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GEOLOGICAL SURVEY

# VEGETATION OF SANDY INTERTIDAL FLATS, WILLAPA BAY, WASHINGTON - SUMMER, 1978

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## INTRODUCTION

This paper reports observations made by the authors on vegetation occurring on sandy tidal flats in Willapa Bay, Washington during the summer of 1978. Features of the vegetation observed include (1) general characteristics - diversity, density, and distribution, (2) assemblages, and (3) factors controlling distribution. These observations are part of a larger study into depositional processes and facies characteristics of modern estuarine deposits.

Geologists from the U. S. Geological Survey have been conducting several studies into modern and ancient environments in or near Willapa Bay during the last several years. Results of these studies are reported in Clifton and others (1976), Clifton and Phillips (1978, 1980), Hill and Chin (1979), Anima (1979), Luepke and Clifton (1979), Hill (1980), and Hill and Chin (1981).

## ENVIRONMENTAL SETTING

The following description of the study area is mainly a synthesis of information contained in Garrett and others (1962), Andrews (1965), Clifton and Phillips (1978), and Anima (1979).

Willapa Bay, a coastal plains estuary, is located on the southwestern Washington coast approximately 47 km north of the Columbia River mouth (Fig. 1). The Bay is a complex estuary composed of three large and several small estuaries forming a water area of about 375 $km^2$. The single bay resulted from the formation of a 32 km long sand bar (North Beach Peninsula) extending northward from the mainland (Fig. 2).

The Bay entrance is about 8 km across and is generally obstructed by large sand shoals. Two main channels occur within Willapa Bay (Fig. 2). The south channel (Nahcotta), about 29 km long, is protected from open water by the North Beach Peninsula. The other channel (East) runs east from the Bay mouth for approximately 19 km and is the mouth of the Willapa River, the largest tributary flowing into the bay. Water depths in the main channels vary from 6 to 25 m while channel widths range from 90 to 2200 m. Both channels show a somewhat sinuous configuration which is influenced by the tides.

Extensive tidal flats represent more than half the bay area, with maximum widths up to one kilometer. Two main environments compose the tidal flats (Clifton and Phillips, 1980): (1) intertidal flats which are inundated by astronomical tides, and (2) supratidal flats which are inundated by a combination of astronomical and meteorlogical tides. Salt marshes occur intermittently between intertidal and supratidal flats. Runoff channels which cross the tidal flats occur throughout the bay. Sediments on the flats range from well sorted sand near the main channels to clay in the upper reaches of the tide flats (Fig. 3). In the southern part of the Bay, tidal flats are muddier due to decreases in water circulation and well developed salt marshes. Sections of the north Bay also have dense vegetation on the flats.

The main climate controls over the North Pacific are the semipermanent high and low pressure regions, terrain, and the ocean. During the summer, when a semipermanent high pressure cell predominates, air flow is northwesterly, cool, and relatively dry. In the winter, the Aleutian low pressure replaces the high. Air flow becomes southwesterly and brings moist air onshore. Willapa Bay experiences gale force winds during winter storms.

Mean annual precipitation is about 220 cm. Monthly precipitation is least in July/August (4 cm) and greatest in December (38 cm). However, only a few precipitation records are available for the basin; records from higher elevations are rare. The mean annual air temperature varies from approximately $11^{\circ}C$ (July) to $4.5^{\circ}C$ (January). Extreme temperatures are infrequent and of short duration; overall, the moderating influence of the ocean is noticed in the air temperatures of the area. Relatively high humidities (70-85% in winter, 25-70% in summer) result in low water losses to evaporation. The annual evaporation is about 51-64 cm.

Characteristic of mixed tides on the Pacific coast, tides in the Bay show diurnal inequality. Between mean higher high water and mean lower low water, the diurnal difference is 2.5 m at the Bay mouth to 3.1 m at Nahcotta. Willapa Bay has a water-covered area of about 375 $km^2$ at mean high tide; at low tide only 178 $km^2$ is covered with water. The result is approximately 197 $km^2$ of broad tidal flats (Fig. 2).

Average current velocity during ebb and flood tides is about 2.5 knots. The greatest currents (4-6 knots) occur on the ebb tide at the bay mouth. Even greater velocites may occur during periods of strong south winds due to the northward flow of the ebbing tide coupled with the wind effects. Waves generated offshore have little effect on the inner Bay because of the protection afforded by North Beach Peninsula. An exception is at the Bay entrance where bottom sediment is intensively reworked by waves. Local winds are the most significant agent generating waves in the inner Bay.

Water characteristics in Willapa Bay may change rapidly. About 65% of the water leaves the Bay on an outgoing tide. If this water is caught up in a littoral drift, it is swept away and replaced with ocean water on the incoming tide. On the average, water temperatures range from 7-9 $^{o}$C in the winter to 14-20 $^{o}$C in the summer.

The fall season is a period of relatively high salinity (30 parts per thousand). This results when the Columbia River plume shifts to the south and water offshore of the Bay mouth is replaced with more saline ocean water. During winter, salinity can drop as low as five parts per thousand due to (1) increased runoff from winter precipitation and (2) the Columbia River plume swinging to the north. With decreases in the amount of runoff during the spring, the salinity begins to increase (approximately 20 parts per thousand). Summer salinities (about 25 parts per thousand) result from much reduced rainfall and the influx of more ocean water. The salt water wedge is sharpest in the summer and fall.

Willapa Bay receives runoff from about 2400 $km^2$ of land (principally the west flank of the Willapa Hills). Due to seasonal variation in precipitation and lack of snow or other surface storage to maintain summer flow, runoff is variable. During July to September, runoff accounts for less than 2% of the average annual runoff. Average runoff varies widely between tributary basins. For example, average runoff for the North River basin is about 150 cm, whereas it is over 250 cm in the Naselle River basin. Overall, the runoff figures are generally higher than would be anticipated from available precipitation records.

Sediments in the Bay are supplied by the Pacific Ocean, terrace deposits, rivers, and aeolian sand deposits. The Pacific Ocean supplies most of the sand deposited in the Bay and on the tidal delta at the Bay entrance (Fig. 3). A combination of littoral drift and tides causes extensive erosion along Cape Shoalwater. The eroded sediment is carried onto the tidal delta and into the Bay; in the Bay it is deposited along Toke Spit and Ellen Sands.

By erosional processes, large amounts of mud and sand are derived from the Quaternary terraces around the Bay. During high tides (especially in the winter and /or associated with storms), wave action undercuts the vertical cliffs and stacks causing slumping or slides of the deposits.

Nine rivers supply sediment to Willapa Bay. The majority of clay and silt (minor amounts of gravel and sands) deposited in the Bay come from these rivers.

Sand flats adjacent to North Beach Peninsula are composed mainly of sediment blown from aeolian deposits on the barrier spit. Some sediment is also provided by subtidal channels eroding into beach and nearshore sands.

The specific study area for this report is located on the intertidal flats from Goose Point to Pickernell Creek on the east side of Willapa Bay (Fig. 4). Geographically, this area occupies a mid-estuary position. The width of the flat varies from a few hundred meters to as much as a kilometer. Limited salt marsh and supratidal flat environments occur near the Palix River and Pickernell Creek. Indurated terrace deposits occur along the entire shoreline adjacent to the study area.

Within the specific study area, the average textural characteristics are best described as poorly sorted, fine-grained sand with strongly-fine skewed leptokurtic distributions. Distribution patterns of textural parameters (Fig. 5) show consistent trends of sediments fining upslope and up-estuary reflecting a response to decreasing hydraulic energy and increasing distance from the main sand source (the tidal inlet).

Composition of sediments on the intertidal flats between Goose Point and Pickernell Creek are mainly (greater than 90%) light minerals, mostly quartz with small amounts of lithic fragments, pumice, vegetation, and biogenic shell fragments. Heavy minerals make up about 4% of the sediment. The most common heavy minerals are clinopyroxene, orthopyroxene, hornblende, epidote, and opaque. Clay minerals comprise less than 5% of the sediment. The principal clay minerals are montmorillonite, illite, and chlorite. Fossils (micro + macro) make up less than one percent of the sediment.

Within the specific study area, bed forms range from large sandwaves to small-scale ripples. Due to low sedimentation rates on the flats, the sediment experiences extensive biogenic reworking except where local conditions preclude infaunal activity. Therefore, bioturbate textured sediments are characteristic of these mid-estuary intertidal deposits.

## GENERAL CHARACTERISTICS OF VEGETATION

### Taxonomy

#### Seagrasses

Intertidal vegetation consisted in part of 2 species and 3 varieties of seagrasses (Fig. 6). **Zostera marina** occurred in two vegetative forms: 1) an "intermediate" (int.) size variety with leaf blade widths up to 5 mm and lengths to 20-30 cm, and (2) the well known long wide-leaved (lwf) form typical of the Pacific coast of North America with leaf blades from 5-10 mm wide and lengths up to one meter. **Zostera noltii** occurs in only one vegetative form, a short narrow leaf variety - leaf blade width is generally 1 mm and height about 10 cm. **Z. noltii** apparently is an introduced species (Sayce, 1976).

#### Salt Marsh Grasses

Intertidal salt marsh grasses were predominantly of 3 types: **Triglochin maritima**, **Salicornia** sp., and **Scirpus americanus** (Fig. 7). Only salt marsh grasses occurring in the intertidal zone (i.e., "lower marsh") were considered, no terrestrial marsh vegetation was studied.

### Distribution and Relative Abundance

#### Seagrasses

Seagrasses occur throughout the study area with the exception of the east side of Goose Point. Grassflats are generally patchy and discontinuous in the upper and middle intertidal but dense and continuous on the lower intertidal flats. Sparse to dense patches of **Z. noltii** dominate the upper intertidal zones throughout the study area. Middle intertidal zones are dominated by sparse to moderate (rarely dense) mixed stands of **Z. noltii** and **Z. marina** (int.). The "landward" and "seaward" edges of this mixed zone grade into relatively pure stands of **Z. noltii** and **Z. marina** (lwf) respectively. Lower intertidal flats are characterized by dense, well-developed **Z. marina** (lwf) beds.

Salt Marsh Grasses

Salt marsh grasses occur primarily in the southern part of the study area, although flats east of Goose Point have small, localized supratidal salt to brackish water marsh clumps. Topographic "Holocene" lows in the Pleistocene terrace topography are filled with dense and luxuriant stands of brackish to fresh water (terrestrial) marsh grasses. Gradations occur from terrestrial to supratidal to intertidal or lower marsh. Intertidal salt marsh grasses occur in small clumps and patches, often with a thin film of algae between clumps. Salt marshes also occur on the intertidal flats at Copper Point and Pickernell Creek.

## ASSEMBLAGES AND ZONATIONS

### Seagrasses

Seagrasses occur in specific assemblages which are restricted in distribution. Upper intertidal flats are characterized by relatively pure sparse to dense stands of **Z. noltii**. However, in places, upper flats may contain **Z. marina** (int.) mixed with **Z. noltii**. **Z. marina** (int.) always occurs in topographic lows when found on the upper flats (i.e., where water is persistently ponded even on very low tides).

Middle intertidal flat areas are characterized by mixed stands of **Z. noltii** and **Z. marina** (int.). Mixed grassflats grade upslope into relatively pure **Z. noltii** and downslope into relatively pure **Z. marina** (lwf). Ridge and trough topography, where present on the intertidal flats, impart both a vertical and a horizontal zonation on the seagrasses present. **Z. noltii** occurs both on the ridge crest and in the trough whereas **Z. marina** (int.) occurs only in the troughs.

Lower intertidal flats characteristically exhibit dense and well developed grassflats of pure **Z. marina** (lwf). These grassflats are extensive and extend from the lower intertidal flats to the eastern levee of the Nahcotta Channel (up to 1 km in extent).

## Salt Marsh Grasses

Salt marsh grasses also occur in distinct assemblages and zonations with diversity increasing landward (upslope). At Copper Point, **Triglochin** is predominant on the lower parts of the upper intertidal zone and is mixed with **Scirpus** on the higher part of the upper intertidal. These species grade into a higher supratidal to terrestrial marsh which contains more diverse assemblages. At Pickernell Creek, **Triglochin** occurs in a different assemblage but has the same zonation within the lower marsh. **Triglochin** dominates the lower part of the upper intertidal, occurring in small dense clumps. On the higher part of the upper intertidal **Triglochin** occurs mixed with **Salicornia**. In every clump observed, **Salicornia** was always topographically higher and surrounded by **Triglolchin**. Some **Scirpus** occurs on the highest upper intertidal to supratidal zones.

## FACTORS CONTROLLING DISTRIBUTION

Diverse, yet interdependent, physical factors control to a large extent the distribution, assemblage, and zonation of both seagrasses and salt marsh grasses within the intertidal flat areas. Factors influencing and acting upon seagrasses are (Phillips, 1972): (1) salinity, (2) temperature, (3) substrate, (4) light and depth, (5) waves, surge, and currents. Factors acting upon salt marshes include (Chapman, 1938): (1) elevation, (2) salinity, (3) drainage, (4) aeration, (5) water table, (6) rainfall, (7) soil, (8) evaporation, (9) temperature, and (10) biota.

Seagrasses are strongly controlled by substrate type and elevation as well as tidal action. Grassflats thrive in dense and well-developed stands where 1) sufficient modern sediment covers the indurated Pleistocene surface, 2) intertidal flats are relatively free of topographic ridge and trough systems, and 3) efficient drainage is carried out by intertidal runoff channels. The area between station 712-1 and station 719-6 (Fig. 4) is a type example of this case. Lowermost intertidal flats bordering the Nahcotta Channel are another good example. Seagrasses will grow on practically any sediment type, but initial colonization will occur only if organic matter is present in the sediment (Den Hartog, 1970).

Elevation of the intertidal flats is a determining factor in controlling seagrass and salt marsh zonation. A normal zonation of seagrasses from upper to lower intertidal would show: Z.

**noltii** ---> **Z. noltii** + **Z. marina** (int.) ---> **Z. marina** (lwf). However, where ridge and trough or relict topography dominate the flats, both vertical and horizontal zonations and assemblages are imparted by topography present. As stated previously, **Z. noltii** will occur both on the ridges and in the troughs while **Z. marina** (int.) will occur only in the troughs. The same holds true in general for relict topographic highs and lows. However, where relict topography on the intertidal flats is composed of indurated mud, little to no vegetation will be present. Where topographic lows occur on the intertidal flats and water is persistently ponded from one tidal cycle to the next, dense stands of mixed seagrasses may be present even on the upper intertidal (as near Pickernell Creek). The topographically "highest" parts of the intertidal flats, such as ridge crests, are often void of any seagrass cover due to extensive subaerial exposure during low tides.

Tidal action is important in controlling seagrasses. Those areas of the intertidal flat that are regularly inundated and efficiently drained ("flushed") support the densest and most well-developed seagrass beds. The highest parts of the upper intertidal (to supratidal) where inundation is accomplished only on the highest high tides support very little to no seagrass cover (except where topographic lows might pond water).

Intertidal saltmarsh grasses are governed predominantly by water/substrate salinity and elevation. In lower marsh zones, regularly inundated by tides, **Triglochin** predominates. Upslope and higher topographically, **Scirpus** and **Salicornia** occur mixed with **Triglochin**. These areas are subjected to less frequent inundation and fewer hours of submergence on the average. **Triglochin**, **Salicornia**, and **Scirpus** themselves grade into and then are replaced by other marsh grasses in the supratidal to terrestrial marsh zones. The occurrence of marshes in "Holocene" lows in the Pleistocene terrace topography seems to determine where salt marshes will occur in the study area. In other parts of Willapa Bay, this observation does not necessarily hold true. Soil salinity seems to be a controlling effect as the higher marsh areas which undergo greater dessication show higher salinities. High saline content in substrates inhibits growth and abundance of salt marsh grasses (Atwater, 1979). A factor which was not investigated, but which may be an important controlling factor is interspecific competition between marsh plants.

## SUMMARY

Reconnaisance of the tidal flats between Goose Point and Pickernell Creek in Willapa Bay suggested the following major trends for seagrasses: (1) **Z. marina** (lwf) was most dense in subtidal and continually ponded areas of the flats, (2) **Z. marina** (int.) was found mixed with **Z. noltii** on the mid-tidal flat and to a lesser extent with **Z. marina** (lwf) on the lower tide flats, (3) **Z. noltii** was limited primarily to the upper and mid-tidal flats. **Z. noltii** was the most ubiquitous of the three forms present. Major controlling factors in the physical environment were relative lengths of subaerial versus tidal inundation, effectiveness of tidal circulation, and relative elevation of the tide flat surface.

Salt marshes within the study area occurred primarily in small circular clumps directly seaward of topographic lows in the Pleistocene terrace topography. Salt marsh grasses show a distinct increase in density and diversity from the upper intertidal into terrestrial marshes (upslope). **Triglochin** occurs in pure stands on the upper intertidal flats and in mixed stands with **Scirpus** or **Salicornia** in supratidal flat areas. Controlling physical factors appear to be water salinity, substrate salinity, and elevation. Recent salt marsh geographic distribution from Goose Point to Pickernell Creek seems to be controlled by antecedent Holocene topographic lows in the Pleistocene terraces.

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## LIST OF FIGURES

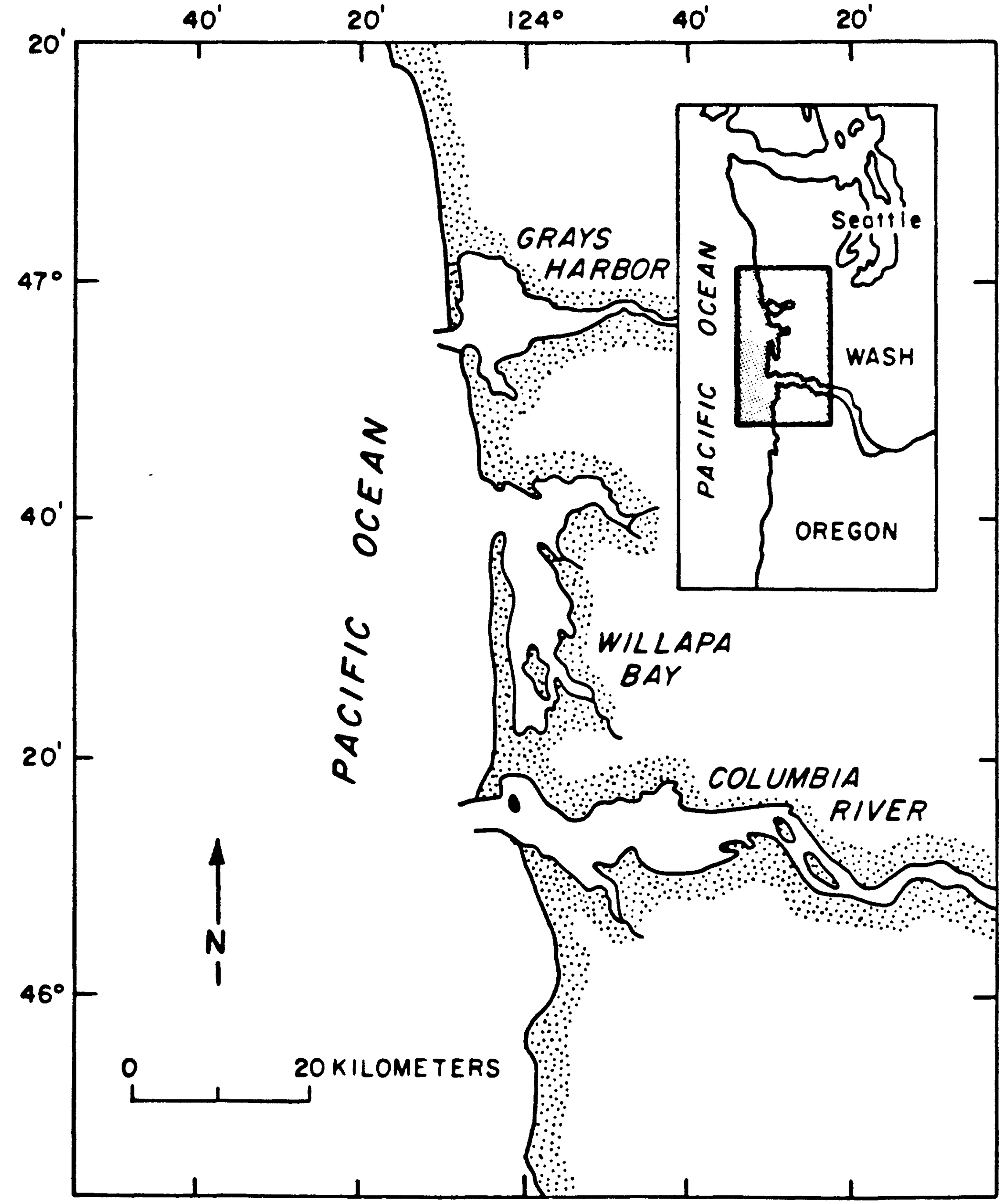
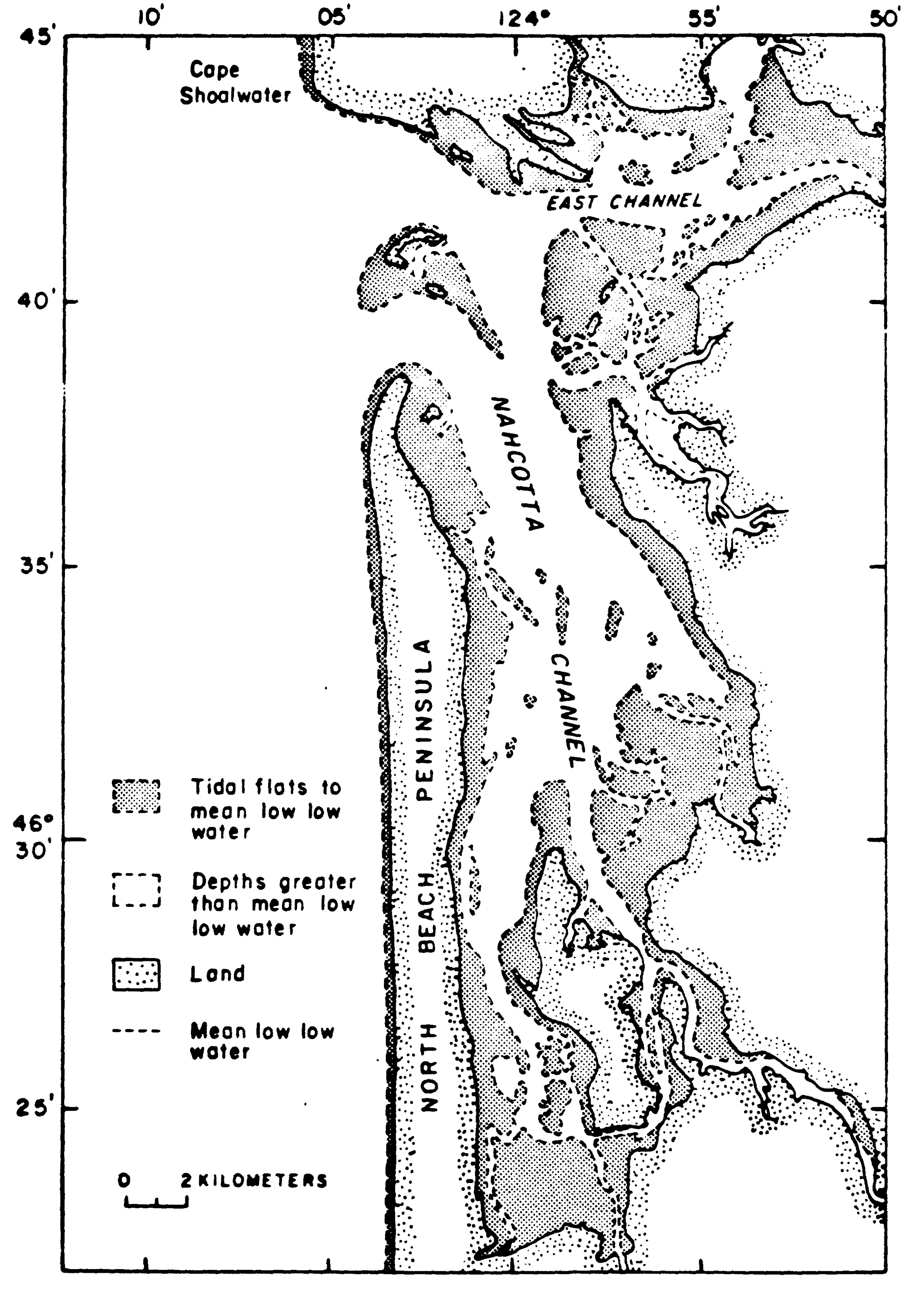

40'
20'
124°
40'
20'
20'
47°
40'
20'
46°
GRAYS HARBOR
PACIFIC OCEAN
WILLAPA BAY
COLUMBIA RIVER
N
0
20 KILOMETERS
Seattle
PACIFIC OCEAN
WASH
OREGON

FIG.1



10'
05'
124°
55'
50'
45'
40'
35'
46°
30'
25'
Cape
Shoalwater
EAST CHANNEL
NAHCOTTA
CHANNEL
NORTH BEACH PENINSULA
Tidal flats to mean low low water
Depths greater than mean low low water
Land
Mean low low water
0 2 KILOMETERS


FIG.

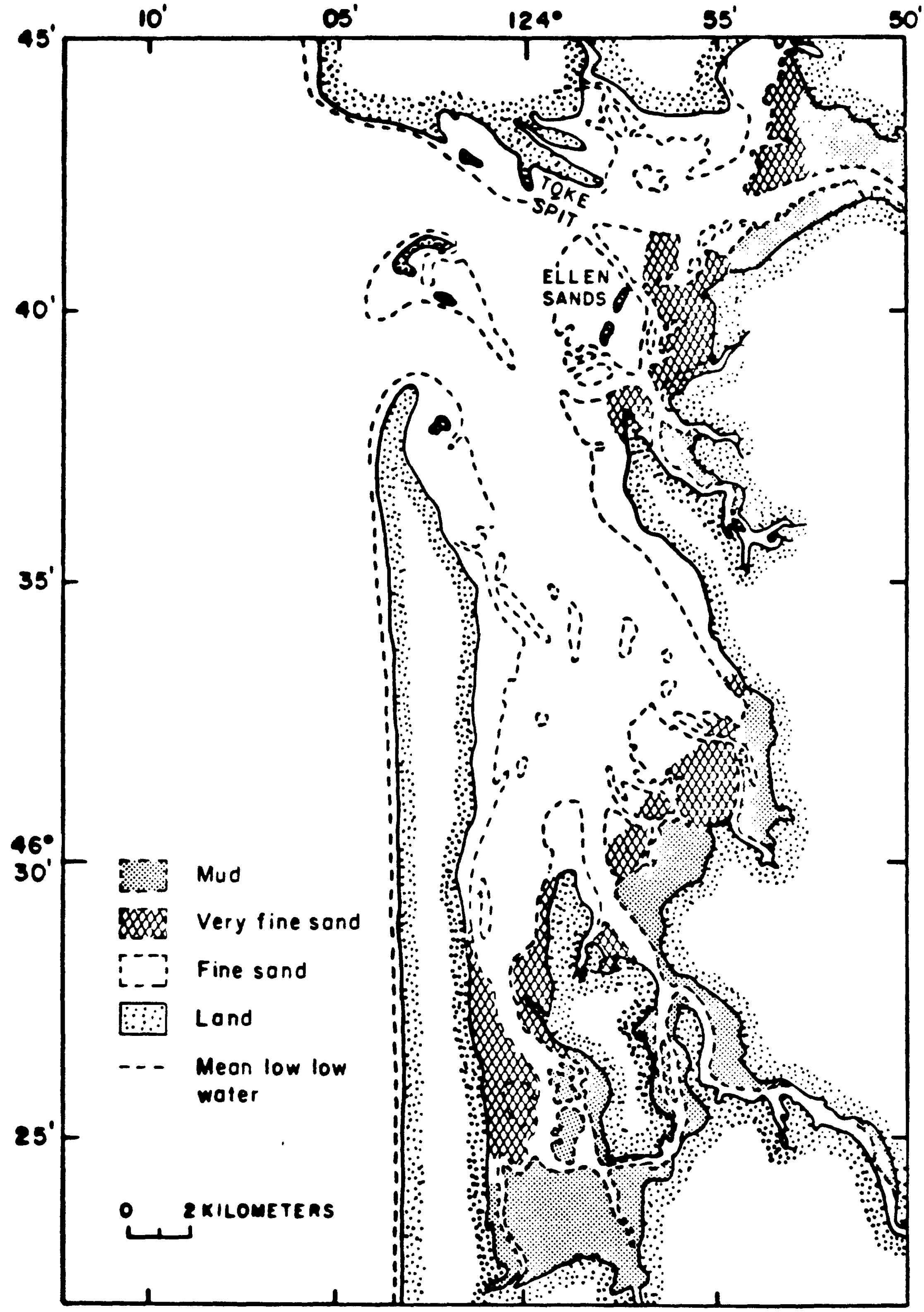

10'
05'
124°
55'
50'
45'
40'
35'
46°
30'
25'
TOKE SPIT
ELLEN SANDS
Mud
Very fine sand
Fine sand
Land
Mean low low water
0 2 KILOMETERS

FIG.3

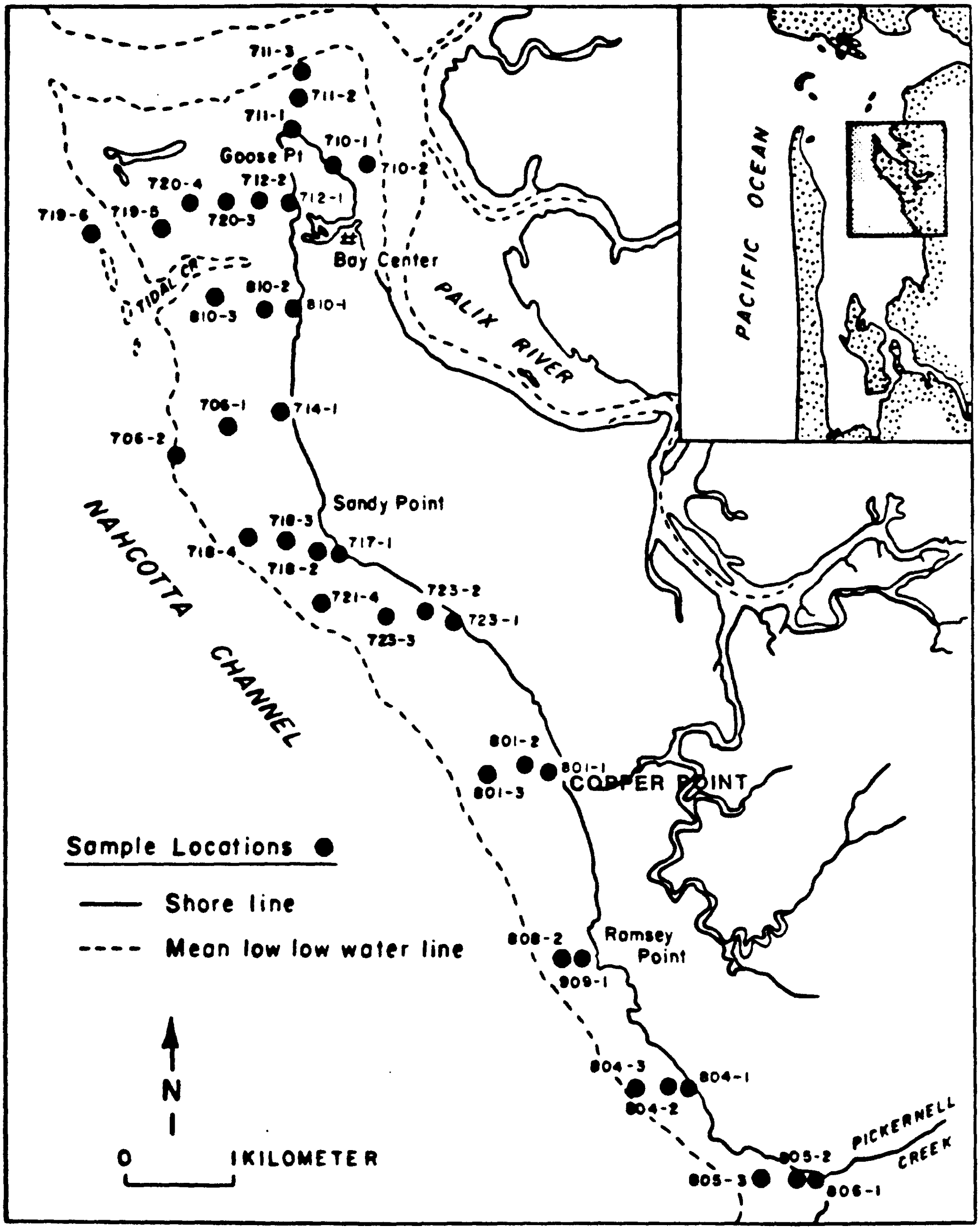

PACIFIC OCEAN
NAHCOTTA CHANNEL
PALIX RIVER
Goose Pt
Bay Center
TIDAL CR.
Sandy Point
COPPER POINT
Ramsey Point
PICKERNELL CREEK
711-3
711-2
711-1
710-1
710-2
720-4
712-2
712-1
719-6
719-5
720-3
810-2
810-3
810-1
706-1
714-1
706-2
718-3
717-1
718-4
718-2
723-2
721-4
723-1
723-3
801-2
801-1
801-3
808-2
809-1
804-3
804-1
804-2
805-2
805-3
806-1
Sample Locations
Shore line
Mean low low water line
N
0 1KILOMETER

FIG.4

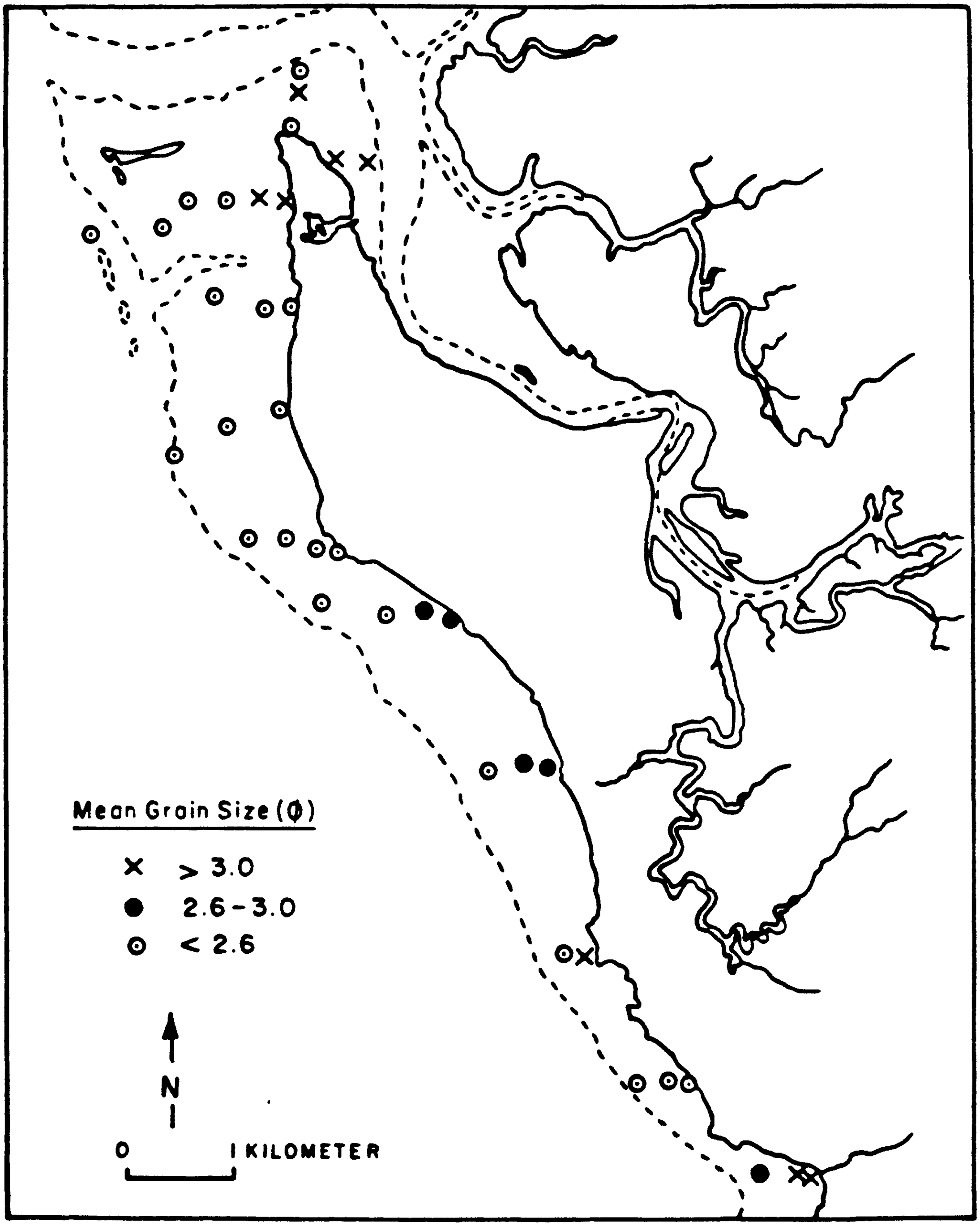
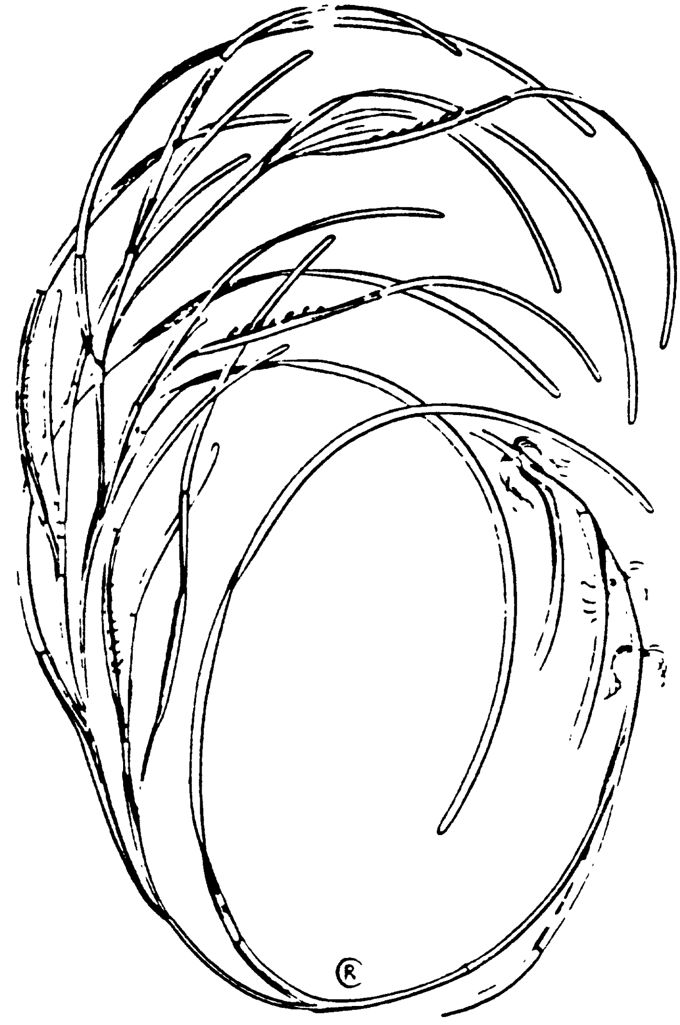
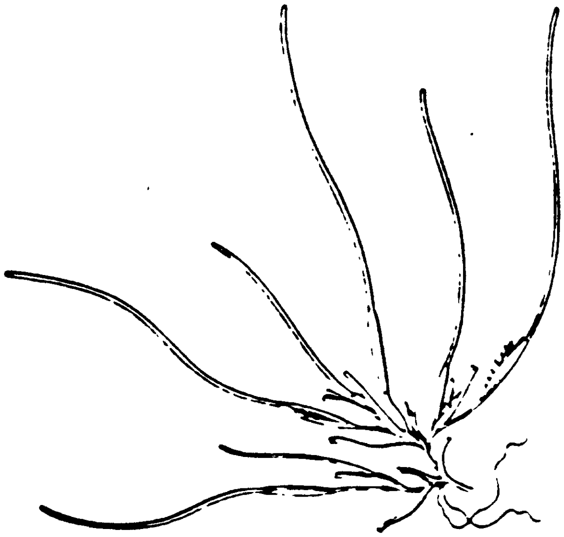



FIG.5

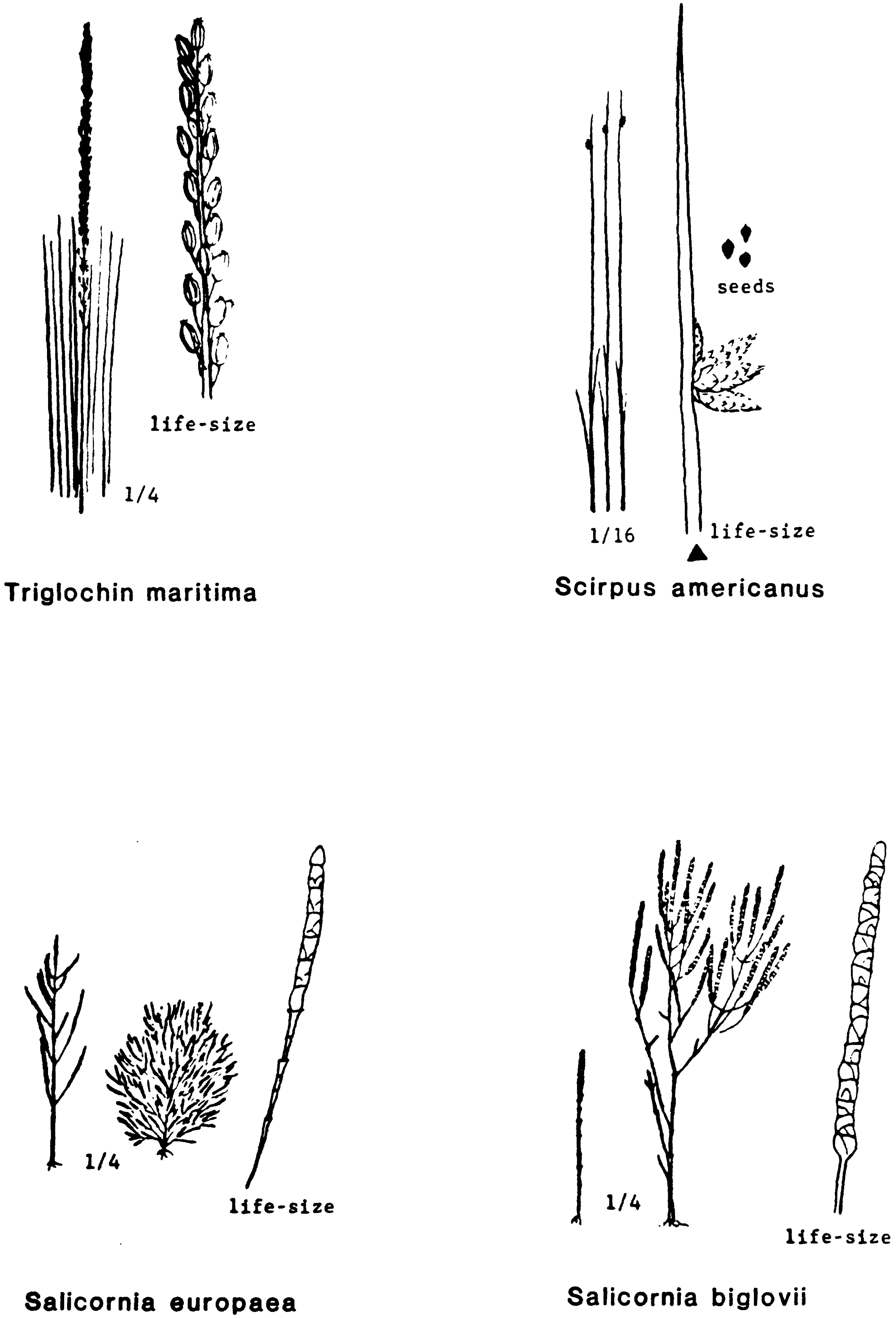


Zostera marina L.



Zostera noltii

FIG.6




TWO POSSIBILITIES FOR SALICORNIA sp.

FIG.