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INTERIM REPORT

Mangrove response to sea level rise: The Rufiji Delta, Tanzania

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1 Intention

Sea level rise due to global warming will have important effects on low lying, depositional coastlines. These effects will not be confined to the simple case of increased rates of flooding, but will include redistribution of the coastal sediments and the gradual evolution of a new set of coastal landforms. The effect on inter-tidal wetlands, such as temperate salt marsh or tropical mangrove will be especially marked, although little research has yet been conducted into the details of the response of these coastal systems. The importance of such inter-tidal areas is now recognised. They serve as flood defences, fish nurseries, silt and effluent traps as well as being important wildlife refuges with a significance beyond their local area. It is vital that we understand the effects a rising sea level will have on these important areas so that we may create management systems which will enhance rather than negate the natural changes which are about to occur.

Work currently being carried out on temperate salt marsh systems suffering accelerated sea level rise due to tectonic changes, has so far produced a number of important conclusions which, it is felt may apply to the tropical mangrove system. These conclusions may be summarised:

1. Sea level rise causes horizontal erosion of the outer, seaward edge of the salt marsh.

2. The inner, landward surfaces of the marsh experience accelerated vertical accretion.

3. This accretion is sufficient to keep pace with sea level rise, so that the marsh surface does not become drowned out.

4. The sediments for this accelerated accretion derive, in part, from the erosion of the seaward edge of the marsh area.

5. The eroded sediments are confined within the inter-tidal zone, moving in and out with the tides, but stored on the mud flats, seaward of the marshes, during the low tide period.

6. The amount of erosion and the response of the inter-tidal morphology is related to wave activity. Infrequent, high wave energy causes high erosion rates at the marsh edge. These eroded sediments are moved onto the mudflats, thus creating a reduced foreshore slope. More frequent low energy waves move sediments from the mudflats onto the marsh, thus creating a steeper foreshore slope.

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These conclusions may also apply to the tropical mangrove system. To see whether they do, it is first necessary to treat them as hypotheses and to test these against field measurements taken in mangrove inter-tidal areas. The present research project attempts to do this using measurements from the Rufiji Delta, Tanzania. The intention is to ascertain whether the mangrove system works in the same way as the temperate salt marsh and then to produce a detailed management plan for such areas which will allow the mangrove to maintain itself despite increased sea levels. Thus, for example, if sediments are eroded from the seaward edge of the mangrove and subsequently deposited further inshore on the mangrove surface, it would not be sensible to protect mangrove against erosion by the creation of coastal defence works. If this were done, then the mangrove surface would be starved of sediments and would gradually drown as sea level rose. The outcome of the present research in this case would be to suggest that erosion is a vital component of the natural response of the mangrove to sea level rise and should be allowed to continue unchecked if the main extent of the mangrove is to survive.

As well as these physical aspects of the mangrove system, the biological response to sea level change must also be addressed. Unlike terrestrial ecosystems, the mangrove swamp nutrient cycle is an open system, resulting in the exchange of nutrients, detritus and sediments with periodical tidal flushing, and occasional fresh water runoff. Attempts at quantifying these fluxes have shown conflicting results with some localities suggesting export or "outwelling" of mangrove detritus, while other sites have shown low nutrient losses implying considerable degradation and re-cycling of litterfall in situ. Similarly, some salt marsh systems have been shown to be net exporters of detritus while other marshes appear to be net importers of particulate matter.

Such questions of ecosystem function form part of the Rufiji mangrove research, in particular the relationship between the production and flux of organic debris, and the inorganic sedimentation is being investigated to give an integrated picture of the mangrove response to sea level increases.

2 Field Area

At 1022 km^2, the Rufiji Delta, Tanzania contains the largest area of estuarine mangrove in East Africa and provides the nursery grounds for 80% of Tanzania's prawn fishing industry. Although the mangroves are exploited locally for building purposes, firewood, charcoal and tanin, the area is otherwise untouched by human interference and thus provides a unique field area to test the research hypotheses outlined above. Furthermore, the whole seaward edge of the delta is broken up into a number of promontories which allow precise definition of research areas to be made.

The Rufiji Delta has approximately 100km of seaward margin facing the Indian Ocean. Most of this margin consists of mangrove although fringing beaches do seperate the mangrove from the sea along some of the coast. Whilst, in the past, the delta mouth was to the south east, the present active delta - that is, the portion presently acting as the mouth of the River Rufiji - lies along the northern coastal stretch approximately defined as north of the point known as Ras Dima. The research area selected for the present project is principally confined to the most northerly peninsula on which is situated the fishing village of Simba Uranga, although some measurements have been made on the Kiomboni peninsula.

The recent geological history of the northern delta is characterised by the development of a series of narrow and often patchy sand ridges, generally at right angles to the main channels, separated by extensive mangrove swamps of mixed *Rhizophera-Avicennia-Ceriops* composition. The ridges, which can be traced northwards to extensive beachridge sequences on the mainland coast, are characterised by non-mangrove vegetation (in which coconut is prominent) and often bordered by lower, seasonally flooded saline flats colonised by *Ceriops* and dwarf *Avicennia*. These ridges are thought to represent former barrier islands at the delta margin, perhaps formed by spit segmentation from longshore bars at the mainland coast; their modern analogies are the islands of Simba Uranga and Kiomboni. The pattern of ridges and intervening swamps therfore suggests a process of episodic delta extension to the north, with opportunistic mangrove colonisation behind each successive delta front island. The heights of the ridges are difficult to explain in relation to present sea level and may relate to higher sea levels during the last 10 000 years.

The present delta edge is characterised by extensive erosion of the mangrove swamps. Comparison between the present edge of the Simba Uranga coast and that shown on the 1966 maps of the area suggests that approximately 1km of mangrove has been eroded away - a rate of over 40m per year. Such a dramatic change from progradation which has characterised the delta's history for the past 10 000 years may be in response to a rise in sea level. Such a change in sea level may partly be caused by global warming but may also be due to tectonic subsidence of the deltaic sediments, a process shared by many of the world's delta regions.

3 Deployment

The research project began in 1989 with a series of base line surveys. Island margins were mapped using compass/pace and levelling methods, with particular regard to evidence for former mangrove colonisation, to establish the change in elevation between former mangrove surfaces and present inter-tidal mudflats. Standard UNESCO point-centred quadrat methods were used to determine mangrove composition and structure at selected sample sites and along transects within the swamps. Measurement of tree diameter, height and spacing were made to determine relative density, dominance and frequency of mangrove tree species. Some sediment sampling was also undertaken beneath representative forest types.

Several surveys were initiated with the intention of repetitive measurements at yearly intervals over the next three years. These surveys were as follows:

a) Horizontal extent.
Mapping of the horizontal extent of the mangrove and its associated mudflat complex using a combination of field survey (theodolite) and air photographs.

b) Vertical elevation.
Surface elevation transects were surveyed at right angles to the present sea coast using standard levelling techniques. All elevations were surveyed to an arbituary datum established at high tide.

A number of measurement systems were set up in 1989 and these will provide further data for hypothesis testing during the coming three year period. They are:

a) Accretion/erosion measurements.
Along each of the surveyed transects a series of accretion plates were installed. These were surveyed and repeat measurements of their depth were begun at three monthly intervals thus providing a record of the variability of the surface elevations.

b) Tidal measurements.
Tidal currents, sediment load and amplitude are surveyed using current meter and turbidity meter transects on a 6 monthly basis along the Simba Uranga distributary. As a link between the tidal work and the research within the swamps, a mangrove creek monitoring station was set up to study fluxes of water and sediment through the mangrove drainage network. In a pilot study, water level, current velocity and suspended sediment concentrations were recorded over neap and spring tidal cycles. Results indicated that imports of suspended sediment levels on the flood tide were negligible but significant sediment export took place during the ebb tide.

c) Ecosystem function.
Particulate matter collected on filter papers during the hydrological exercises is being partitioned between organic and inorganic sources. These studies should be related to the long term monitoring of organic inputs to the mangrove swamp surface but initial deployments of litter traps in 1989 were not successful. Future work might consider the rate of litter survival and removal on the mangrove forest floor and the incorporation of organic matter into mangrove soils.

d) Wave energy.
A wave staff was installed and daily measurements of wave height and period are made.

4 Results

Preliminary results of the long term measurements outlined above will not be available until the end of 1990 at the earliest. Preliminary observations indicate that erosion is extremely rapid along the sea coastline of the delta and a strip up to 1km wide of mangrove vegetation appears to have been lost since the last official survey in 1966. If this is a true reflection of the erosion rate along the Rufiji delta front then there is cause for serious concern. An erosion rate of 40m per year is extremely rapid on a world scale. However, it must be stressed that further results are neccessary before any such conclusions can be firmly stated. Within the delta channel patterns of bank collapse and associated mangrove mortality were mapped by boat survey. The pattern here seems to be largely conditioned by estuarine meander-bend migrations and therefore do not demonstrate any long term progression.

The preliminary results of accretion plate measurements support the hypothesis that vertical accretion is taking place within the mangrove area at the same time that horizontal erosion is removing the outer seaward margin. Accretion rates of 2cm per year have been extrapolated from these results, but again caution is needed in interpreting such short term measurements.

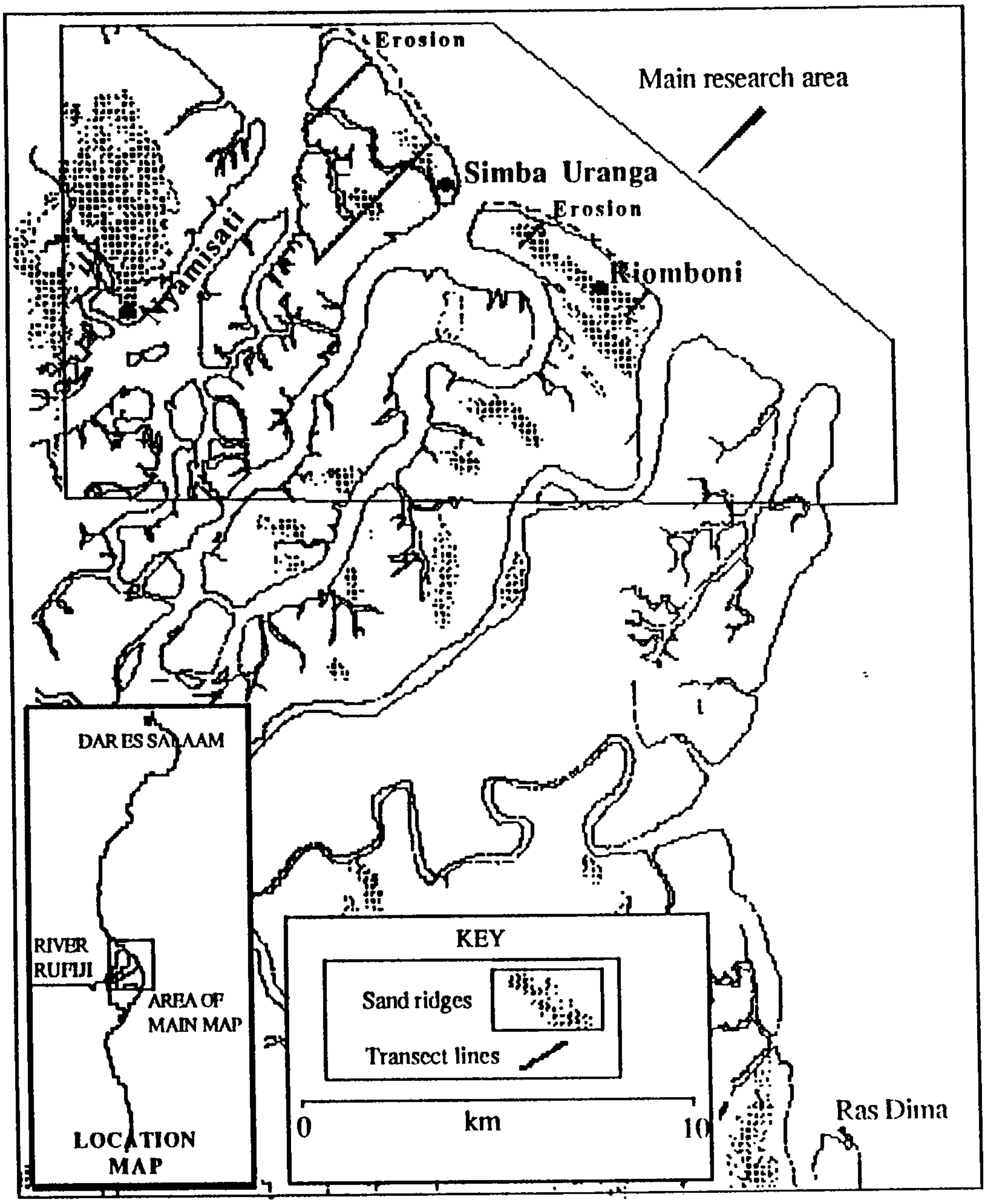
The spatial distribution of the horizontal erosion is also of interest. On the two deltaic peninsulas studied so far - Simba Uranga and Kiomboni - both of which have a coastline which is orientated northwest-southeast, the mangrove erosion has been concentrated in the northwest, while the southeastern extremity on Simba Uranga is accumulating sandy beach deposits, and on Kiomboni has new mangrove colonisation. It may be suggested from this distribution that the coastlines of these two peninsulas are becoming reorientated, that is they are tending towards a more west-east orientation rather than their present northwest-southeast orientation. Reasons for this reorientation are difficult to define. It may be proposed that a slight change in the direction of the prevalent northeast monsoonal winds on this coast is being experienced. This would alter the dominant wave direction and cause redeposition of the seaward delataic sediments in the manner described. Such a change in the northeast monsoon may well be the result of global warming mechanisms creating alterations in the position of the continental high pressure systems.

The processes by which mangrove vegetation dies back is still unclear. Observations suggest that the seaward strip of *Avicennia* may be killed by an encroachment of sandy sediments thrown there by wave action. Sedimentological investigations suggest that such sands are present in the deltaic deposits and are released by shorewards erosion but move only a short distance into the mangrove while the finer silt and clay grains are suspended and moved much further landwards. This implies that the process is some what circular, or self maintaining - erosion releases sand sized sediments which, due to sea level rise, are forced inland to cover the pneumataphores of the fringing mangroves, these die back exposing sediments to fresh erosion which in turn releases more sands.

5 Preliminary Conclusions

It is too early to offer any firm conclusions as to the changing morphology of the Rufiji Delta or of the mechanisms which cause such changes in tropical mangroves. There is, however, some preliminary evidence to support the conclusions from temperate salt marshes that horizontal erosion and vertical accretion occur simultaneously on different parts of the same inter-tidal profile, and that this will result in a translation of the profile both upward and landward due to sea level rise.

The long term development of such a profile translation and the effect of the reorientation of the shoreline must depend on the rates of global warming and its associated sea level rise. It is clear, even from these preliminary results, however, that major changes are about to take place in the mangrove environment. Given the importance of mangrove, it is essential that we initiate a sensible management plan to ensure their continued survival. Such a management plan may indicate that the most sensible procedure is to allow natural processes of coastline adjustment to changing sea level to continue without human interference. On the other hand it may be that a detailed appreciation of the mechanisms involved would allow management strategies to be set up which could produce a more rapid adjustment to changing conditions than would be possible under natural forces. The research initiated in the Rufiji Delta is designed to provide this understanding of the processes of adjustment and the programme of measurement over the next three years will provide some of the answers required.



Map to show location of Rufiji Delta research activities.

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