey Department of Environmental

Protection provided three benchmarks. One was Station E55, located within the mainland raw the hinging marsh northeast of Tuckerton, where the mean tidal range is 61 cm (2.0 ft). As Figure 3-2 shows, transacts T9-TI6 were surveyed there. The other two benchmarks were Stations M55 and P55, located along the Great Bay Boulevard marsh, where the mean tidal range is 96.9 cm (3.18 ft). These benchmarks were used for transacts TI-T8.

The dashed line in Figure 3-2 shows how we arbitrarily subdivided the study area into these two primary survey areas to account for the significant variations in tidal range. The indicated subdivision is not exact, since a continuum exists, but it was necessary for scenario modeling, which is described later in the report. These two ranges represent the typical excursion of water levels between mean high water and mean low water. Since they are statistical averages, they can be related to local mean sea level by definition. In other words, mean high water at the Great Bay Boulevard marsh would be 48.5 cm (1.59 ft) above local mean sea level, while mean low water would be 48.5 cm below it. Similarly, in the Tuckerton marsh, mean high water would average 31 cm (1.0 ft) above local mean sea level. These tides compare with a mean ocean tidal range of 1.1 m (3.7 ft) in Little Egg inlet.

Because of the difficulty of wading through very soft muds, w had to limit the length of the transacts. Although this biased the sample somewhat, logistics prevented a more rigorous approach. Nevertheless, very detailed information on marsh zonation and boundaries in New Jersey is available on 1:2,400 photo maps prepared by the New Jersey Department of Environmental Protection. We used portions of these maps in our study to estimate areal coverage of each marsh type. Budget limitations prevented us from determining all areas by planimetry, so we substituted representative grid squares.

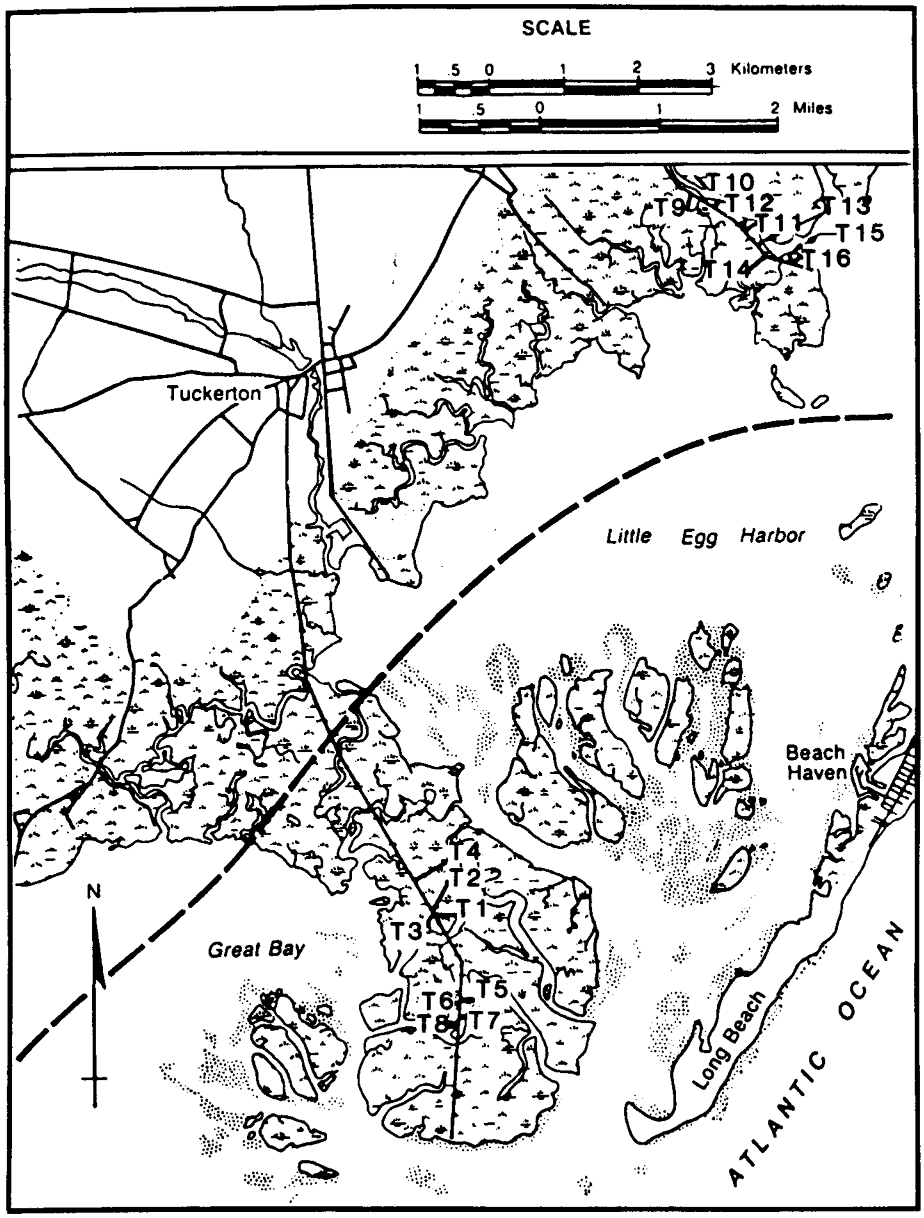
For each transect, w measured the elevation and distance from the benchmark using a rod and level. Data points were surveyed wherever there was a noticeable break in slope or change in species. Typically, we recorded at least 20 survey points along each transect, with the average distance between points being about 7.5 m (25 ft). Our field team of three people included a biologist who kept parallel notes with the surveyors on the actual species at and between each survey point. Along each transect me collected and tagged samples of species for laboratory typing and verification, noting such information as the elevation of the boundaries between different species. By measuring the length of the transect that a species covered and dividing it by the transect's total length, we computed percentages for the distribution of each species along a transect.

The demarcation between terrestrial plants and salt-tolerant species can often be abrupt because of a sudden change in slope at that point. Wetland transects commonly consist of a series of low-relief steps between areas of rare or less constant elevation, with each step representing the upper or most landward deposit of detritus for a particular tide level. However, me have also observed areas where slopes are almost uniform from highland to tidal flats (Kana, Baca, and Williams 1986).

Results of Individual Transects

Table 3-1 summarizes the results of the sixteen transacts, dividing them between the Tuckerton marsh's 61 cm (2.0 ft) tidal range and the Great Bay Boulevard marsh's 96.9 cm (3.18 ft) range. It presents the principal species observed along each transect, their "modal"-or most common-elevations, the percentage of each transect they covered, and the length of each transect. For example, in transect number 3, short *S. alterniflora* was found at a modal elevation of 86.9 cm (2.85 ft) and covered 94 percent of the transect.

FIGURE 3-2
LOCATION OF THE STUDY AREA AND SIXTEEN TRANSECTS



Because species often overlapped, the sums of the percentages exceed 100. In addition, to omit any marginal plants that exist at transition zones, a modal elevation differs slightly from the arithmetic or weighted mean. Appendix 3-A contains histograms of species occurrence. Plots of the profiles of each transect, showing the modal elevations of the substrate and zonation of plant species are available from the authors.

TABLE 3-1

MODAL ELEVATIONS OF PRINCIPAL SPECIES AND PERCENTAGE OF TRANSECT COVERED BY EACH (feet, 1929 NGVD)

SPECIES	MODAL ELEVATIONS (percent of transect covered) T1	T2	T3	T4	T5	T6	T7	T8
GREAT BAY BOULEVARD MARSH (TIDAL RANGE = 3.18 FT)								
SP*	3.48 (1)	-	3.96 (3)	-	3.84 (4)	3.90 (4)	4.12 (8)	-
SSA	2.85 (99)	2.74 (82)	2.85 (94)	2.70 (80)	2.70 (90)	2.72 (27)	2.74 (84)	3.07 (82)
WSA	-	-	3.54 (1)	3.60 (1)	-	-	-	-
TSA*	-	1.45 (6)	1.97 (2)	1.19 (2)	1.65 (5)	-	2.05 (6)	1.30 (8)
IF	3.87 (2)	3.77 (1)	3.98 (1)	3.77 (15)	3.71 (1)	3.88 (1)	4.10 (5)	3.23 (1)
PV	4.25 (1)	-	-	4.55 (1)	4.39 (1)	-	4.53 (1)	-
SB*	2.93 (79)	2.70 (44)	2.62 (1)	2.95 (1)	3.00 (1)	2.70 (8)	2.90 (25)	3.08 (1)
LC*	2.87 (59)	2.30 (34)	2.78 (10)	-	2.90 (9)	2.70 (8)	2.90 (25)	3.07 (37)
PP	3.87 (2)	3.98 (1)	-	4.23 (1)	4.39 (1)	-	-	-
PC	-	-	-	-	-	-	-	3.84 (2)
RM	-	-	-	-	-	-	-	-
DS*	-	3.58 (1)	4.17 (1)	-	3.58 (1)	-	-	-
JG	-	-	-	-	-	-	-	-
FA	-	-	-	-	-	0.82 (1)	1.04 (1)	1.20 (2)
UA	-	-	-	-	-	-0.25 (1)	-	-
EA	-	-	-	-	-	-	-	0.80 (1)
CA	-	-	-	-	-	2.84 (68)	-	3.06 (7)
Transect length (ft)	1,059	387	540	232	826	440	193	537

* Species commonly observed in the Charleston case study area.

SP = Spartina patens
SSA = Short S. alterniflora
WSA = Medium S. alterniflora
TSA = Tall S. alterniflora
IF = Iva fructescens
PV = Panicum spp.
SB = Salicornia spp.
LC = Limonium carolinianum
PP = Pluchea purpurescens
PC = Phragmites communis
RM = Ruppia maritime
DS = Distichils spicata
JG = Juncus gerardi
FA = Fucus (algae)
UA = Ulva (algae)
EA = Enteromorpha (algae)
CA = Cyanophycean algae

TABLE 3-1 (Cont'd)

MODAL ELEVATIONS OF PRINCIPAL SPECIES AND PERCENTAGE OF TRANSECT COVERED BY EACH (feet, 1929 NGVD)

SPECIES	MODAL ELEVATIONS (percent of transect covered) T9	T10	T11	T12	T13	T14	T15	T16
TUCKERTON MARSH (TIDAL RANGE = 2.0 FT)								
SP*	2.28 (1)	2.74 (33)	3.28 (17)	3.24 (51)	3.14 (12)	3.02 (20)	3.28 (9)	3.28 (6)
SSA	2.30 (99)	-	3.23 (25)	3.16 (47)	2.98 (57)	2.90 (73)	3.24 (52)	3.03 (80)
WSA	2.30 (33)	3.20 (51)	3.18 (42)	3.33 (13)	-	-	2.69 (22)	-
TSA*	2.33 (23)	2.31 (1)	2.83 (1)	2.62 (2)	-	2.82 (3)	1.36 (1)	-
IF	2.24 (13)	-	-	-	3.23 (1)	3.07 (2)	-	-
PV	-	4.70 (11)	3.55 (6)	-	-	-	4.37 (2)	4.29 (1)
SB*	2.17 (1)	-	-	3.44 (1)	2.97 (1)	2.85 (1)	-	2.65 (5)
LC*	-	-	3.04 (1)	3.18 (1)	2.90 (14)	-	-	2.65 (5)
PP	-	-	-	3.47 (1)	-	-	-	3.93 (1)
PC	-	3.90 (51)	3.55 (10)	-	3.68 (31)	3.42 (18)	4.12 (13)	3.91 (11)
RM	-	-	1.63 (11)	2.17 (6)	-	2.09 (1)	-	-
DS*	2.29 (16)	3.28 (1)	3.35 (26)	2.90 (1)	3.35 (24)	3.07 (16)	-	-
JG	-	-	-	-	-	3.36 (1)	-	-
FA	-	-	-	-	-	-	-	-
UA	-	-	-	-	-	-	-	-
EA	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-
Transect length (ft)	305	121	638	554	145	384	281	558

* Species commonly observed in the Charleston case study area.

SP = Spartina patens
SSA = Short S. alterniflora
WSA = Medium S. alterniflora
TSA = Tall S. alterniflora
IF = Iva fructescens
PV = Panicum Spp.
SB = Salicornia Spp.
LC = Limonium carolinianum
PP = Pluchea purpurescens
PC = Phragmites communis
RM = Ruppia maritime
DS = Distichils spicata
JG = Juncus gerardi
FA = Fucus (algae)
UA = Ulva (algae)
EA = Enteromorpha (algae)
CA = Cyanophycean algae

WETLAND TRANSECTS

The individual components of the New Jersey salt marsh occupy zones consistent with other East Coast areas (reviewed in Nixon 1982). The major zones differentiated in our study are high, low, and transitional marsh. *S. alterniflora* is frequently dominant in terms of plants per square meter. In transects for this study, the plant occurred in three growth forms: tall, medium, and short. The tall plants occur as the dominant low marsh species, usually as a fringe along the outer periphery of the high marsh. Short *S. alterniflora* is often the dominant plant in the high marsh, and the less common medium *S. alterniflora* is found in the low marsh, or in high marsh with adequate water circulation. The distinction between medium and short *S. alterniflora and* other growth sizes is imprecise, but was made in the field to add more insight into zonation.

The dominant high-marsh species in the Tuckerton transects (in decreasing order of abundance) mere short *S. altemit7ora, Spartina patens,* medium *S. altemit7ora, and Distichlis spicata.* In the Great Bay Boulevard marsh where tide range is higher, short *S. alterniflora was* again dominant with *Limonium carolinianum and Salicornia spp.* next in importance. Although less than 20 cm (7.9 in) in height, short *S. alternit7ora* is a mature plant capable of producing abundant seeds. It was often codominant with *S. patens,* which was at slightly higher elevations. While pure stands of windblown *S. patens* mere common, it is decreasing in abundance because of manmade (Gosselink and Baumann 1980) and natural causes (Niering and Warren 1980) and is often being replaced by short *S. alterniflora. Distichlis spicata and Salicornia* spp. mere commonly associated with either high-marsh species-the former more frequently with *S. patens* and the transition zone, and the latter with short *S. alternit7ora.* Due to its salinity tolerance, *Salicornia* spp. was common throughout the study area as well as in shallow pannes where it grew in association with a mat of Cyanophycean algae.

Transitional species occur in zones between high marsh and terrestrial vegetation, between high and low marsh, and between low marsh and water. *Panicum spp., Iva frutescens, Pluchea pupurescens, Juncus gerardi, and Phragmites communis* occur at the upper limit, or transition zone, of high marsh. The last species is less salt-tolerant and grows at lower elevations only in brackish and freshwater areas. *Iva frutescens* is a conspicuous plan**t** found wherever adequate elevation exists, whether on the upper high marsh or on elevated areas produced by spoil. No other plant is as common in both elevated situations, and it was also the only woody plant found in the transects. Other plants in the upper high-marsh transition zone were *Panicum spp.* (usually *P amarun* and P *virgatun).* The plants formed belts on the highest elevated marsh areas, frequently as roadside vegetation. *Pluchea purpurascens* appeared at moderate elevations, frequently with *Iva frutescens and Distichlis spicata. Juncus gerardi* was uncommon in the transects, usually occurring in the upper zone of high marsh. *Phragmites communis* was found at the upper elevation of high marsh, frequently along the roadside, when in coastal areas. However, in coastal rivers" it was often dominant in the low marsh, where it formed dense stands.

Cyanophycean algae were the principal submerged plants in the high marsh where they existed as thick mats in pannes and low-lying areas. The seagrass, *Ruppia maritima, was* common in deeper potholes of the high marsh. The dominant plants at the outer margin of the low marsh mere the Chlorophycean alga, *Enteromorpha* spp. and *Ulva* spp., and the Phaeophycean alga, *Fucus* spp. These were submerged at high tide and were attached to rocks and shells.

Composite Transects

Because of the complexity and varied tidal ranges of the intertidal wetlands in the New Jersey study area, me developed two typical transects to model the scenarios of future sea level rise. The approach we used was similar to the approach used for Charleston (Kana, Baca, and Williams 1986). We used the weighted average percentage of transects covered by each species and their modal elevations and then selected the "indicator," or dominant, species for the Tuckerton and Great Bay Boulevard marshes according to the following steps:

1) Interpolate elevations, at 7.5 m (25 ft) horizontal increments, along each transect.

2) Based on the "distribution of species" graphs (Appendix 3-A) for each transect, determine what species are found, at 25-ft horizontal increments, along each transect.

3) If the total number of occurrences is greater than ten for any given species, construct a frequency histogram for that species. From the histogram, determine the modal elevation for that species.

4) If the total number of occurrences is less than eleven for any species, determine the modal elevation by graphically averaging the transect cross-section.

We prepared frequency histograms for six species and tidal range combinations having a sufficient number of data points (Appendix 3,A). We also computed the mean elevation and corresponding standard deviation for all species. After weighting the "percentage occurrence" or percentage of transacts covered by all species, me compiled a summary, or composite list. Table 3-2 gives the results by tidal range for each portion of the study area.

The dominant plant was *S. alterniflora* in both tidal-range zones, with the short variety covering 49-77 percent of the composite transacts. Its modal elevation (86.6-99.1 cm [2.81-3.25 ft., Table 3-2) in the Tuckerton Marsh was similar to that in the Great Bay Boulevard marsh despite a difference in mean high water of over 15 cm (0.5 ft). In fact, the mode was reversed for the lower tidal-range marsh, being slightly above the Great Bay Boulevard marsh elevation. One would expect just the opposite, since high-marsh elevation normally increases with tidal range. Since the difference is subtle here, me believe it may be due to the altered drainage of the Tuckerton marsh, which is dissected by numerous ditches. Mosquito-control ditches or similar features increase circulation and may also impound water over the marsh, possibly elevating mean water levels or increasing the duration of flooding. A subtle change such as this could alter flooding frequency and displace marsh habitats upward. Unfortunately, there is no way to confirm this hypothesis for the Tuckerton marsh. However, me believe the difference is real for the present data set.

Second in importance was *S. patens* (23 percent) in the Tuckerton marsh and L. *carolinianum* (23 percent) and *Silicornia* spp. (20 percent) in the Great Bay Boulevard marsh. S. *patens* was less common in the Great Bay Boulevard marsh but occurred at significantly higher elevations as m expected: 122 cm (3.99 ft) versus 92.7 cm (3.04 ft) in the Tuckerton marsh (Table 3-2). All of these species are indicative of high marsh or the transition above high marsh. While much less common than in South Carolina, tall *S. alternit7ora* nevertheless is an important indicator species of low marsh for New Jersey. We found that it occurred over 4 percent of the composite transect but at higher elevations in the lower tidal range Tuckerton marsh (+ 73 cm [2.4 ft.] than in the Great Bay Boulevard marsh (+48.5 cm U.59 ft.). This apparent opposite trend may be related to its occurrence along the banks of mosquito ditches and the possible superelevated man water levels within the Tuckerton marsh.

Phargrmites communis (giant reed) was almost absent in the Great Bay Boulevard marsh but was very common as a fringing species along the Tuckerton marsh. Its modal elevation of 1.15 cm (3.78 ft) provides a good indicator of the upper limit of yearly tides for the area, since it requires fresh to brackish water.

Figures 3-3 and 3-4 illustrate two hypothetical composite transacts for the principal tidal range arm around the Tuckerton and Great Bay Boulevard marshes based on the results in Table 3-2. Each includes elevation divisions, species zonation, and representative tidal levels. The profiles are by no means precise, but they provide an indication of the relationships between each wetland subenvironment.

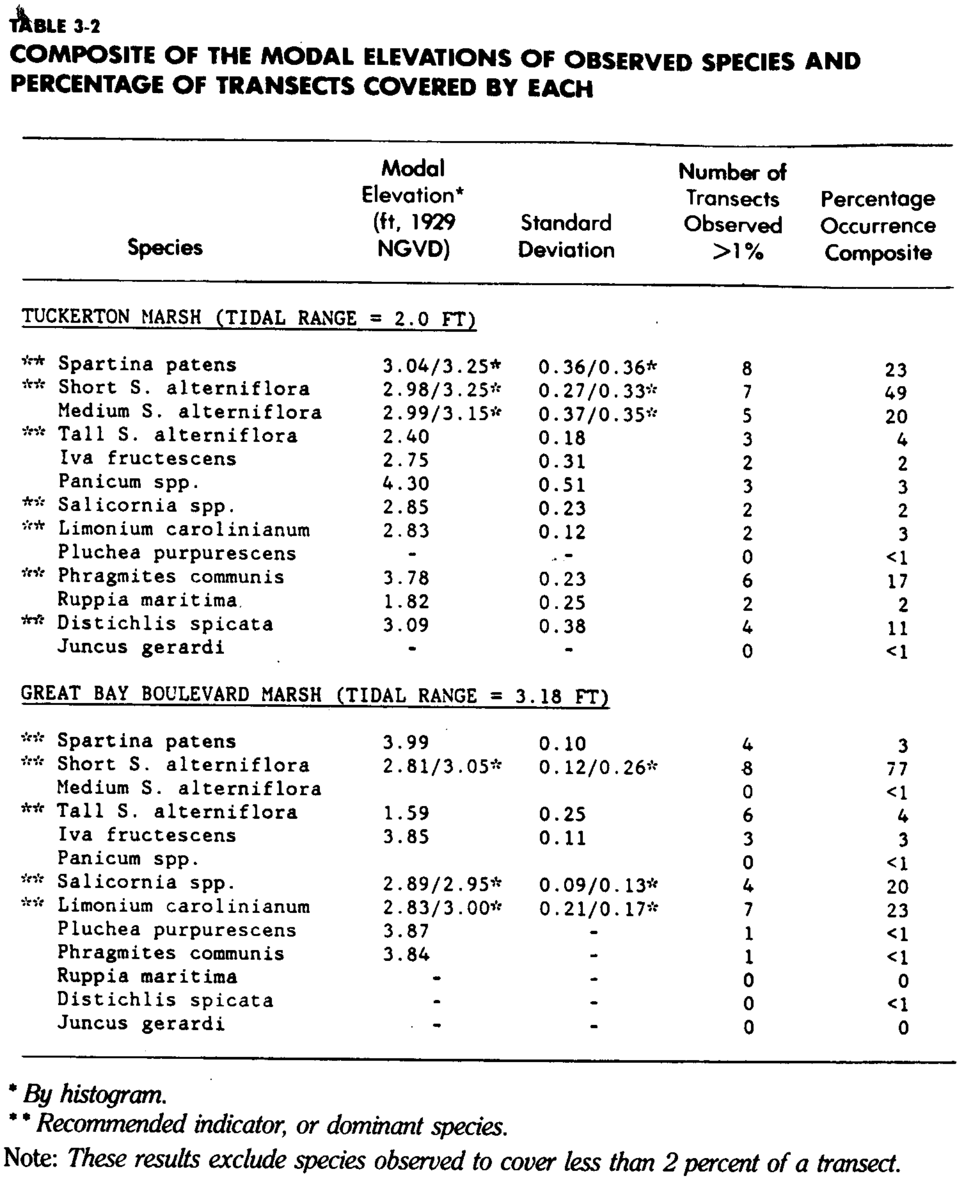


TABLE 3-2

COMPOSITE OF THE MODAL ELEVATIONS OF OBSERVED SPECIES AND PERCENTAGE OF TRANSECTS COVERED BY EACH

Species	Modal Elevation* (ft, 1929 NGVD)	Standard Deviation	Number of Transects Observed >1%	Percentage Occurrence Composite
TUCKERTON MARSH (TIDAL RANGE = 2.0 FT)				
** Spartina patens	3.04/3.25*	0.36/0.36*	8	23
** Short S. alterniflora	2.98/3.25*	0.27/0.33*	7	49
Medium S. alterniflora	2.99/3.15*	0.37/0.35*	5	20
** Tall S. alterniflora	2.40	0.18	3	4
Iva fructescens	2.75	0.31	2	2
Panicum spp.	4.30	0.51	3	3
** Salicornia spp.	2.85	0.23	2	2
** Limonium carolinianum	2.83	0.12	2	3
Pluchea purpurescens	-	-	0	<1
** Phragmites communis	3.78	0.23	6	17
Ruppia maritima	1.82	0.25	2	2
** Distichlis spicata	3.09	0.38	4	11
Juncus gerardi	-	-	0	<1
GREAT BAY BOULEVARD MARSH (TIDAL RANGE = 3.18 FT)				
** Spartina patens	3.99	0.10	4	3
** Short S. alterniflora	2.81/3.05*	0.12/0.26*	8	77
Medium S. alterniflora			0	<1
** Tall S. alterniflora	1.59	0.25	6	4
Iva fructescens	3.85	0.11	3	3
Panicum spp.			0	<1
** Salicornia spp.	2.89/2.95*	0.09/0.13*	4	20
** Limonium carolinianum	2.83/3.00*	0.21/0.17*	7	23
Pluchea purpurescens	3.87	-	1	<1
Phragmites communis	3.84	-	1	<1
Ruppia maritima	-	-	0	0
Distichlis spicata	-	-	0	<1
Juncus gerardi	-	-	0	0

* *By histogram.*

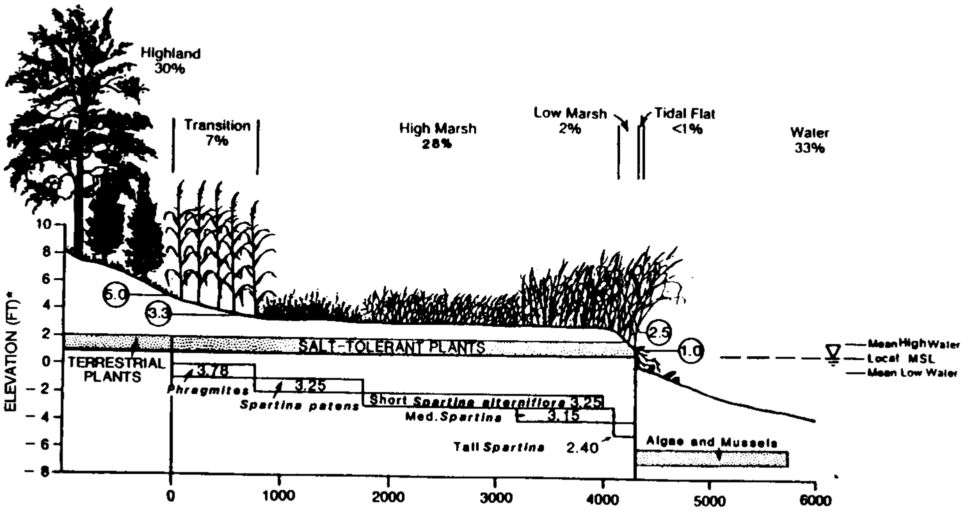
** *Recommended indicator, or dominant species.*

Note: *These results exclude species observed to cover less than 2 percent of a transect.*

In comparison to the composite transect for Charleston (Kana, Baca, and Williams 1986) Tuckerton's transects are more terraced, with abrupt changes in slope at transitions between tidal flat, low marsh, and high marsh. The circled elevations in Figures 3-3 and 3-4 are the interpreted upper and lower limits of each subenvironment, based on data The from profiles of sixteen transects of the Tuckerton and Graeat Bay Bolevaard marshes.[2] The transects establish the effective lower limit of marsh at elevations of 31 cm (1.0ft) and 37cm (1.2ft) for the low and high tidal range areas, respectively. A major difference between the Tuckerton and the Great Bay Boulevard marshes is the distribution of tidal flats. Tuckerton's fringing marsh has very little, whereas the Great Bay Boulevard marsh is bordered by wide flats representing fully one-third of the wetland areas.

FIGURE 3-3

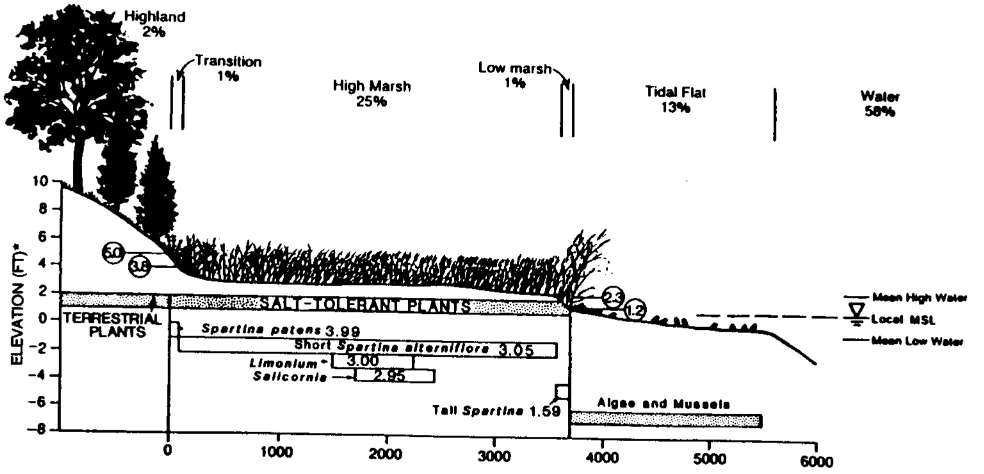
COMPOSITE TRANSECT OF THE TUCKERTON MARSH (Tidal Range = 2.0 ft)



* *Elevations are relative to the 1929 NGVD sea level.*

FIGURE 3-4

COMPOSITE TRANSECT OF THE GREAT BAY BOULEVARD MARSH (Tidal Range = 3.18 ft)



* *Elevations are relative to the 1929 NGVD sea level.*

The overall zonation given on the composite transects is empirical for central New Jersey and does not presume exact inundation tolerances for each wetland species. A more comprehensive study would be required to establish the elevation ranges and frequency of occurrence of all species-a difficult undertaking, considering the problem of accessing this of any marsh.

Estimation of Areas

Two sources of information were available for estimating areas of land, water, and wetlands within the New Jersey study area: (1) USGS 7.5-minute quadrangles and (2) New Jersey Department of Environmental Protection (1:2,400 scale) wetland photo maps with marsh types delineated.

Using the topographic and wetland zonation maps, we estimated the number of acres of each subenvironmnt for each tide-range zone. For budgetary reasons, it was not possible to analyze the 100 wetland maps that make up the study area. Instead, several of these representative 1:2,400 photo maps mere chosen for detailed area checks on the ratio of high marsh to low marsh and tidal flats. These ratios were checked against our surveys to ensure consistency with the composite transacts. As in the Charleston case study, the level of precision is limited, but reasonable for scenario modeling. In contrast to Charleston, the New Jersey study area had a more even mix of highland, marsh, and water. In the Tuckerton subdivision, highland, high marsh, and water areas each made up about 30 percent of the area. The next highest area, with 7 percent coverage, was the transition zone. Interestingly, low marsh comprises barely 2 percent of the low tidal-range zone.

With the Great Bay Boulevard subdivision, water, high marsh, and tidal flats dominate in a 4:2:1 ratio, comprising 96 percent of the area. Little highland, transition zone, or low marsh occurs. The total area of the study subdivisions was 16,400 acres (Tuckerton marsh) and 18,300 acres (Great Bay Boulevard marsh), compared with 45,500 acres for the Charleston study area.

SCENARIO MODELING AND RESULTS

After establishing the basic relationships among elevation, wetland habitats, and species occurrence for Tuckerton/Little Egg Harbor, we developed a conceptual model for changes in marsh under accelerated sea level rise and applied the model to the case study area.

Assumptions Used for Scenario Modeling

The major assumptions we used for scenario modeling concerned the annual rise in sea level, the average sedimentation rate, and the cutoff elevations for the various subenvironments.

Rise in Sea Level.

Based on an earlier study (Barth and Titus 1984), we chose three scenarios of future sea level rise: baseline, low, and high (described in Chapter 1).[3] To be consistent with the previous study, we projected the scenarios to the year 2075-95 years after the baseline date of 1980 used to determine "present" conditions.

Sedimentation Rate.

The model for future wetlands zonation also accounted for sedimentation and peat formation which raise, the substrate (absolute elevation) in concert with sea level rise. Sedimentation and peat formation have kept pace with rising relative sea level of 3 mm (.1 in) per year during the past century over much of the East Coast [e.g., Ward and Domeracki (1978), Duc (1981), Boesch et al. (1983)]. If sea level rises much more rapidly than vertical accretion rates, however, wetland zones will migrate landward.

Weathering rates in the middle Atlantic states are generally lower than the southeastern United States. Nevertheless, after review of the literature on marsh sedimentation, we found no substantial difference between the Charleston and New Jersey study areas. For the Charleston case study, we assumed for modeling purposes an average annual rate of 5 mm (.2 in) per year based on limited reports by Ward and Domeracki (1978) and summaries by Hatton et al. (1983). Similarly, limited results are available for the New Jersey region. Meyerson (1972) reported a rate of 5.8 mm (.23 in) per year for a marsh in Cape May, New Jersey. In nearby Delaware, rates of 5.0-6.0 mm (.20-.24 in) per year were reported by Stearns and MacCreary (1957) in *S. alternit7ora* marsh and by Lord (1980) in short *S. alternit7ora* marsh. Richard (1978) reported rates of 2.0-4.2 mm (.08-.17 in) per year in a Long Island (New York) *S. altemit7ora* marsh. Although the rate of marsh accretion will depend on proximity to tidal channels (sediment sources) and density of plants (baffling effect and detritus), we believe these published rates are reasonably representative for the case study area. Thus, for purposes of modeling, we assumed a sedimentation rate of 5 mm (.2 in) per year. Obviously, the actual rate will vary across any wetland transect, so this assumed value represents an average. Lacking sufficient quantitative data and considering the broad application of our model, we found it was more feasible to apply a constant rate for the entire study area, even though this assumption may overestimate the rate of vertical accretion in the irregularly flooded transition zone between low marsh and terrestrial highland.

Elevation Zones

Transformation of wetland environments under various sea level rise and sedimentation scenarios also required assumptions regarding existing elevation zonations. The field transacts provided criteria for delineating the upper and lower limits of several subenvironments that could be considered as discrete zones for area estimation.

We assumed the cutoff elevation for highland around Tuckerton is 1.5 in (5.0 ft) NGVD, based on results of the transacts and observations in the field. In general, this area is free of yearly flooding and tends to mark the transition from salt-tolerant species to terrestrial vegetation. Although terrestrial vegetation occurs at lower elevations that are impounded between dikes or ridges, this situation is less relevant for sea level rise modeling. The zone of concern is the area bordering tidal waterways where slopes are assumed to rise continuously without intermediate depressions (see composite transacts in Figures 3-3 and 3-4).

The transition zone is defined as a salt-tolerant area between predominant, high-marsh species and terrestrial vegetation. This area is above the limit of fortnightly (spring) tides, but is generally subject to tidal and storm flooding several times each year. The indicator species for this zone were found to be *Panicton* spp. and *Phragmites communis* in the low4idal-range Tuckerton marsh and *S. patens and Iva frutescens* in the Great Bay Boulevard marsh.70

High marsh is defined for the study areas by variable elevation ranges of 70 to 120 cm (2.3-3.8 ft) for the Great Bay Boulevard marsh and 76 to 101 cm (2.5-3.3 ft) for the Tuckerton marsh, based on the transacts. Dominant species include short *S. altemiflora* at 93.0 cm (3.05 *ft), Lirnoniwn carolinianurn* at 92 cm (3.0 ft), 4nd *Salicomia* spp. at 89.9 cm (2.95 ft) for the Great Bay Boulevard marsh and *S. patens* at 107 cm (3.5 ft) and short *S. altemit7ora* at 99.1 cm (3.25 ft) for the 'Tuckerton marsh.

Low marsh ranges from +31 to + 76 cm (1.0 to 2.5 ft) based on results of the transacts, with a narrower range of elevations (37 to 70 cm R.2-2.3 ft]) in the higher tidal-range Great Bay Boulevard marsh. The principal indicator species, tall *S. atterniflora,* occurred at 48.5 and 73.2 cm G.59 and 2.40 ft), respectively, in the Great Bay Boulevard and Tuckerton marshes. Sheltered tidal flats actually occur between mean low water and mean high water but were found to be more common in the elevation range of zero to 31 or 37 cm 0.0 or 1.2 ft).

Results for Central Now Jersey

From these scenarios and the sedimentation rate of 5mm (.2 in) per year, we computed the net substrate elevation change for the year 2075, as shown in Table 3-3. Note in Mie 3-3 that the combined sea level rise scenarios and sedimentation rate yield a *positive* change in substrate elevation for the baseline and a *negative* change for the low and high scenarios. The results of the scenario models for the New Jersey study area are given in Tables 3-4 and 3-5. Table 3-4 divides the number of acres in the study area and the percent of the area they cover according to principal zones. It shows existing coverage (1980) and the predicted coverage for the baseline, low, and high scenarios for the year 2075. 'Table 3-5 lists the net change in acres for each scenario compared with the coverage in 1980. The baseline 2075 results are a projection of recent historical trends in sea level rise.

TABLE 3-3
SEA LEVEL RISE SCENARIOS TO THE YEAR 2075

Scenario	Sea Level Rise by 2075	Average Annual Rise	Annual Sedimentation Rate	Annual Net Substrate Change	Substrate Change by 2075
Baseline	+26.6 cm (0.87 ft)	2.8 mm	5 mm	+2.6 cm	+21 cm
Low	+87.2 cm (2.86 ft)	9.2 mm	5 mm	-4.2 cm	-40 cm
High	+163.4 cm (5.36 ft)	17.2 mm	5 mm	-12.2 cm	-116 cm

TABLE 3-4
NUMBER OF ACRES (PERCENT COVERAGE) FOR PRINCIPAL ZONES UNDER VARIOUS SCENARIOS AND DATES

Zone	Existing 1980	Baseline 2075	Low Scenario 2075	High Scenario 2075
TUCKERTON MARSH (TIDAL RANGE = 2.0 FT)				
Highland	4,900 (30)	5,600 (34)	4,300 (26)	2,600 (16)
Transition	1,200 (7)	4,600 (28)	1,100 (7)	1,100 (7)
High Marsh	4,600 (28)	600 (4)	500 (3)	500 (3)
Low Marsh	300 (2)	200 (1)	4,800 (29)	1,000 (6)
Tidal Flat	10 (<1)	10 (<1)	300 (2)	700 (4)
Water	5,400 (33)	5,400 (33)	5,400 (33)	10,500 (64)
TOTAL	16,400 (100)	16,400 (100)	16,400 (100)	16,400 (100)
GREAT BAY BOULEVARD MARSH (TIDAL RANGE = 3.18 FT)				
Highland	300 (2)	500 (3)	200 (1)	30 (<1)
Transition	200 (1)	2,000 (11)	200 (1)	30 (<1)
High Marsh	4,600 (25)	2,700 (15)	700 (4)	30 (<1)
Low Marsh	200 (1)	1,500 (8)	3,300 (18)	200 (1)
Tidal Flat	2,400 (13)	2,400 (13)	900 (5)	200 (1)
Water	10,600 (58)	9,200 (50)	13,000 (71)	17,800 (97)
TOTAL	18,300 (100)	18,300 (100)	18,300 (100)	18,300 (100)

Baseline 2075 and Low Scenario. Under existing trends, the model developed for this study, similar to Charleston, predicts a net *increase* in substrate elevation under the baseline condition where sedimentation rate exceeds sea level rise. As Tables 3-4 and 3-5 indicate, the biggest changes would be an increase in the transition zone area in the Tuckerton marsh and creation of more low marsh along Great Bay Boulevard. The percentage of highland would increase significantly with the addition of 900 acres, or 3 percent of the entire study area.

The low scenario implies a much different change in character of the study area. Under this model, net substrate elevation would decrease by the year 2075, but the change would be relatively small-around 40 cm. A review of Tables 3-4 and 3-5 and of Figures 3-5 and 3-6 shows the major impact would be a replacement of high marsh with comparable areas of low marsh. Overall, the number of acres of transition marsh, high marsh, and low marsh would almost exactly balance out. Most of today's tidal flats in the Great Bay Boulevard marsh subdivision would become inundated and add to the open water area. Higher mean water levels would displace approximately 700 acres of highland, killing plant species that cannot tolerate frequent tidal inundation (high-marsh species) but promoting growth of other species that can (low-marsh species).

Both the baseline and low scenario models represent relatively minor and gradual changes within the New Jersey study area. The net change in overall wetland acreage is insignificant. However, the distribution of each subenvironment will undergo major changes and profoundly affect marsh ecology. Since recent studies place a high probability on the low scenario in the future (Titus et al. 1984), the major trend in New Jersey would be replacement of high marsh with low marsh. Current low marsh and certain transition zones would be eliminated.

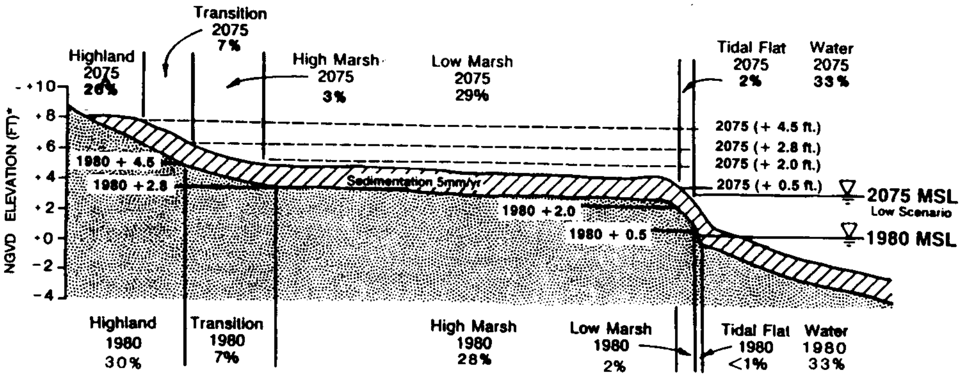
TABLE 3-5

NET CHANGE IN ACRES (AND PERCENTAGE) BETWEEN 1980 AND 2075 FOR PRINCIPAL ZONES UNDER VARIOUS SCENARIOS

Zone	Baseline		Low Scenario		High Scenario	
TUCKERTON MARSH (Tidal Range = 61 cm [2.0 FT])						
Highland	+700	(14)	-600	(12)	-2,300	(47)
Transition	+3,400	(283)	-100	(8)	-100	(8)
High Marsh	-4,000	(87)	-4,100	(89)	-4,100	(89)
Low Marsh	-100	(33)	+4,500	(1,500)	+700	(233)
Tidal Flats	0	(0)	+300	(3,000)	+700	(7,000)
Water	0	(0)	0	(0)	+5,100	(94)
TOTAL						
GREAT BAY BOULEVARD MARSH (Tidal Range = 96.9 cm [3.18 FT])						
Highland	+200	(67)	-100	(33)	-270	(90)
Transition	+1,800	(900)	0	(0)	-170	(85)
High Marsh	-1,900	(41)	-3,900	(85)	-4,570	(99)
Low Marsh	+1,300	(650)	+3,100	(1,550)	0	(0)
Tidal Flats	0	(0)	-1,500	(63)	-2,200	(92)
Water	-1,400	(13)	+2,400	(23)	+7,200	(68)
TOTAL						

FIGURE 3-5

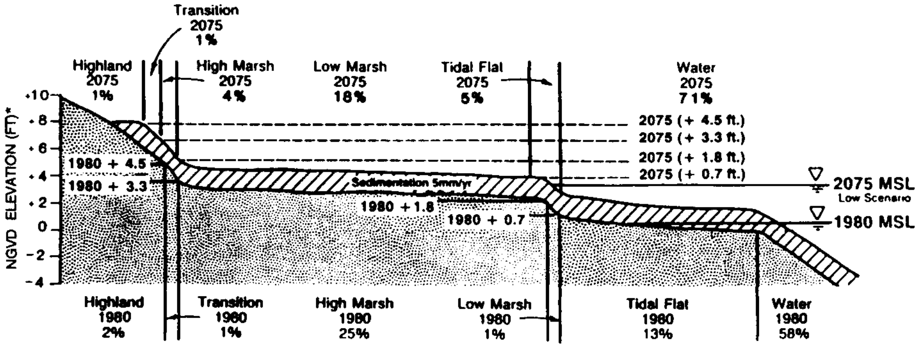
CONCEPTUAL MODEL OF A LOW-SCENARIO SEA LEVEL RISE IN THE TUCKERTON MARSH (Tidal Range=2.0 ft)



**Axis on left shows NGVD elevation; spot elevations are relative to 1980 or 2075 mean sea level.*

FIGURE 3-6

CONCEPTUAL MODEL OF A LOW-SCENARIO SEA LEVEL RISE IN THE GREAT BAY BOULEVARD MARSH (Tidal Range=3.18 ft)



**Axis on left shows NGVD elevation; spot elevations are relative to 1980 or 2075 mean sea level.*

In a gradual scenario, this change would be facilitated by the present distribution of species in the study area. Short *S. altemiflora* (present high marsh) would increase in area and adjust to rising sea level easily as taller forms. *S. patens,* which is currently dominant in many high-marsh areas, would recede inland since it is not adaptable to high water levels. It and many other high- marsh species would most likely disappear as they lost suitable high-marsh habitat and mere compressed in narrowing zones between rising sea level and coastal development. A similar situation is now occurring where *S. patens* is declining in coastal areas and is being replaced by short *S. altemit7ora and Juncus gerardi* is declining throughout (Niering and Warren, 1980). Seagrasses would also be affected and might increase in abundance as present stagnant depressions increased in depth and circulation.

A summary of the predicted effects of gradual sea level rise (low scenario), without human intervention and based on the adaptability of the plants, is presented in Table 3-6. Short S. *altemil7ora* is listed as a significant loss; however, the plants would simply adapt to become taller forms. The critical losses in the high marsh would be *Spartina patens, Distchlis spicata, and Juncus gerardi.* Losses in *Phragmites communes* would be attributable to increased salinity as mail as rising sea level.

High Scenario. The high scenario predicts a net *decrease* in substrate elevation of over one meter (3.3 ft) by the year 2075. Under this scenario, major land and marsh losses would occur throughout the study area. In the 'Tuckerton marsh, 2,300 acres of present highland would become inundated and almost 3,500 acres of marsh (57 percent) would be lost. Open water would almost double by 2075. In the Great Bay Boulevard marsh, over 90 percent of the existing wetlands would be lost. The percentage of open water would increase from 58 percent to 97 percent of the subdivision area. Overall for the New Jersey study area, about 50 percent of existing highland would become inundated, water areas would increase by over 75 percent, and marsh wetlands would decrease by over 70 percent. Figures 3-7 and 3-8 are conceptual models of the marsh loss in these two areas.

All of these estimates assume that wetlands form inland as sea level rises. For the Great Bay Boulevard marsh, this is reasonable. However, for much of the case study area, the land immediately inland of the marsh either is developed or could be developed in the next few decades. Thew areas would have to be abandoned for new marsh to form inland. Otherwise, the wetlands could be completely squeezed between an advancing sea and development, which does not retreat.

TABLE 3-6

EFFECTS OF GRADUAL, LONG-TERM SEA LEVEL RISE ON COMMON SPECIES FOR THE NEW JERSEY STUDY AREA UNDER THE LOW SCENARIO

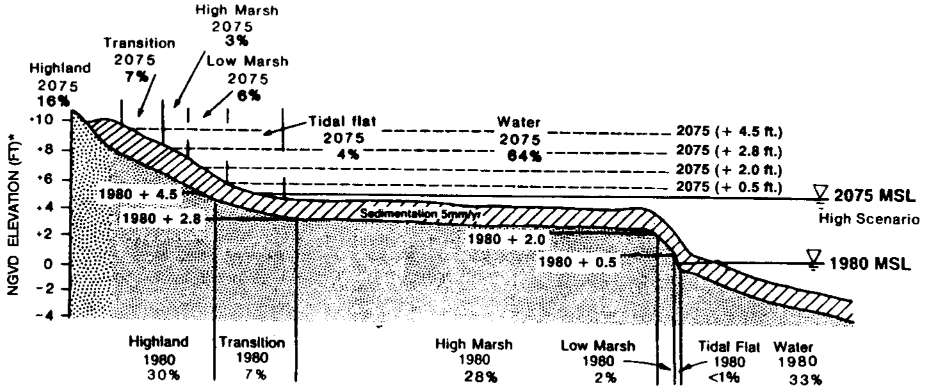
Effects	High Marsh Transition	High Marsh	Low Marsh Transition	Low Marsh	Sub-merged
Significant Losses	PC,JG	SSA,SP,DS	LC	--	--
Significant Gains	--	--	--	TSA,MSA	RM
Minor Losses/Gains	IF,PV,PP	SB	SB	--	--

SP = *Spartina patens*
SSA = Short *S. alterniflora*
MSA = Medium *S. alterniflora*
TSA = Tall *S. alterniflora*
IF = *Iva frutescens*
PV = *Panicum* spp.
SB = *Salicornia* spp.

LC = *Limonium carolinianum*
PP = *Pluchea purpurescens*
PC = *Phragmites communis*
RM = *Ruppia maritima*
DS = *Distichlis spicata*
JG = *Juncus gerardi*

FIGURE 3-7

CONCEPTUAL MODEL OF A HIGH-SCENARIO SEA LEVEL RISE IN THE TUCKERTON MARSH (Tidal Range=2.0 ft)



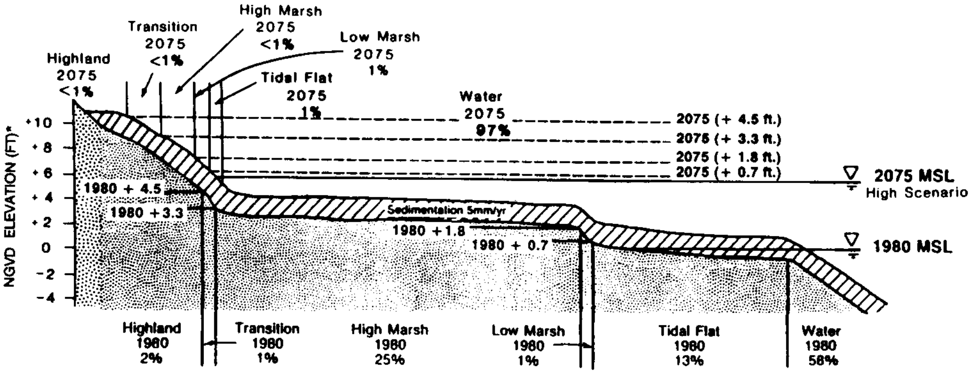
**Axis on left shows NGVD elevation; spot elevations are relative to 1980 or 2075 mean sea level.*

Comparison with Charleston. The major difference between the responses of the New Jersey and Charleston coastal areas to accelerated sea level rise would be under the low scenario. In the case of Charleston, the more productive *S. altemit7ora* low marsh would suffer significant net loss, whereas New Jersey would possibly gain slightly by a transformation from high marsh to low marsh. This difference is, of course, related to the significant difference in present distribution of high and low marsh for each area. Low marsh, which at present dominates in Charleston, would most likely become tidal flats; high marsh, which at present dominates the New Jersey study area wetlands, would become low marsh and actually promote the tall growth form of *S. alterniflora.*

Under the high scenario for both areas, 70-80 percent of existing wetlands would become submerged or transformed into tidal flats. There are significant potential impacts to highlands

FIGURE 3-8

CONCEPTUAL MODEL OF A HIGH-SCENARIO SEA LEVEL RISE IN THE GREAT BAY BOULEVARD MARSH (Tidal Range=3.18 ft)



**Axis on left shows NGVD elevation; spot elevations are relative to 1980 or 2075 mean sea level.*

suggesting that shore-protection measures would be considered in both study areas to protect existing developed land at marginal elevations above the marsh transition zone. The critical highland elevations in Charleston are between 2.0 m and 3.0 m (6.5 ft and 10 ft), compared to between 1.5 and 2.6 m (5.0 ft and 8.5 ft) in New Jersey. This difference, of course, is attributable to the lower tidal range in New Jersey.

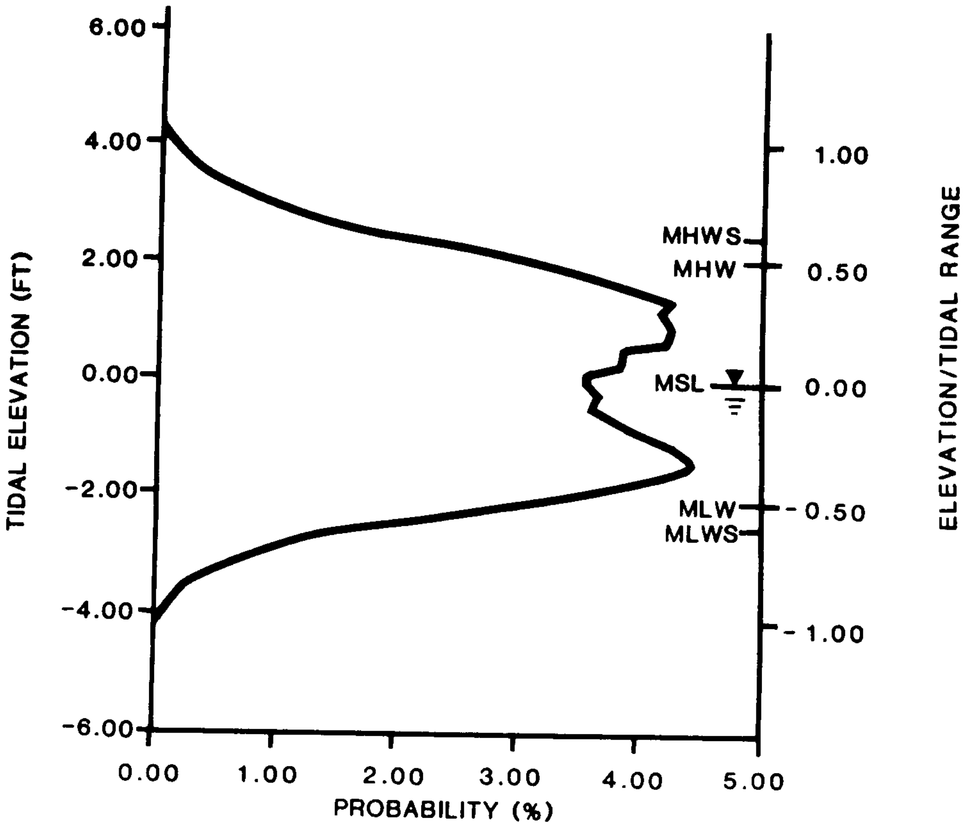
Normalized Elevations

The absolute modal elevation for each species is site-specific for the two marsh areas near Tuckerton. Presuming that the zonation is controlled primarily by tidal inundation, it is possible to normalize the data for variable tidal ranges based on frequency curves for each water level. Figure 3-9 contains a tide probability curve for Atlantic City, New Jersey, near the study area, based on detailed statistics of Atlantic Coast water levels given in Ebersole (1982). The left axis gives the absolute elevation with respect to local MSL, and the right axis has normalized the data as a function of the tidal range. Note that MHW and MLW, the average high and low water levels, respectively, plot at ±0.50 ft on the right-hand axis. This curve has be-en transformed in Figure 340 into a cumulative probability curve which is a measure of the relative duration of flooding at various tide levels.

The data are also normalized for the two specific tidal range areas in the New Jersey study area. Superimposed on the curves are the normalized modal elevations for key wetland species. The relative position of each species is the same, but note the displacement of the entire suite to higher levels in the 2.0-ft (61-cm) tidal range marsh. Tall *S. altemit7ora* occurs at predicted MHW in the Great Bay Boulevard marsh (elevation/fidal range = 0.50), but at a much higher relative elevation in the Tuckerton fringing marsh (elevation/tidal range = 1.20 ft [36.6 cm])-a difference of 0.7 ft (21 cm). Similarly, short *S. altemiflora* is displaced by an elevation/tidal range ratio of approximately 0.7.

If marsh vegetation depends primarily on duration of inundation, one or both sets of these data would be immediately suspect. Therefore, m reviewed the data to determine possible sources of error. First, we compared the results with a similar curve for Charleston (Kana, Baca, and Williams, 1986, Figure 2-7B). The Charleston results are in good agreement with the Great Bay Boulevard marsh (96.9 cm [3.18 ft. tidal range) area. Tall *S. alternit7ora* in New Jersey and low marsh *S. altemit7ora* in Charleston both plotted at MHW. The cumulative duration of inundation (probability percentage) in both areas is 10-14 percent. This is very close, given the limit of accuracy in the surveys.

FIGURE 3-9
TIDE-PROBABILITY CURVE—ATLANTIC CITY

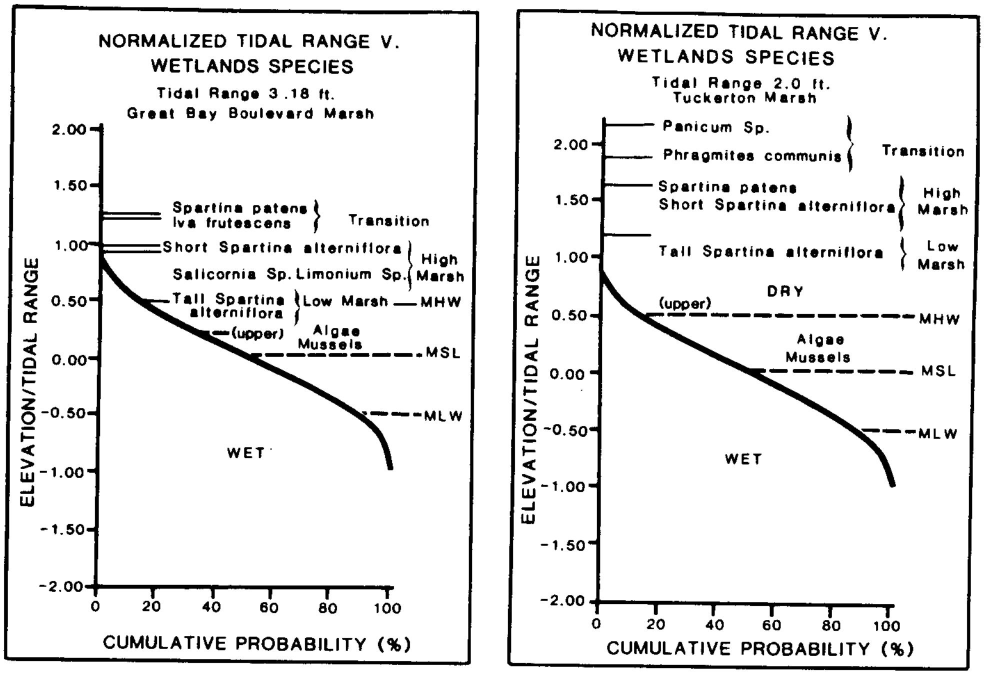


Tide-probability curve based on statistics for Atlantic City, New Jersey (near the study area), given in Ebersole (1982). The data are normalized on the right-hand axis for the local tide range.
Abbreviations: *MHWS (mean high water spring); MHW (mean high water); MSL (mean sea level); MLW (mean low water); MLWS (mean low water spring); Using local MSL as datum.*

The Tuckerton marsh then does not seem to fit the model. This could be due to errors in the benchmark (E55) or tidal records used for the mainland marsh. However, after verifying the records with the National Oceanic and Atmospheric Administration (NOAA), we do not think this is a source of error. Also, tidal data were directly recorded in the immediate vicinity of the Tuckerton marsh transects at three localities as a check on each other by NOAA. The bench- mark and tidal data are sufficiently modern to reflect present conditions so that subsidence or other factors are unlikely to account for the observed differences. This leaves the possibility that while the tidal range is less in the Tuckerton marsh, it is displaced upward as a result of impoundment of water or a difference in water flushing caused by extensive drainage canals. If this were the case, it would be a significant observation indicating the indirect but important effect of canalization on alteration of marsh zonation.

FIGURE 3-10

NORMALIZED, CUMULATIVE PROBABILITY TIDE CURVES FOR THE GREAT BAY BOULEVARD AND TUCKERTON MARSHES



CONCLUSIONS

New Jersey's wetlands have been able to keep pace with the recent historical rise in sea level of thirty centimeters (one foot) per century. However, a one- to one-and-one-half-meter (three-to five-foot) rise would almost certainly be beyond the wetlands' ability to keep pace with the sea.

We estimate that a ninety-centimeter (three-foot) rise in relative sea level would result in a conversion of 90 percent of the study area's marsh from high marsh to low marsh. A large majority of the area's tidal flats could be expected to convert to open water. Although such changes would represent a substantial transformation, the predominance of high marsh in some sense provides a buffer against the impact of sea level rise. Many would view the conversion of high marsh to low marsh as acceptable.

The impact of a one and-one-half-meter (five-foot) rise in sea level would be more severe. Such a rise would result in an 85 percent reduction of marsh and substantial reductions in the area of transition wetlands and tidal flats. The loss of marsh could be even greater if development just above today's marsh precludes the formation of new marsh as sea level rises.

This study did not examine options for increasing the proportion of coastal wetlands that survive an accelerating sea level rise. The institutional pressures to consider this issue may not be great until wetland loss from sea level rise accelerates. Nevertheless, our long-run efforts to protect coastal wetlands may be more successful if some thought is given to long-term measures while the issue is still far enough in the future for planning to be feasible.

NOTES

[1] According to William Maddux of the New Jersey Department of Environmental Protection (personal communication, November 1984).

[2] lots of these profiles are available from the authors.

[3] The scenario referred to as "medium" in Barth and Titus is called "high" in this report.

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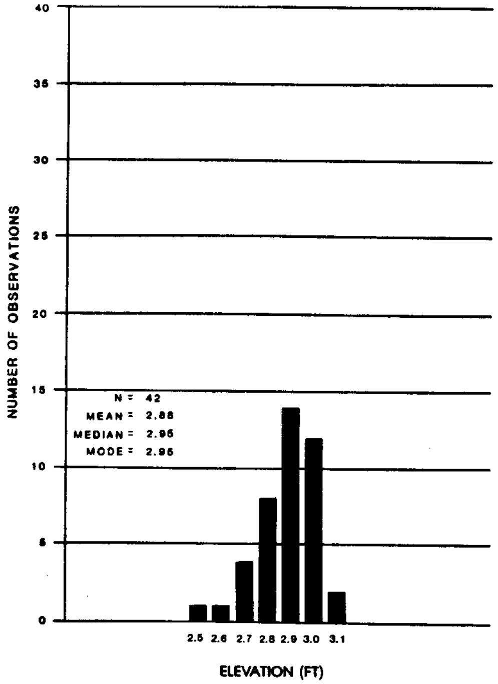
APPENDIX 3-A

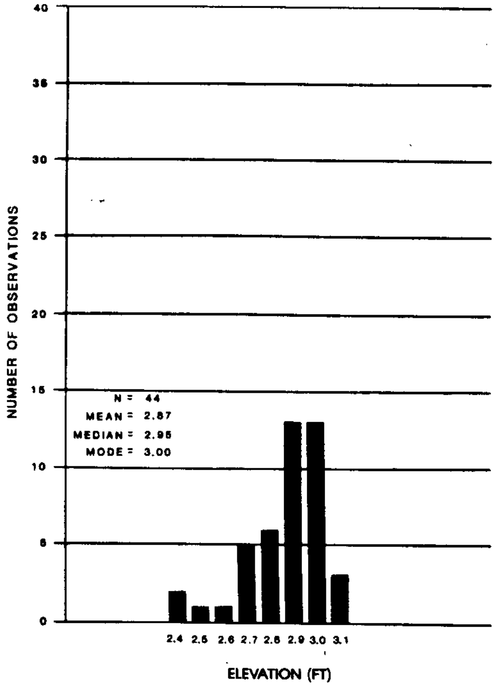
HISTOGRAM OF SPECIES OCCURRENCE

Pages 84-86 show histograms of species occurrence for various species and tidal-range combinations based on the sixteen transacts in the New Jersey study area. Only species having more than ten occurrences at 7.5-m (25-ft) intervals were plotted.

***SALICORNIA SP.* FREQUENCY HISTOGRAM**
Tidal Range=3.18 Ft.

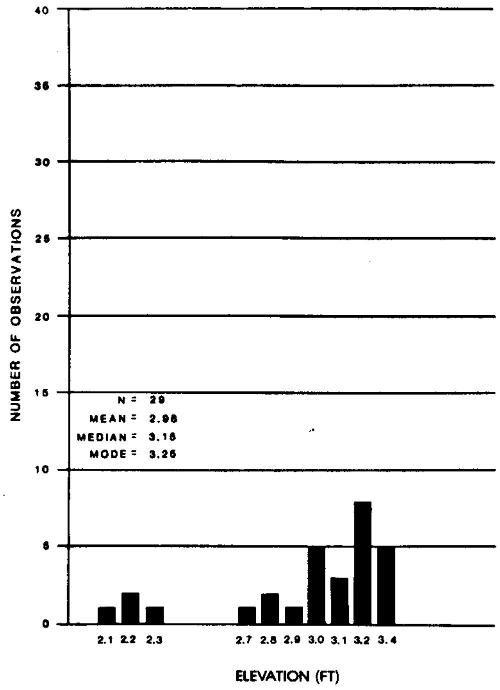


***LIMONIUM CAROLINIANUM* FREQUENCY HISTOGRAM**
Tidal Range=3.18 Ft.



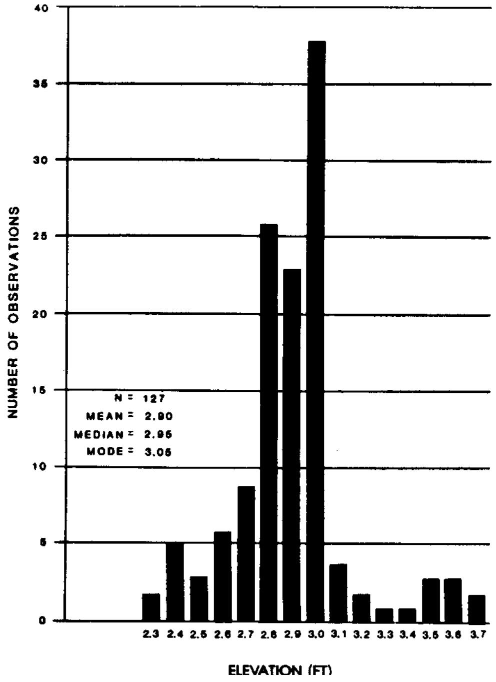
SPARTINA PATENS **FREQUENCY HISTOGRAM**

Tidal Range=2.0 Ft.

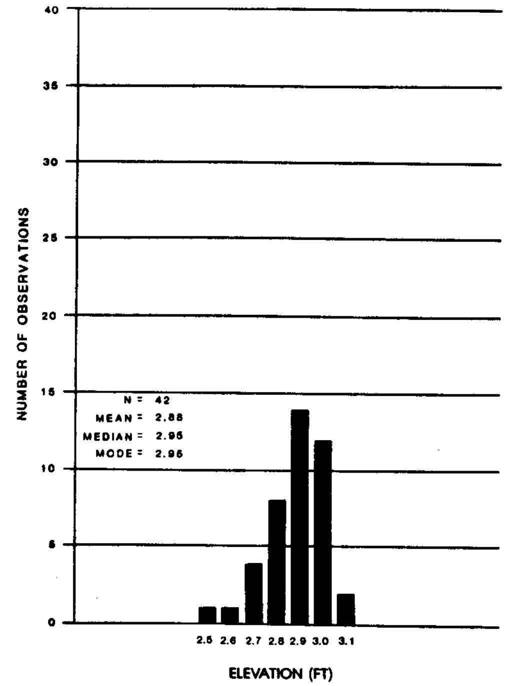


SHORT ***SPARTINA ALTERNIFLORA*** **FREQUENCY HISTOGRAM**

Tidal Range=3.18 Ft.



SALICORNIA SP. FREQUENCY HISTOGRAM
Tidal Range=3.18 Ft.



LIMONIUM CAROLINIANUM FREQUENCY HISTOGRAM
Tidal Range=3.18 Ft.