Western Indian Ocean J. Mar. Sci. Vol. 11, No. 2, pp. 155-166, 2012

Morphodynamics of the Manyema Tidal Delta at Kunduchi, Tanzania

N. Nyandwi[1], Y.W. Shaghude[1], J.W. Mburu[2], A.M. Dubi[3], I. Sanga[3] and R.S. Arthurton[4]

[1]Institute of Marine Sciences, University of Dar es Salaam, P.O. Box 668, Zanzibar, Tanzania; [2]Coast Development Authority, P.O. Box 1322, Mombasa, Kenya; [3]The Nelson Mandela African Institute of Science and Technology, P.O. Box 447, Arusha, Tanzania; [4]5a Church Lane, Grimston, Melton Mowbray, Leics, United Kingdom.

Keywords: Morphodynamics, Kunduchi, Manyema, shoreline change, tidal creek, tidal delta

Abstract—The prevailing northward longshore drift of beach sand on the northern part of Msasani Bay, north of Dar es Salaam, is interrupted at Kunduchi by the tidal flushing of Manyema Creek, a mangrove ecosystem partially developed for salt production. Shoreline changes around the creek mouth in recent decades have eroded coastal land and destroyed buildings, prompting stakeholders to construct protective groynes and revetments. Sand is transported across the delta by the interaction of two forcing processes – currents that flush the creek in response to tidal variation and, more generally, those generated by monsoonal wind-driven waves. A study of the sand morphology of the creek and delta platform together with time-series satellite imagery permitted demarcation of the respective sand transport pathways and morphodynamic changes in the delta over the last decade. The sand transport regime has promoted erosion of the shore to the south of the creek mouth, and has resulted in intermittent delivery of sand to beaches north of the channel. Attempts to stabilise the shore around the creek mouth are described and their effectiveness evaluated.

INTRODUCTION

The Msasani-Kunduchi shore north of Dar es Salaam in Tanzania has been favoured for beach hotel development (Mashindano, 2004), particularly around the mouth of the Manyema tidal creek at Kunduchi (Fig. 1). The creek itself provides a sheltered harbour for Kunduchi's fishing community (Akaro, 1997), supports a mangrove ecosystem (Richmond, 2002; Wagner *et al*., 2004) and is used for salt production (Muruke *et al*., 1999). Although the Kunduchi waterfront provides an attractive natural amenity for tourism, it also constitutes an unstable shore. Following major erosion episodes in the 1980s which destroyed or threatened beach hotels (Griffiths & Lwiza, 1987; Nyandwi, 2001a), hoteliers and other stakeholders invested in the construction of protective groynes and revetments. The channel at Kunduchi is a feature of the shoreline and forms the mouth of Manyema Creek which experiences strong currents that ebb and flow in response to tidal variation on the Msasani-Kunduchi shore.

Corresponding author: Yohanna W Shaghude
Email: yohanna_shaghude@yahoo.com; shaghude@ims.udsm.ac.tz

Erosion of the Kunduchi shore adjoining the creek mouth and its socio-economic consequences has been widely reported (Mushala, 1978; Griffiths & Lwiza, 1987; Hemed, 1987; Shaghude *et al*., 1994; Francis *et al*., 1997; Dubi, 2000; Kairu & Nyandwi, 2000; Nyandwi, 2001a, b; Masalu, 2002; Makota *et al*., 2004; Shaghude *et al*., 2013). Suggested causes of the erosion include strong easterly winds that coincide with extreme high tides (Lwiza, 1987; Dubi, 2001; Nyandwi & Dubi, 2001; Nyandwi, 2010) and a reduction in the beach sand budget due to sand mining in rivers that discharge into the sea (Griffiths, 1987; Masalu, 2002; Veland, 2005).

This paper considers the role of tidal flushing of the creek in disrupting the prevailing northward longshore beach sand transport in this region (Alexander, 1969; Muzuka & Shaghude, 2000; Shaghude *et al*., 2006; Nyandwi, 2001a). It reports on a study of the sand bedforms and bars of the creek and associated tidal delta platform. It also reviews the coast protection measures installed by stakeholders to stabilise the shoreline adjoining the mouth of the creek. It finally considers whether the morphodynamics of the delta platform have exacerbated the erosion of the Kunduchi shore.

The work was carried out as part of a WIOMSA MASMA (Marine Science for Management)-funded study of shoreline change in Kenya and Tanzania, undertaken from June 2006 to July 2009.

MATERIALS and METHODS

The study site

Manyema Creek is a tidal inlet on the Msasani-Kunduchi shoreline in the Dar es Salaam Seascape (Wagner, 2007), formed by the northward accretion of a 3 km long sand spit across a former coastal embayment south of the village of Kunduchi (Fig. 1). The creek is flushed by semi-diurnal tides which have a maximum spring range of about four metres and a neap range of about one metre. There are two periods of especially high spring tides, mid-March to early June and mid-September to mid-December, associated with the equinox (Pugh, 1987). An intertidal platform (tidal delta) 800 m wide and 1500 m long extends along the shore in each direction and seawards from the mouth of the creek (Fig. 1), interrupting the otherwise regular bathymetry of the Msasani-Kunduchi coast. The creek delta comprises a sand beach against a sandy beach-head which has been subject to severe erosion in recent decades (Makota *et al*., 2004), although it is now partially protected by groynes and revetments. The beach sand is predominantly siliciclastic, discharged from the local hinterland via seasonal

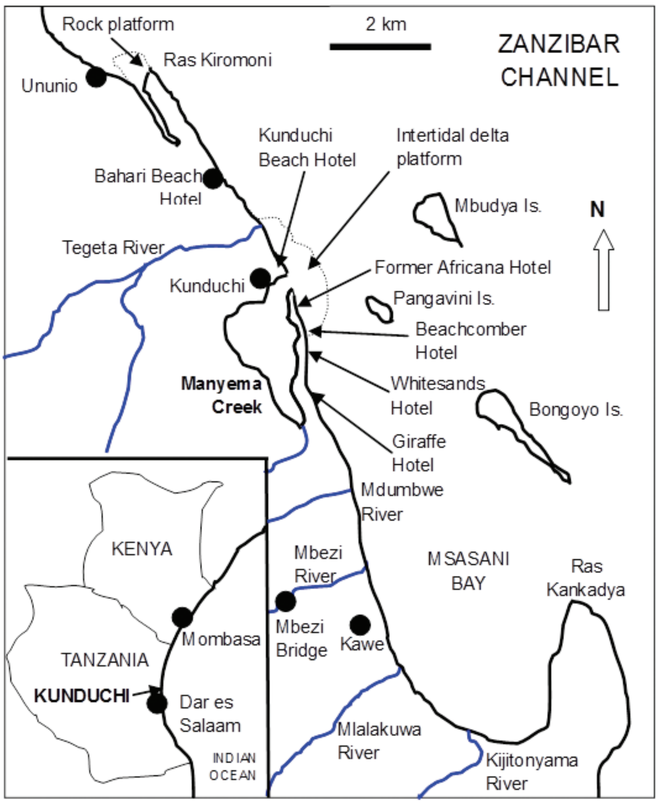

Figure 1. Location of Manyema Creek and its associated tidal delta platform at Kunduchi.

rivers that empty directly onto the shore in times of spate (Fay *et al*, 1992; Shaghude *et al*., 2006). The Zanzibar Channel lies offshore, beyond a zone of dense seaweed, with shoals and patch reefs around islands designated as marine reserves and administered by Tanzania's Marine Parks and Reserves Unit. The waterfront has been developed for private residences and beach hotels and is an important asset for recreation and fishing. Climatically, the site is subject to the regional cycle of the SE (April-November) and NE monsoons (December-March) with prevailing winds that shift with the seasons (Fig. 2).

Makota *et al*. (2004) quantified shoreline change at the mouth of the creek and in the

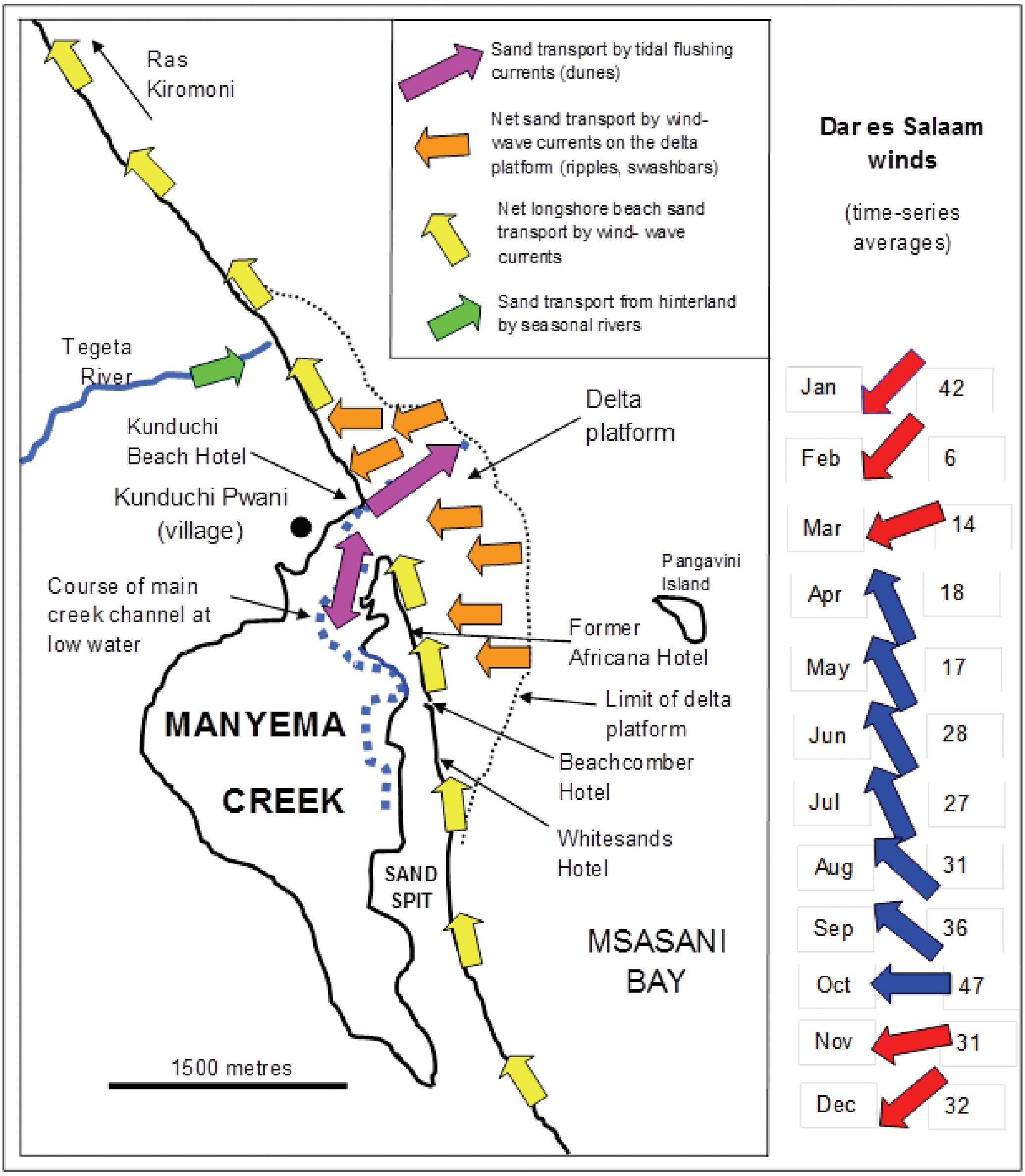

Figure 2. Net sand transport in the creek and delta at Kunduchi and the 25-year mean monthly wind vectors at 3 pm at Dar es Salaam International Airport (Shaghude *et al*., 2013). Numbers on the right of each monthly wind vector show the percentage of mean monthly surface wind frequencies that exceed 5 m/s. Red arrows = NE monsoon; blue arrows = SE monsoon.

tidal delta between 1981 and 2002 using remote sensing and GIS. In the present study, changes in the shoreline and morphodynamic changes on the delta platform were mapped in field surveys conducted during 2007–2009 under low spring tide conditions, and by interpretation of online Google Earth satellite images spanning the period 2003–2010. The distribution and trends in development of sand bedforms on the platform were recorded (Fig. 2) as indicators respectively of tidal and wind-wave induced currents. Tidal current velocities during flood and ebb cycles were measured in the main channel at the mouth of the creek using a recording current meter deployed over four tidal cycles during 11–13 February 2009 (Fig. 3). Sand from the bed of the main creek channel was sampled and analysed for grain size and composition (Fig. 4; Table 1). The grain size analysis of the sand samples was determined by sieving and calculating the grain size measures (graphic mean and sorting) according to Folk and Ward (1957). The percentage of carbonate content was determined in the samples by acid leaching using dilute hydrochloric acid.

Qualitative interviews with 20 stakeholders, mostly local fishermen and villagers from Kunduchi village, were used to gather anecdotal information on shoreline change. Existing coastal protection measures were documented by field inspection and using questionnaires, and appraised for their effectiveness.

RESULTS

Shoreline change

According to anecdotal accounts, recurrent shoreline changes around the creek mouth

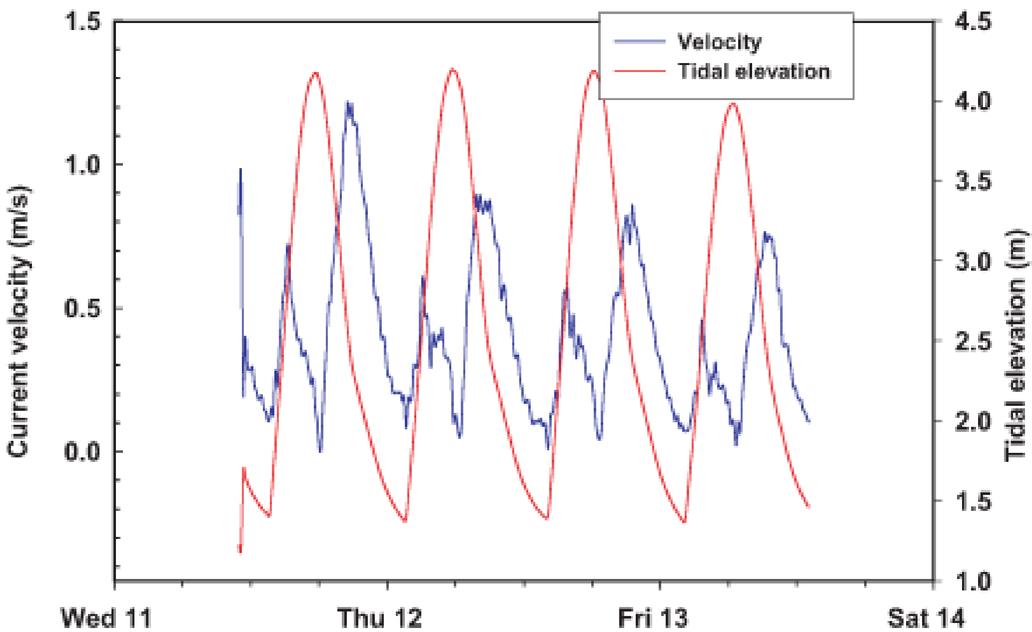

Figure 3. Tidal elevation and current velocities measured during spring tide cycles at the Manyema channel from 11–13, February 2009.

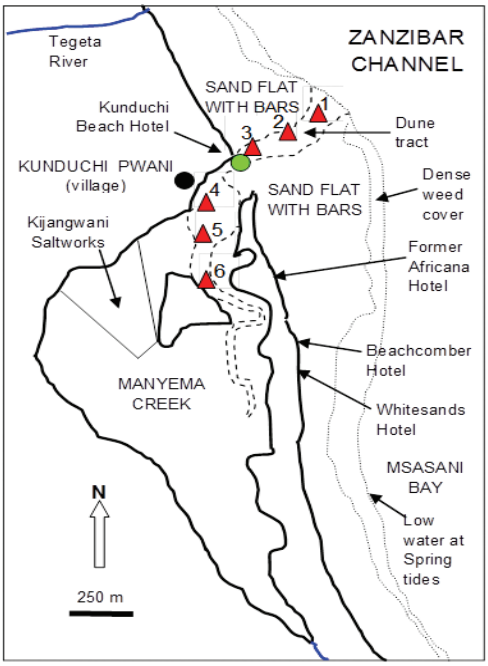

Figure 4. Sand sampling sites in Manyema Creek and on the delta platform at Kunduchi. Green dot = current meter site; Red triangles = sand sampling sites (1-6, Table 1).

Table 1. Calcium carbonate content and grain size (graphic mean and sorting) of sediment in grab samples taken from the channel off Kunduchi Beach Hotel (Fig. 4).

Sample No.	Carbonate %	Mean (phi)	Sorting (phi)
1	4.51	0.684	0.735
2	1.36	0.705	0.717
3	1.71	0.372	0.745
4	7.58	0.494	0.648
5	0.30	0.480	0.633
6	1.10	0.873	0.652
Average	2.76	0.601	0.688

(including the site of the former Africana Hotel, Fig. 1) over the past 40 years have led to a retreat of the shoreline of more than 200 m. Evidence of continuing erosion was noted during our survey in July 2007.

Interviewees stated that erosion was more intense during the SE monsoon than during the NE monsoon, and was most severe between the creek mouth and the Whitesands Hotel (Fig. 1). Interviewees also reported that erosion of the creek shore at Kunduchi Pwani (village, Fig. 5) had intensified during the last decade. They stated that erosion of the creek shore at the village was regarded as a serious problem, with five houses damaged during the last eight years. The village fish market, constructed in the 1970s, had been relocated three times since the 1980s (Akaro, 1997). This history of shoreline change around the creek mouth has been corroborated by Makota *et al*. (2004) in their analysis of aerial photographs and satellite imagery covering the period 1981–2002.

Analysis of the 2003-2010 Google Earth satellite imagery in the present study has indicated no further radical change to the shoreline except at the site of the former Africana Hotel adjoining the mouth of the creek (Fig. 1), where seawall construction and landfill operations have produced a localised seaward shift.

Sand bedforms

Field surveys of the largely emergent delta platform at low spring tide on the mornings of 6–8 April in 2008 revealed two distinct regimes in sand bedform (Fig. 2). A tract of dunes (Soulsby, 1997) lined the floor and flanks of the main creek channel and its seaward extension from the creek mouth. Extensive flats with current ripples (Soulsby, 1997) characterised the platform to the north and south of the dune tract, the ripples being superimposed by elongated banks or swash bars (FitzGerald *et al*., 2000).

Dunes up to 2 m in length were aligned parallel to the course of the channel (Fig. 6a), their steep leeward slopes facing seaward and indicating an ebb current direction. They comprised sand that was mostly coarse-grained and moderately to moderately well sorted, but included shell and hard coral fragments (Table 1). They formed a lining to the main creek channels (Fig. 4, sites 4–6) and a partially submerged tract some 200 m wide extending seawards from the creek mouth (Fig. 4, sites 1–3; Fig. 6b). This dune tract gave way to braided distributary channels

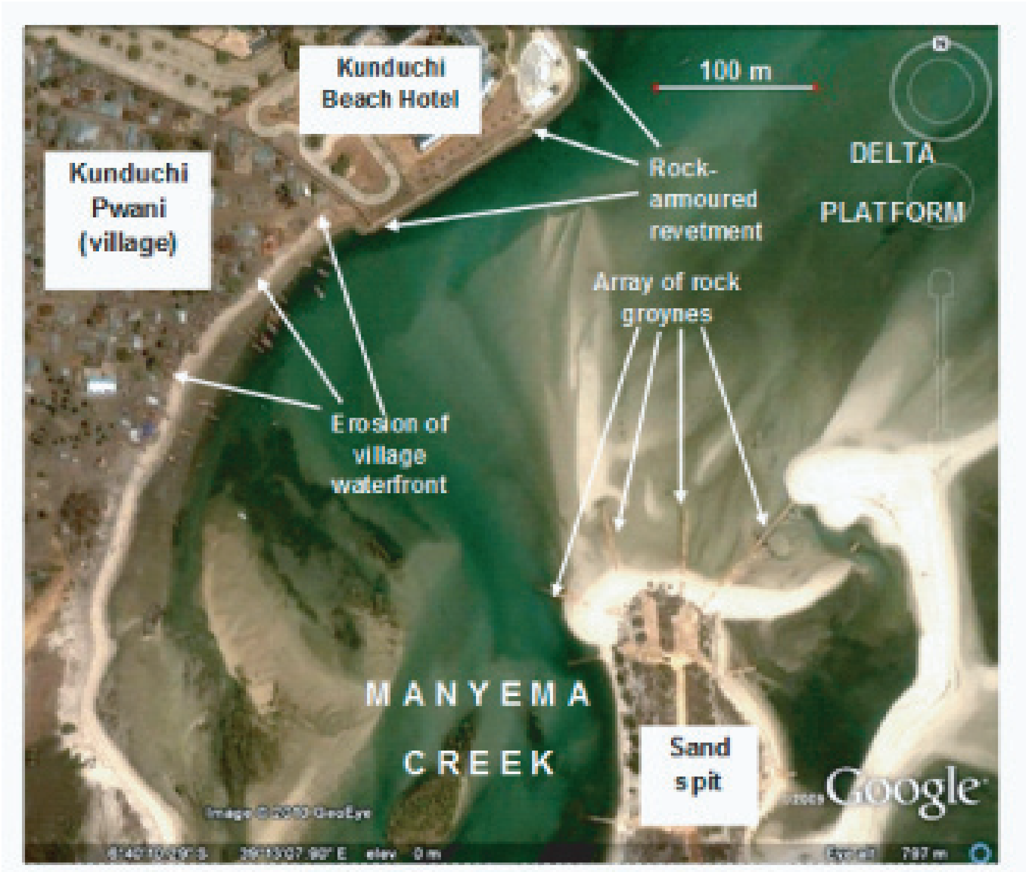

Figure 5. Rock groynes installed around the sand spit south of Kunduchi indicating erosion at Kunduchi village and revetment protection at Kunduchi Beach Hotel. Image, 8 November 2005 © 2010 GeoEye.

as one approached the rim of the platform; these were marked by an increase in water depth and breaking waves. Observations at the rim revealed that sand discharged from these braided streams became entrained by currents generated by wind-driven breakers. The northern flank of the dune tract comprised a linear bar (FitzGerald *et al*., 2000) covered by dunes aligned north to north-westwards, askew to the main trend and terminating abruptly in the north in rippled sand (Figs 6c and 8); these dunes are indicative of a northward ebb-current overwash.

The ripples on the sand flats forming the platform to the north and south of the dune tract were aligned NNW, lying generally parallel to the shore. They had wavelengths of 25–35 cm and were asymmetrical in cross-section, their steep leeward flanks indicating shoreward sand transport (Fig. 7). The rippled flats consisted of medium sand, with some locally coarse-grained sand, and were greenish-buff in colour. Their associated swash bars, also mainly of medium-grained sand, were pale buff and had crescent-shaped crests up to two metres above the surface of the flat. The swash bars were typically asymmetrical in cross-section, with their steep, leeward slopes facing shoreward. The swash-bars formed a series on the northern part of the platform *en échélon* between the platform's seaward fringe and the shore. Time-series satellite images captured stages in the morphodynamics of these sand bodies (Fig. 8), illustrating the process by which individual banks migrate and ultimately coalesce with the shore in what is referred to as "swash-bar welding" (FitzGerald *et al*., 2000). After a period of beach erosion, part of the revetment at the Kunduchi Beach Hotel (Fig. 8) was overwhelmed by sand delivered by this

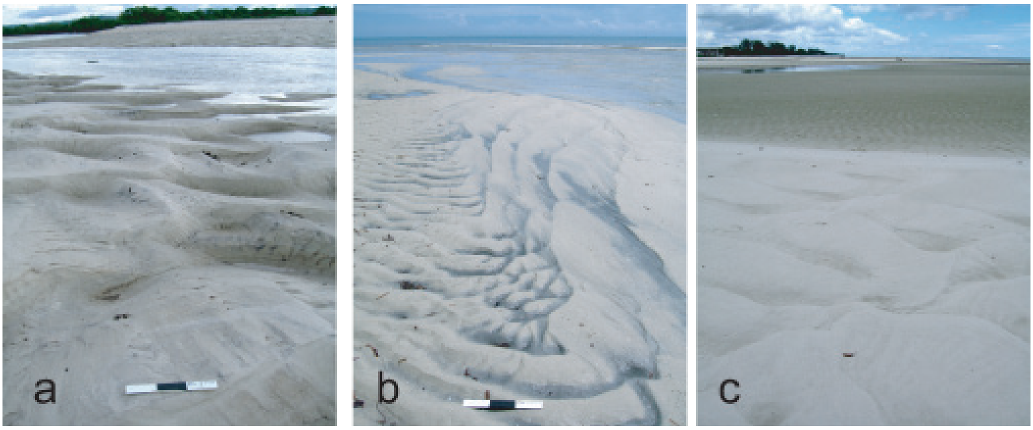

Figure 6. Sand bedforms at Manyema Creek during low water: a) Dunes on creek channel floor, view up-creek, 10 April 2008; b) dunes interfering with current ripples, 7 April 2008, view to NE; c) dunes on a linear bar wash onto a rippled sand flat, 7 April, 2008, view to N. Total scale bar length = 30 cm.

welding process in April 2008. The swash-bars were less well defined on the southern part of the platform, lacking the conspicuous crescent form of their northern counterparts. The regular NNW alignment of current ripples tended to be distorted around sand bars, indicative of wind-wave diffraction. There were also instances of interference and superimposition of ripple-sets, suggestive of short-term changes in wind-wave forcing.

The current meter installed in the main creek channel off the Kunduchi Beach Hotel for the duration of four spring tidal cycles (Fig. 4) recorded a maximum current velocity during the flood tide of 0.7 m/s, and a maximum velocity during the ebb of 1.2 m/s (Fig. 3). The maximum velocities were attained during the middle part of the period of ebb flow within each tidal cycle.

Figure 7. Current ripples on the sand flat north of the creek mouth at low water, 8 April 2008, view to S; leeward faces (in shade) indicate shoreward sand transport. Total scale bar length = 30cm.

Coast protection measures

Two types of protective structure have been installed at Kunduchi Hotel in attempts to stabilise the shoreline around the mouth of Manyema Creek (Fig. 5). Revetments have been installed on the creek and seaward shores on the northern side of the creek mouth, providing protection to the Kunduchi Beach Hotel. The revetments were constructed in 1999 and were reported to cost US$4.5 million. They have rock-armoured faces and incorporate alternating layers of concrete blocks, boulders, sand-bags and gabions with geo-fabric membranes. At the time of the survey, the shore at this site was not threatened by erosion. Instead, the beach was so charged with sand that much of the revetment's seaward face was buried and some of it was overtopped.

An array of groynes has been installed on the southern side of the creek mouth,

Figure 8. Time-series images of the delta platform off Kunduchi Beach Hotel: a) 20 December 2003 ©2010 DigitalGlobe; b) 8 November 2005 ©2010 GeoEye.

constructed of blocks of roughly quarried limestone. The groynes were constructed during 2005–2007 around the tip of the spit (Fig. 5). Individual groynes are up to 2.5 m high and extend up to 75 m into the creek channel. The initial construction cost of a typical groyne was approximately US$43,000; some have since been modified at additional cost.

DISCUSSION

The long-term north-north-westerly longshore drift of beach sand along the northern part of Msasani Bay to Ras Kiromoni (Muzuka & Shaghude, 2000; Shaghude *et al.*, 2006; Nyandwi, 2010) is manifested geomorphologically in the 3 km long sand spit which has accreted across the former coastal embayment now occupied by Manyema Creek (Fig. 1). The spit morphology has recorded the historical dominance of the SE monsoon and the prevailing wind-wave regime. Longshore beach sand transport is driven by the incidence of the onshore swell and locally generated wind-waves; the forcing vectors of the latter in the Dar es Salaam area change through the monsoon cycle (Fig. 2) as described by Shaghude *et al.*, 2013.

Sand transport across the creek mouth

This study explored the mechanism by which sand is transferred to the northern shore of Kunduchi from beaches to the south, across the mouth of Manyema Creek, using the record of sand bedforms on the surface of the delta platform at low spring tide. The bedforms described are the respective manifestations of two distinct sand transport processes acting on this platform at Kunduchi.

Lower current velocities recorded by the current-meter in the flood tide compared with those in the ebb (Fig. 3) indicated greater strength in the ebb flow. Comparable ebb-current dominance has been reported at Mtwapa Creek near Mombasa in Kenya (Magori, 2004). We interpreted the observed dune bedforms as being formed by currents during the middle part of the ebb tidal discharge from Manyema Creek (Fig. 3), along the main creek channels and within a well-defined tract from the creek mouth across the platform (Fig. 2). Because the platform was submerged by the rising tide, we were unable to ascertain whether comparable dune bedforms were formed during the flood flow – such structures are likely to be destroyed by the stronger ebb currents. The provenance of coarse-grained sand, including shell debris on the floor of the creek (Fig. 4, Samples 4, 5 and 6; Table 1), is unclear. Such sand might have been derived from the creek mouth during extreme flood-tide events. Alternatively, it may have arisen from erosion of earlier spit deposits.

During the spring tide cycle, when the tidal range attains a maximum of about four metres, ebb flushing of the creek transports sand across the platform, discharging it seawards at its rim and also to the platform flats by lateral overwash (Fig. 6c). During neap cycles, the tidal exchange in Manyema Creek is much reduced with commensurately less flushing and reduced sand transport.

Sand discharged by ebb tidal flushing at the platform rim is transported back across the platform by wind-generated waves and currents, the direction of transport being determined by the wind-wave regime. The forcing dominance of the SE monsoon over the NE monsoon suggests that there is net transport to the northern part of the delta platform (Fig. 2).

Apart from the dune tract, the current ripples and swash bars of the platform consistently indicate shoreward transport of the sand except in areas subject to wave diffraction, assuming that they lie perpendicular to the direction of the current which formed them (Fig. 7). The time-series satellite imagery of the northern part of the platform revealed that the swash bars themselves migrate shorewards, as a group *en échelon* (Fig. 8). Intermittent swash-bar welding (FitzGerald *et al*., 2000) on the northern shore of the creek mouth results in beach sand budgets that are inter-annually sparse or rich.

The transfer of sand from the southern delta flat to the dune tract appears to occur via a complex of bars south of the dune tract with lee slopes that face NW. Sand bars in this position on the platform may exacerbate the severe shoreline erosion that has occurred between the creek mouth and the Beachcomber Hotel in recent decades (Fig. 2; Nyandwi, 2001a). While this shore is exposed to wind-wave forcing in the SE monsoon, the bars partially shelter it from the NE monsoon, restricting replenishment of the depleted beaches by longshore drift from the north. Other factors that may contribute to this are a reduction in the beach sand budget due to sand mining in rivers that discharge to the Msasani-Kunduchi shoreline (Griffiths, 1987) as well as obstruction of longshore sand transport by the groynes at and to the south of the Beachcomber Hotel (Shaghude *et al*., 2013).

Shoreline protection measures

Although the amenity of the shore has attracted hotel developers to the area, its dynamic morphology has obliged stakeholders to undertake expensive coastal protection measures. These measures, particularly the groynes, have tended to degrade the shore's natural capital.

Of particular concern is the fact that the protective structures at Kunduchi village may be causing the erosion reported on its shore (Fig. 5). Villagers believe that erosion has intensified either because of construction of the adjoining hotel revetment or installation of the groynes on the southern side of the creek mouth. Collectively, these structures may have restricted tidal flow on the southern side of the channel, shifting the main tidal stream towards the village. It remains to be seen whether the groyne array around the spit will effectively stabilise it in the long-term.

Acknowledgments–The study was funded by a Marine Science for Management (MASMA) grant from the Western Indian Ocean Marine Science Association (WIOMSA) which is gratefully acknowledged. Logistical support for the coordination of the project was provided by the Institute of Marine Sciences of the University of Dar es Salaam, Zanzibar (Tanzania) and the Coastal Development Authority of Kenya. We are also grateful for constructive comments by a reviewer of an earlier version of the manuscript.

References

Akaro RR (1997) Beach erosion and human activities -- a case study of Kunduchi fishing village in Dar es Salaam. Tanzanian Journal of Population Studies and Development 4: 91-100

Alexander CS (1969) Beach ridges in northeast Tanzania. Geographical Review 59: 105-122

Dubi A (2000) Coastal erosion. In: Ngusaru AS (ed) The present state of knowledge of marine science in Tanzania: Synthesis report. Tanzania Coastal Management Partnership and the Science and Technical Working Group, May 2000. Working Document: 5047 TCMP, pp 5-42 (Available at http://www.crc.uri.edu/download/2001_5047_TCMP_Knowledge.pdf).

Dubi AM (2001) Frequency and long-term distribution of coastal winds of Tanzania. In: Richmond MD and Francis J (eds). Marine Science Development in Tanzania and Eastern Africa. Proceedings of the 20th Anniversary Conference on Advances on Marine Science in Tanzania, 28 June – 1 July 1999, Zanzibar, Tanzania, pp 131-144

Fay M, Masalu DCP, Muzuka ANN (1992) Siliciclastic-carbonate transition in surface sediments of a back-reef lagoon north of Dar es Salaam, Tanzania. Sedimentary Geology 78: 49-57

FitzGerald DM, Buynevich IV, Fenster MS, McKinlay PA (2000) Sand dynamics at the mouth of rock-bund, tide-dominated estuary. Sedimentary Geology 13: 25-49

Folk RL, Ward WC (1957) Brazo River bar, a study in the significance of grain size parameters. Journal of Sedimentary Petrology 27:3-27

Francis J, Nyandwi N, Msuya FE (1997) Interdisciplinary survey on the status and socio-economic impacts of coastal erosion along the Tanzanian coastline and islands. Summary Report: UNESCO-Kenya National Seminar on Sustainable Coastal Development through Integrated Planning and Management Focused on Mitigating the Impacts of Coastline Instability, Mombasa, 23-25 June 1997. UNESCO, Nairobi, pp.79, (Available at: http://unesdoc.unesco.org/images/0013/001383/138391eo.pdf)

Griffiths CJ (1987) The impact of sand extraction from seasonal streams on erosion of Kunduchi. In: Beach erosion along Kunduchi Beach, North of Dar es Salaam. Beach Erosion Monitoring Committee Report to National Environment Management Council, pp 36-47

Hemed IA (1987) Seasonal variations in the beach configurations. In: Beach erosion along Kunduchi Beach, North of Dar es Salaam. Beach Erosion Monitoring Committee Report to National Environment Management Council, pp 26-31

Kairu K, Nyandwi N (eds) (2000) Guidelines for the study of shoreline change in the Western Indian Ocean region. IOC Manuals and Guides (40), UNESCO 2000, Paris, 55 pp

Lwiza KM (1987) Waves, tides, currents and winds. In: Beach erosion along Kunduchi Beach, North of Dar es Salaam. Beach Erosion Monitoring Committee Report to National Environment Management Council, pp 36-47

Magori C (2004) Hydrodynamic Modeling of a Mangrove-Fringed Estuary, Mtwapa Creek, Kenya. PhD Thesis, Free University of Brussels, Belgium, 196 pp

Makota V, Sallema R, Mahika C (2004) Shoreline change detection using remote sensing and GIS: Case study of Kunduchi shores. Western Indian Ocean Journal of Marine Science 3: 1-10

Masalu DCP (2002) Coastal erosion and its social and environmental aspects in Tanzania: A case study in illegal sand mining. Coastal Management 30: 347-359

Mashindano O (2004) Private foreign investment and the poorest countries: The case of Tanzania. Canadian Development Report 2004: Investing in Poor Countries, Who benefits? The North South Institute 32 pp (Available at: http://www.nsi-ins.ca/english/publications/cdr/default.asp)

Muruke MHS, Mgaya YD, Julius A, Semesi AK (1999) Salt production and related activities along the mangrove ecosystem in Bagamoyo area. In: Howell KM, Semesi AK (eds) Coastal resources of Bagamoyo District, Tanzania. pp 85-91.

Muzuka ANN, Shaghude YW (2000) Sediment distribution along Msasani beach, north of Dar es Salaam harbour. Journal of African Earth Sciences 30: 417-426

Nyandwi N (2001a) Reassessment of the nature of beach erosion north of Dar es Salaam, Tanzania. In: Richmond MD, Francis J (eds) Marine science development in Tanzania and eastern Africa, WIOMSA Book series No.1, Regal Press Kenya Ltd, pp 107-120

Nyandwi N (2001b) Survey of extent of human-induced beach erosion problems in Tanzania. In: Richmond MD, Francis J (eds) Marine science development in Tanzania and eastern Africa, WIOMSA Book series No.1, Regal Press Kenya Ltd, pp 121-129

Nyandwi, N (2010) The major cause of observed erosion surge on the beaches north of Dar es Salaam city. Tanzania Journal of Science 36: 73-84

Pugh DT (1987) Tides, surges and mean sea-level: a handbook for engineers and scientists. Wiley, Chichester, 472 pp

Richmond MD (ed) (2002) A field guide to the seashores of Eastern Africa and the Western Indian Ocean Islands. Sida/SAREC – UDSM, 461 pp

Shaghude YW, Mutakyahwa MKD, Mohamed SK (1994) National report on the status of coastal erosion, sea-level changes and their impacts, Tanzanian case. IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts, Zanzibar, United Republic of Tanzania, 17-21 January, 1994. Submitted papers 1. Coastal Erosion. IOC Workshop Report (96) Supplement 1, pp 85-106

Shaghude YW, Nyandwi N, Muzuka ANN, Dubi AM, Mwaipopo OU (2006) Sediment characteristics and hydrodynamic settings of the reef platform sediments of Kunduchi, north of Dar es Salaam harbour. Tanzania Journal of Science 32: 36-52

Shaghude YW, Mburu JW, Uku J, Ochiewo J, Nyandwi, N, Magori, C, Sanga I, Arthurton R (2013) Beach sand supply and transport at Kunduchi, Tanzania and Bamburi, Kenya. Western Indian Ocean Journal of Marine Science 11:135-154

Soulsby RL (1997) Dynamics of marine sands: A manual for practical application. Thomas Telford, London, 249 pp

Veland S (2005) Building houses on sand: Resilience analysis of erosion, sedimentation and coastal management in Msasani bay, Tanzania. MSc Thesis, Noragric, Norway, 56pp (Available at: http://www.umb.no/noragric/publications/msctheses/2005/2005_mnrsa_Veland-Siri.pdf)

Wagner GM (2007) The Dar es Salaam seascape: A case study of an environmental management ‘hotspot’. Western Indian Ocean Journal of Marine Sciences 6: 85-109

Wagner GM, Mgaya YD, Akwilapo FD, Ngowo RD, Sekadende BC, Allen A, Price N, Zollet EA, Mackentley N (2004) Restoration of coral reefs and mangrove ecosystems at Kunduchi and Mbweni, Dar es Salaam, with community participation. In: Richmond MD, Francis J (eds) Marine Science Development in Tanzania, Proceedings of the 20th Anniversary Conference on Advances in Marine Science in Tanzania, WIOMSA Book Series (1), Sida, pp 467-487.