TIDAL SALT MARSHES AND MANGROVE SWAMPS

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Summary

Tidal salt marshes and mangrove swamps occur on marine and estuarine coastlines that are sheltered from intense wave activity in locations that allow fine-grained sediment to accumulate. Tidal salt marshes extend from the arctic to subtropics where they are replaced by mangrove swamps. Marshes are dominated by herbaceous or low shrubby vegetation while trees dominate mangrove swamps. The vegetation cover in both swamps and marshes may be reduced in arid regions where high rates of evapotranspiration result in high soil salinities.

Both mangroves and salt marshes occur over a narrow elevation range spanning mean high water and their continued existence requires that their surface elevation increase in step with sea level rise. Accumulation of both mineral and organic sediments is important to this process of vertical soil accretion. Rates of mineral sediment deposition among wetlands will increase with increasing concentration of suspended sediment. Within wetlands rates of deposition decrease with increasing surface elevation and distance from the source of floodwaters. Plant growth helps to stabilize mineral sediment deposits and contributes to the soil as below-ground growth as well as litter.

Wetland deposits increase in thickness with rising sea levels, helping to store excess nutrients and pollutants that are introduced into coastal waters. However, filling, draining and dredging of coastal wetlands has resulted in extensive loss of mangroves and tidal salt marshes. Some wetlands may not be able to vertically accrete at the pace of the increased rate of sea level rise expected from greenhouse warming, but can

laterally accrete landward. Barriers and development at the inland edge of coastal wetlands will prevent this migration and such wetlands may be lost.

1. Definition and Distribution

Tidal salt marshes and mangrove swamps occur on marine and estuarine coastlines that are sheltered from intense wave activity in locations that allow fine-grained sediment to accumulate. Tidal salt marshes extend from the arctic to subtropics where they are replaced by mangrove swamps. The marshes are dominated by herbaceous or low shrubby vegetation (Figure 1). Trees dominate the mangrove swamps (Figure 2) that are generally confined to the regions approximately 30 degrees north and south of the equator. In some locations, such as the southern limit of mangroves in Australia mangrove "trees" may be of short stature, forming more of a shrubland, difficult to differentiate on the basis of the plant life form alone. Here taxonomic distinctions become most important. Mangroves are found in 114 countries and territories, and at least two inventories estimate their total global area as approximately 181,000 km^2. Some countries and regions have inventoried salt marsh area – the total from these inventories comprises 22,000 km^2. As there is no data on the extent of saltmarshes on the coasts of Asia, South America, and Australia the global area of salt marshes is probably considerably greater.

Figure 1. View of salt marsh, looking towards upland at the restored buildings of Le Village Historique Acadien, Pubnico, Nova Scotia (Canada). High marsh in the foreground is covered by salt meadow hay (*Spartina patens*) a grass that does not stand erect, but falls over forming a mat of grass. Just beyond is the low marsh with erect salt marsh cordgrass (*Spartina alterniflora*) providing a contrasting texture. The low marsh borders a creek and the sequence of low marsh and high marsh is mirrored on the other side. To the left of the photo, near the toe of the upland slope, is a stack of salt meadow hay resting on a raised platform. The hay was harvested in a reconstruction of Acadian agricultural practices. Photo by author.

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Figure 2. A stand of mangroves, at low tide, on Batan Bay estuary in the Aklan Province of the Philippines. The trees (of the genus *Rhizophora*) are locally known as Bakhaw. Photo courtesy of P. Kelly.

These wetland ecosystems are exposed to air much of the time, but subject to flooding by coastal waters. The flooding regime may be dominated by either astronomical tides or meteorological tides, when water levels may be wind-driven. Tidal wetlands also exist in the freshwater, upper reaches of many estuaries, but are not considered here.

Unvegetated flats (of mud or sand) are often present within the intertidal zone seaward of the swamp or marsh, and seagrasses may extend from the lowest areas of the intertidal to subtidal regions (i.e., continuously submerged by coastal waters). Elevation of the marsh or swamp surface generally increases landward from the seaward edge, or toward creekbanks, but may be dotted with permanent and temporary pools, usually referred to as "pans" in salt marshes. Although changes in elevation seem minor, a small change in elevation results in a significant variation in the frequency at which tidal flooding can occur. With increased elevation there is decreased flooding frequency resulting in changes in soil conditions that are reflected by distinctive changes in vegetation. The higher flooding frequency along tidal channels results in high rates of sediment deposition that may cause formation of an elevated berm, or levee. In mangrove swamps such berms may be particularly prevalent and characterized by a distinctive swamp zone referred to as fringe mangroves. Where berms are well developed the interior, or basin, mangrove soils are at lower elevations and subject to more extended periods of submergence and saturated soil conditions. In salt marshes areas subject to the most frequent tidal flooding are referred to as low, or submergent marsh, and those subject to infrequent flooding as high or emergent marsh.

2. Climate

Because they are flooded with saline water, vegetation of mangrove swamps and tidal salt marshes must be able to tolerate not only flooded soil conditions, but also accumulation of salt and, with anaerobic conditions, toxic sulfides in their rooting zone.

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Evapotranspiration increases salinity of soils, so that they may have salt concentrations greater than that of seawater (32 ppt). Precipitation and daily tidal flooding reduce the impact of evapotranspiration. Inputs of freshwater through surface and ground water drainage from terrestrial areas reduce salinities in adjacent portions of the wetland, thus highest soil salinities are found mid-way between the seaward and upland edge of tidal saline wetlands. Wetland soil salinities are highest in arid regions where evapotranspiration rates are high and rainfall low. Marshes in dry mediterranean climates, such as those found in southern California and on the Rhone Delta have reduced plant cover. Under extremely arid conditions the soil surface may be covered by a layer of dried sea salts, rendering it inhospitable to most higher plants.

Figure 3. Salt marsh at St. Paul Bay, Newfoundland. The gray mass of dead eelgrass in the foreground is called “wrack.” The irregular marsh surface and boulder field on the tidal flat are typical of northern salt marshes. Photo by author.

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In boreal and arctic marshes rates of evapotranspiration are not only low in relation to precipitation, but melting sea ice further reduces local surface water salinity. In winter, movement of ice (during tides and storms) has a dramatic impact on the physiography of the marsh. Large boulders entrapped in the ice can be dragged across the marsh, gouging out depressions and making the surface quite irregular. In areas, such as small embayments along the coast of Newfoundland, Canada, ice action will eventually form a boulder field seaward of the marsh on the tidal flat. The boulder field then acts to shelter the marsh within the embayment.

3. Soil Accretion and Geomorphic Evolution

Both mangroves and salt marshes occur over a narrow elevation range spanning mean high water and changes in local sea levels directly impact physical and biological processes in these wetlands. On coastlines subject to isostatic rebound (due to recent glaciation), marshes may become stranded above the level of tidal flooding, left as an indicators of past, higher sea levels. Examples of stranded marshes can be found on the coast of Canada's Hudson Bay.

3.1. Processes of Vertical Soil Accretion

On coastlines subject to rising sea levels tidal wetlands are assumed to adjust their elevation in step with sea level changes. Figure 4 depicts the processes that play a role in marsh and swamp accretion. Surface elevation can increase through inputs of mineral sediment and organic matter – it can decrease through decomposition of organic matter and compaction of the soil. Thus, controls of plant productivity and sediment supply greatly impact vertical accretion and the ability of a wetland to keep pace with rising sea level. Submerged salt marsh deposits found on the continental shelf of the Northwest Atlantic provide striking evidence that the rate of marsh elevation increase during the early Holocene could not compensate for the rapid sea level rise caused by melting of ice sheets and thermal expansion of the ocean.

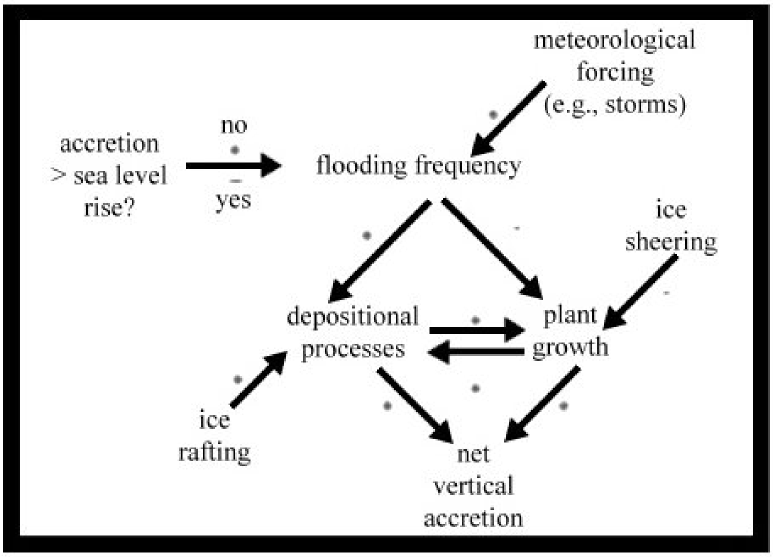

Figure 4. Interaction of factors critical in vertical soil accretion. Plus (+) signs indicate a positive response and negative (-) signs, a negative response. Photo by author.

In North America and Europe much research has been focussed on assessing rates of vertical soil accretion and the relative importance of factors affecting this process. Processes can be studied over many time scales: millennia, using carbon-14 dating; centuries, using lead-210 dating or identification of historic changes in regional vegetation through pollen stratigraphies; decades using cesium-137 dating, and years or seasons using sediment marker horizons or SETs (sediment elevation tables). Dating of marsh sediments over the historical period allows us to compare marsh soil accumulation rates to local records of sea level rise, and when available, tide gauge records. These comparisons allow scientists to determine whether elevations have been in equilibrium with recent changes in relative sea level, or if wetlands are threatened with submergence. The relative importance of factors controlling vertical sediment accretion varies depending upon the time scale studied. There is also considerable spatial variation, on the small scale within a wetland and over broader geographic areas, among estuaries.

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Biographical Sketch

Gail Chmura's professional experience with coastal ecosystems began as a biologist with the US State of Rhode Island Coastal Zone Management Program. In 1981 she was awarded a US National Sea Grant Fellowship to serve as a legislative aid for the US House of Representatives. where she worked on legislation and policy in coastal conservation and pollution. She began her research on salt marsh soils at the University of Rhode Island where she obtained an M.S. in Plant and Soil Science. She later obtained a Ph.D. in Marine Sciences (minor Geology) from Louisiana State University. In 1989 she received a Fulbright Fellowship to study marine geology at the Netherlands Institute for Sea Research. Since 1990 Dr. Chmura has been a faculty member of the Geography Department at McGill University.In 1996 was U.S. National Research Council Senior Research Associate at the US Environmental Protection Agency where she conducted research on geological indicators of estuarine health.

Dr Chmura has conducted research on coastal ecosystems along both sides of the Atlantic and over a wide range of latitudes from boreal (Gulf of St. Lawrence) to sub-tropical (Gulf of Mexico). She is interested in processes of salt marsh accretion and marsh paleoecology as well as the role of coastal wetlands soils as sinks for metals, nutrients and greenhouse gases.

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