

tidal flats, the fewer sessile organisms that will be present because of the exposure factor. Another limiting factor to benthic organisms is an oversupply of suspended sediment particles in the water column. Filter feeders are prone to siphon clogging, and they cannot live under such conditions. The other important limitation is a mobile sediment bed caused by strong tidal currents. Many infaunal organisms, especially sedentary ones, need a reasonably stable sediment base in which to burrow and maintain an existence. It is obvious therefore, that the problems confronting benthic organisms are numerous in estuaries.

## SALT MARSHES

It is typical for a portion of the outer margin of an estuary to be covered by a marsh. The proportion of the estuary that supports this environment ranges widely—from essentially all of the estuary except for tidal channels to only a border a few meters wide. The proportion of the estuary that is covered by marsh tends to indicate the maturity of the estuary or the degree to which it has been filled in with sediment. For example, some of the estuaries on the Georgia coast have little open water except near the inlet between the barrier islands. Only tidal creeks dissect the extensive marsh environment in these sedimentologically



**FIGURE 6.18**

Photograph of an extensive salt marsh along the southeastern coast of the United States.



**FIGURE 6.19**

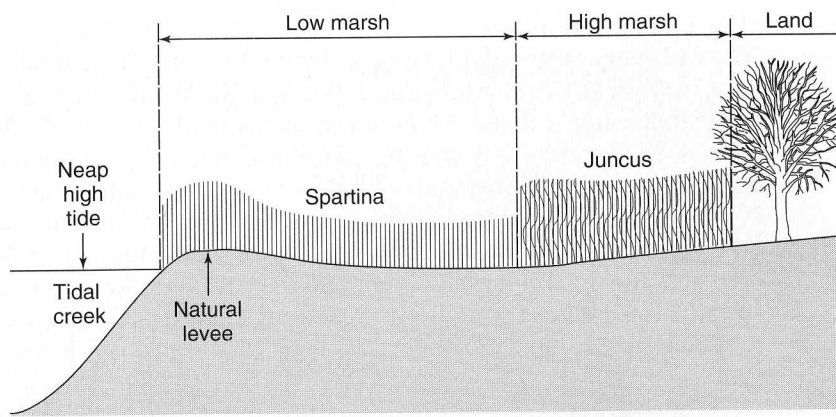
Photograph showing a narrow marsh fringe in The Bay of Fundy is considered to be immature in its sediment infilling.

mature estuaries (Fig. 6.18). By contrast, the German Wadden Sea is bordered by a narrow marsh, and the Bay of Fundy supports a narrow and discontinuous marsh environment (Fig. 6.19), evidence of a sedimentologically immature estuary.

### Formation of a Coastal Marsh

A marsh is really the vegetated portion of the higher intertidal environment. Above about neap high tide there is little energy to disturb the sediment substrate, and the sediment that accumulates there tends to be relatively fine grained. All of these factors provide support for vegetation, an undisturbed place of fine, organic-rich sediment. Certain opportunistic and tolerant grasses thrive in this environment. There are two that are particularly prone to establish dense stands on such substrates—*Spartina* and *Juncus* (Fig. 6.20). Although they are not the only marsh taxa, these are the most widely distributed in North America.

The specific type of grass that develops a marsh depends upon climate and latitude. In the southern coasts *Spartina alterniflora* is the low marsh grass that is found between neap and spring high tide; in most estuaries this is a narrow



(a)



(b)

**FIGURE 6.20**

Diagram a) and photo b) showing *Spartina* and *Juncus* zonation along the margin of an estuary.

(a - From Edwards, J. M. and Frey, R. W., 1977, Substrate characteristics within a Holocene salt marsh, Sapelo Island, Georgia, *Senckenbergiana Maritima*, 9, pp. 215-259)

range in elevation of a few tens of centimeters, but up to a few meters in estuaries with very large tidal ranges. Individual plants are generally about knee-high but vary greatly depending upon their specific location within the marsh and the availability of nutrients. The highest plants tend to be on the highest elevations, that is, the levees of the channel margins and near spring high tide. The *S. alterniflora* plants at the lowest part of the marsh may be quite small and scattered.

*Juncus* is the high marsh grass in low to mid-latitudes and is restricted to the elevation at about spring high tide. This plant, also called the *needle rush*, is as tall as a person and has a pointed end that has been known to penetrate shoes. It attains this height throughout the extent of the spring tide position of the estuary margin. In more northern areas the high marsh is characterized by *Spartina patens*.

In high latitudes the high and low marsh are characterized by two species of *Spartina*. In the low marsh this is *S. alterniflora* but here it does not grow very tall. The high marsh is characterized by *S. patens*, which grows taller.

The marsh environment in the estuary is really like the floodplain in the river system: (1) it is typically cut by channels having point bars, (2) it has natural levees, and (3) crevasse splays may breach the levees. The channels display meanders with cutoffs like oxbow lakes. Once sediment accumulation on a tidal flat reaches about the neap high-tide level, colonization by *Spartina* begins to take place. It has the ability to grow on local sites just because they have reached the appropriate elevation. For example, the crest of a large bedform such as a sand wave may have marsh vegetation whereas the trough does not. Eventually the marsh becomes nearly flat or gently sloping and continuously covers the surface.

Marsh vegetation tends to be quite dense and provides an excellent sediment trap in two ways. First, the grass slows the flow of tidal waters to permit settling out of fine suspended sediment particles to the floor of the marsh. Second, considerable fine sediment adheres to the marsh grasses as the turbid water flows past. Both of these mechanisms provide for slow accumulation of generally muddy sediment. Suspension feeders living within the marsh grass produce pellets that accumulate within the marsh and that contribute to its aggradation. After sediment has reached approximately the level of spring high tide the *S. alterniflora* will give way to *Juncus*. Sediment accumulates very slowly in the high marsh because it is only flooded a few days during each lunar tidal cycle and because the sediment-laden water column is quite thin in this area.

A convenient way to consider marsh development is through the relative distribution of the low and high marsh portions of the total vegetated environment (Fig. 6.21). Without using any absolute ages, we can consider young, mature, and old marshes to reflect their progressive development, assuming that sea level has not changed substantially. A young marsh is one that has mostly low marsh vegetation, that is *S. alterniflora*, with perhaps only a fringe of high marsh around the outer edge. Tidal channels are abundant, providing good drainage and sediment supply. This stage of marsh development is present until enough



(a)



(b)

**FIGURE 6.21**

Photos showing three stages of marsh development: a) youthful with mostly low marsh; b) mature with a nearly even mixture of high and low marsh; and c) old age with mostly high marsh.

(Courtesy of Joe Wadsworth)



(c)

**FIGURE 6.21** (Cont.)

sediment has been delivered to the upper intertidal area to support an increased upper marsh community.

The intermediate stage of marsh development has a near-equal distribution of high and low vegetation types, and there are fewer tidal channels than in the young marsh. As the sediment continues to be delivered to the upper intertidal area, the marsh becomes quite "old" in its development. *Juncus* or *S. alterniflora* characterizes nearly all of the marsh with a few large tidal creeks interrupting an otherwise continuous stand of this species. Continued sediment accumulation will allow land plants to encroach into the marsh as the estuary becomes smaller.

The end product of this scheme of succession of land plants, marsh, and tidal flats into the estuary will be its complete infilling. Because they are sediment sinks, this is their eventual fate unless sea level changes either enlarge the estuary or abandon it at a high level, in which case, terrestrial vegetation will likely move in.