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Salt Marshes and sea level rise: marsh dynamics in relation to accretion processes and accretion enhancement techniques

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Abstract

Sea-level rise will become a worldwide threat to coastal marshes by affecting the marsh vegetation through an increase in number of tidal flooding and an increase in wave energy. The survival of the salt marshes depends on the accretionary-erosional balances in both the marsh zone itself and in the pioneer zone in front of the marsh. The salt marshes along the main coast of the Netherlands Wadden Sea are stimulated by human intervention (siltation constructions) in the natural processes. Evaluation of the effects of climatic change in this area is necessary not only for predictions of future situations but also for the active management and the elaboration of mitigating measures in order to prevent salt marsh erosion.

1. INTRODUCTION

The Wadden Sea is a shallow tidal sea of about 8,000 km^2 situated along the coast of the Netherlands, Germany and Denmark. An essential characteristic of the Wadden Sea system is the emergence of large tidal flats at low water. A part of special interest are those higher flats along the mainland and the Wadden Sea face of the barrier islands, because on these parts salt marshes are found.

Much research has been done concerning the conditions of growth, accretion and erosion processes and vegetational succession in the salt marsh area. Accordingly, the vertical growth of the mudflat-marsh is determined by the rates of minerogenic and organogenic sedimentation, the frequency and period of tidal flooding and the overall compaction of the sediment (Allen, 1990; Craft et al., 1992). The sedimentation rate on the marsh is controlled by the mean tidal amplitude and is a function of the height of the mud flat and salt marsh to mean high water level (Dijkema et al., 1990). In addition, the sedimentation rate on mud flats is high in those areas which are sheltered, frequently overflooded and where the sediment supply is high. The zonation (succession) of the vegetation on the salt marsh is dependent on the surface elevation, the tidal amplitude and the drainage of the area (Armstrong et al., 1985). If the accretion of sediment on the marsh itself remains behind an increase in sea-level rise the marsh will be more frequent overflooded and the vegetation detoriation will increase (Reed and Cahoon, 1992).

The Wadden Sea is a unique nature area with wildlife of many different species containing fishes, birds and mammals. The tidal flats and salt marshes act as nursery grounds for

migrating birds and contain extremely large numbers of benthic invertebrates and are characterized by high biomass. Most of the salt marsh area in the Wadden Sea can be found attached to the main coast. Here, the marshes stabilize the shoreline and afford protection to developed areas during storms by absorbing and dissipating wave energy, and by storage of water. A rapid increase in mean high water levels might lead to severe erosion of salt marshes and tidal flats. A loss in the marsh area will affect the coastal protection to storm surges and will have major consequences for migratory birds and for the estuarine ecosystem in the Wadden Sea.

The effects of sea level rise on the development of salt marshes can be described in a general manner as follows. The higher mean sea level causes an increase in the tidal storage volume of the flat and marsh area resulting in an extended drainage and associated outbuilding (erosion) of the gully system. In addition the distribution of wave heights over time may shift towards the higher wave domain because the increase in water depth allows higher waves to penetrate towards the flat-marsh area. The higher wave attack normally will result in flatter profiles. Furthermore the seaward boundary of the pioneer vegetation may shift landward. In the other hand the increased frequency of tidal flooding of the marshes will result possibly in larger sedimentation rates and thus a vertical upbuilding of the salt marsh. Hence the heightening of mean sea level is expected to be associated with an erosional tendency of the flats and the transition zone of the pioneer vegetation and with an accretional tendency of the higher marsh area.

Small changes in the boundary condition for the development of tidal flats (hydrodynamic parameters like mean sea level, wind induced wave heights and tidal currents) will have consequences for the sedimentation- and erosion-processes on the tidal flats and in the salt marshes. The pioneerzone, in this respect, is of major importance for the salt marsh. It is transitional to the tidal flats and it is situated on a level which is most affected by wave action. Erosion of the pioneerzone during an increase in rising high-tide levels will lead to cliff formation and marsh erosion from the seaward edge. The pioneer zone contains the pioneer vegetation *Salicornia dolichostachya* and an erosional tendency of this zone will be indicated by a landward retreat of this species.

The present research addresses the hydrodynamic processes and expected changes in the flat-salt marsh area in order to develop management strategies and mitigating measures.

2. RESEARCH AREA

As early as 1930, brushwood groynes have been build along the mainland coast of the Netherlands Wadden sea to stimulate accretion of sediment. The construction of the brushwood groynes significantly increased the rate of sedimentation in the areas in between (Dijkema et al.,1990). The excavation of ditches in the sedimentation area ensured an increase in dewatering in such a way that the succession of pioneer vegetation towards higher order vegetation originated. The sedimentation rate and seaward expansion of the salt marsh area was higher during the first years of the construction of the brushwood groynes (1960-1978). After this period the salt marsh expansion arrested and even erosion within the sedimentation fields occurred. Partly this can be ascribed to a reduction of the management effort, but other factors have to play a part as well. Recent loss in salt marsh area in the Wadden sea might be due to an accelerated increase in mean high water to 0.44 cm yr^{-1} from 1961 to 1983 (Dijkema et al., 1990), from which about 75% is calculated to be due to an increase in wind

speed between 1976 and 1983 (Bossinade et al., 1993).
It is expected that changes in the hydrodynamic boundary conditions will first be noticeable in the pioneer zone. The research, therefore, is focused on the hydrodynamic processes in the pioneer zone and investigates the boundary conditions for the growth and survival of the pioneer vegetation.

3. MEASUREMENTS

The sediment bed in the pioneer zone consists of mud and fine sand and can be classified as a cohesive bed. Erosion of a cohesive bed or deposition of cohesive material will be confined to a near bed layer and will be hard to measure in situ. Both erosion- and sedimentation- processes are controlled by the near-bed hydrodynamic processes as represented by the bed-shear stress (Partheniades, 1986). The net result of erosion- and sedimentation-processes is determined on one hand by the exerted shear stress (induced by waves and currents) and on the other hand by the strength of the bed.

An intensive field campaign was started in April 1993. During this field campaign the shear stress and shear strength determining hydrodynamic parameters were measured in the pioneer zone. Two field sides have been chosen along the Dutch Wadden Sea coast which show a difference in the development of the pioneer zone and in the expansion of the salt marsh. One area is characterized by a salt marsh retreat in the last ten years whereas the other area shows a steady sedimentation in the same period. Simultaneous experiments in both areas will characterize the differences between the repetition and magnitude of the hydrodynamic processes that take place in both salt marsh areas. The hydrodynamic measurements in the pioneer zone includes the determination of wave height distribution throughout the year, tidal current velocities, wave induced current velocities, related erosion- and deposition processes and sediment transport. The germination and growth of the pioneer vegetation is monitored in both areas. Field experiments as well as laboratory experiments were carried out in order to determine the boundary conditions for the establishment of the pioneer vegetation, for the effects of future changes in hydrodynamic processes on the vegetation and the effect of pioneer vegetation on sedimentation- and erosion-processes in the salt marshes. The results are used to draw up and calibrate a *Salicornia* computer simulation model which describes the life cycle of this pioneer vegetation species.

4. RESULTS

The results from this research show that sand is transported as bed load in the pioneer zone whereas mud is transported in suspension. In this respect, it is important for the salt marsh as well as for the pioneer zone how much sand or mud is available in front of the flat-marsh zone for the transportation into the salt marsh works. The Wadden morphology in front of the salt marshes partly determines the rate of sedimentation in the pioneer zone. Differences in the Wadden morphology consequently will lead to spatial differences in salt marsh development along the Wadden Coast.

It was assumed that the construction of the brushwood groynes would limit wind wave growth in the pioneer zone and thereby decrease the turbulence in the near bed region and as a result decrease erosion of the sediment bed. However, measurements have shown that this

is not the case. Wind waves are fully developed within a distance of thirty meters from the groynes. The distance between the groynes measures at present 400 meter. The construction of groynes, however, significantly increased sedimentation. It seems likely that the groynes reduce the current induced turbulence and thus increase the deposition of suspended sediments.

The germination, growth and survival of the pioneer vegetation is determined in great extend by the hydrodynamic parameters. For instance the wash away of seeds and seedlings during the first week of gemination is a function of the mobility of the top layer of the bed. This means that the seaward expansion of the pioneer vegetation is determined not only by the frequency and duration of overflooding but also by the composition (mud/sand ratio, shear strength) of the bed.

This research is carried out in order to investigate the effects of the present management techniques on erosion- and sedimentation-processes during an increase in sea level rise. The results of the present investigations indicate that variable arrangements and outlines of the brushwood groynes may be applied in order to stimulate the deposition in the area. As such it may combat the negative effects of sea level rise in these areas.

5. REFERENCES

Allen, J.R.L., 1990. Salt-marsh growth and stratification: A numerical model with special reference to the Severn Estuary, Southwest Britain. Marine Geology, vol 95, pp 77-96.

Armstrong, W., E.J. Wright, S. Lythe and J.T. Gaynard, 1985. Plant zonation and the effects of the spring-neap tidal cycle on soil aeration in a Humber salt marsh. Journal of Ecology, vol 73, pp 323-339.

Bossinade, J.H., J. van den Bergs and K.S. Dijkema, 1993. The influence of the wind on the annual mean high water along the Frisian and Groninger Wadden Sea coast (in Dutch). Rijkswaterstaat, Directie Groningen, Nota Gran 1993-2009, 22 p.

Craft, C.B., E.D. Seneca and S.W. Broome, 1993. Vertical accretion in microtidal regularly and irregularly flooded estuarine marshes. Estuarine Coastal and Shelf Science, vol 37, pp 371-386.

Dijkema, K.S., J.H. Bossinade, P. Bouwsema and R.J. de Glopper, 1990. Salt marshes in the Netherlands Wadden Sea: rising high tide levels and accretion enhancement. In:J.J. Beukema, W.J. Wolff and J.J.W.M. Brouns (eds.). Expected effects of climatic change on marine Coastal ecosystems, Kluwer, Dordrecht, pp 173-188.

Partheniades, E., 1986. The present state of knowledge and needs for future research on cohesive sediment dynamics. Proceedings, 3rd International Symposium on River Sedimentation, vol III, University of Mississippi, pp 3-25.

Reed, D.J. and D.R. Cahoon, 1992. The relationship between marsh surface topography, hydroperiod and growth of Spartina alterniflora in a deteriorating Louisiana Salt Marsh. Journal of Coastal Research,vol 8 ,no 1 , pp 77-87.