Shoreline Changes in the Western Indian Ocean Region

1. INTRODUCTION

The issue of shoreline changes has increasingly become a major social, economic and environmental concern to a large number of countries in the western Indian Ocean (WIO) region, where it poses a serious problem to the environment and human settlements. A number of initiatives aimed at assessing the state of erosion have been implemented by different organizations, but the development of long-term coastal erosion monitoring programmes has not taken place anywhere in the region despite the availability of different tools, such as manuals, prepared specifically for that purpose

Various prevention and mitigation measures have been used to address the problems of coastal erosion, but most of them have failed to bring about any reduction, and some have actually exacerbated the problem. One of the main reasons for their failure is that most of them have been applied without the support of long-term information on erosion processes and rates, or adequate technical support.

The development of a manual on monitoring of shoreline change in the Western Indian Ocean region by IOC-UNESCO (Kairu and Nyandwi, 2000) was among the first initiatives to address the problem. In furtherance of the various initiatives by stakeholders to address the problem and its impacts on the coastal environment, there is an urgent need to develop management tools, strategies and methods and environmentally friendly structures to reduce and mitigate the impact of shoreline change.

The Third Meeting of the Contracting Parties (Conference of Parties, COP) to the Nairobi Convention–Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region–held in Maputo, in December 2001 discussed and approved a biennial (2002–2003) work programme.

The work programme aims at providing UNEP, as the Secretariat of the Nairobi Convention, the Parties to the Convention and partners with a framework for coordinating and implementing priority activities identified. The work programme is the product of a collaborative, participatory and consultative process between UNEP, Governments of States Parties to the Convention, and partners.

The work programme identified priority activities that focus on five main themes – assessment, management, co-ordination, and legal aspects, and crosscutting issues e.g. information dissemination and exchange as well as emerging issues.

In the biennial work programme, under the themes of assessment and management of the coastal and marine environment, (a) coral reefs and their associated ecosystems, (b) shoreline changes and (c) land-based sources of pollution, have all been defined as priority issues.

In fulfillment of the recommendations of the third COP, a Regional Coastal Erosion Workshop was held in November 2002, in Nairobi, Kenya. The main objectives of the workshop were to review, evaluate and discuss:

- Successful approaches in the implementation of appropriate mitigation methods, including effective enforcement of environmental impact assessment requirements and regulation of coastal construction and development where they exist;
- Reports on actual demonstration projects to restore habitats affected by coastal erosion using acceptable mitigation measures and lessons learned, and

- Successful planning and approval process for special area management plans for erosion-prone areas where they exist.

The participants to the workshop presented several case studies that are demonstrating successes and failures of different approaches undertaken to address shoreline changes in different countries in the region. It was agreed that a report describing these case studies and their resources needs in detail should be prepared, highlighting priority activities that need to be undertaken. This report has been prepared to fulfill that purpose.

This report is structured as follows:
Section Two introduces the region in terms of its climatic conditions, hydrodynamic processes and the main geomorphological features and relating them to the vulnerability to shoreline changes of different areas. **Section Three** describes the shoreline change problem. **Section Four** discusses some of the natural causes as well as human activities, that through a complex interaction, are contributing to the shoreline change experienced in different areas of the region. The main social, economic and environmental impacts of shoreline change are highlighted in **Section Five**, while **Section Six** focuses on various measures, strategies and methods that have been undertaken to address shoreline change problems in the region. **Section Seven** discusses a number of lessons identified from the analysis of the information provided in the case studies as well as other sources of information. **Section Eight** proposes more specific recommendations to deal with the issues and problems identified in the report.

2. GENERAL OVERVIEW OF PHYSICAL AND GEOLOGICAL PROCESSES IN THE WIO REGION

The western Indian Ocean region encompasses a wide range of environmental settings as it extends from the waters of Somalia in the north, to the subtropical waters off the coast of northern South Africa. The region includes the waters and coastal zones of the five mainland States of Somalia, Kenya, Tanzania, Mozambique and South Africa; as well as the island States of Mauritius, Comoros, Seychelles, Reunion (France) and Madagascar. The region extends from latitude 0º to 30ºS and longitude 30º to 65ºE (Figure 1).

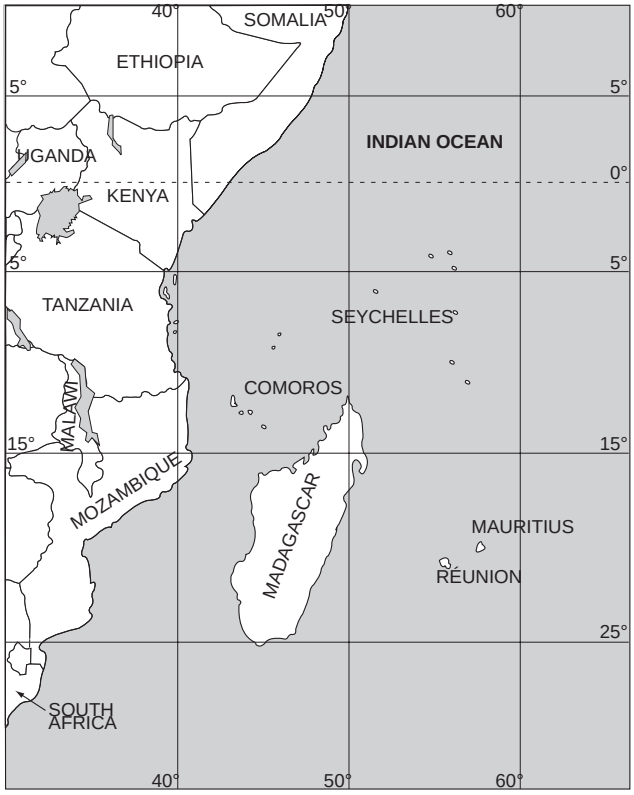

Figure 1. Map of the western Indian Ocean(WIO) region

2.1 Climate, hydrology and oceanography

The climate of most of the WIO region is tropical humid and dominated by seasonal movements of the Intertropical Convergence Zone and the monsoons.

The northern part of the Western Indian Ocean region is dominated by the monsoons, which have a dominant influence on wind direction and strength, ocean currents, temperature, and rainfall, among others.

Ocean currents are important features that strongly influence the distribution of marine organisms and the availability of nutrients. The major currents in the region are strongly influenced by the monsoon winds and shift, reversing direction, according to the season.

There are two monsoon seasons, namely the Northeast monsoon, which prevails November to February and is characterized by higher air temperatures and weaker winds and the Southwest monsoon which lasts from April to September and is marked by lower temperatures as well as stronger winds.

The South Equatorial Current and the East African Coastal Current are strongest during the Southwest monsoon; the East Madagascar and the Mozambique current systems are strongest during the North-east Monsoon. The Somali Current shows reversals in direction reflecting the alternating monsoons.

The southern part of the WIO region, including southern Mozambique, Madagascar, Comoros, Reunion, and Mauritius, lies within a belt affected by tropical cyclones. Cyclones occur during December and March.

Most of the Western Ocean tides are semidiurnal or mixed, mainly semidiurnal. Tidal ranges very greatly within the region (Alusa and Ogallo, 1992). Based on the spring tidal range, the tides are characterised as follows:

- Micro-tidal (0.3-1m) found mainly in the Mauritius and the Reunion;
- Mesotidal (1-2m) found mainly in the Seychelles, the eastern coast of Madagascar and the Rodriguez
- Macrotidal (above 3m) found mainly in the mainland coasts, the Comoros and the western coast of Madagascar.

2.2 Geology and Geomorphology

Many types of geological formation are found in the region, with ages ranging from 200 million years to Recent. For instance, the formations of Tanzania vary in age from Jurassic through Cretaceous to Tertiary and Quaternary, and are composed of both marine and terrestrial sedimentary rocks (Kent et al., 1971). The islands of Reunion, Comoros and Mauritius are essentially volcanic while those of the Seychelles are granitic.

In terms of its geological structure, the coastline of Eastern Africa represents a passive continental margin, from which through geological time continental fragments, large and small, have separated and migrated across the adjoining oceanic crust. Some of these detached continental fragments remain within the region, notably the Seychelles Bank and Madagascar. This structural history has left the mainland states with generally narrow continental shelves. Exceptions include the coasts of southern Mozambique and central Tanzania (in the vicinity of Unguja and Mafia islands) and in the Island states of Madagascar (western coast) and the Seychelles, which are characterized by relatively wider shelves features. The region has an extensive coastline and an expansive coastal zone **(Table 1).**

Comoros and Mauritius are surrounded by deep waters from a few hundred meters to several kilometres offshore. There are shallow banks around Rodriguez and other Mauritian dependencies. The main islands of the Seychelles can be characterised as steep granitic outcrops rising from a broad 'continental' platform; while the Almirantes Archipelago is basically a shelf area. There is an extensive shelf-

Table 1. Coastal Plains and Continental and Island Shelf Areas of the Western Indian Ocean

Country	Land area (km^2)	Coastal land area (km^2)	% Coastal land area	Shelf area (km^2)	Coastline length (km)
Comores	2,236	2,030	100	900	350
Kenya	582,650	32,447	6	655	500
Madagascar	595,790	242,745	41	135,000	4,000
Mauritius	1,865	1,328	100	1,600	200
Mozambique	738,030	162,938	21	120,000	2,500
Seychelles	443	455	100	48,000	600
Somalia	637,657	n/a	n/a	32,500	3,000
Tanzania	939,703	6	6	30,000	800

platform on the axis between the Seychelles and Mauritius.
The primary coastal types of the WIO region include: Exposed low-lying sandy coasts; Exposed rocky coasts; Fringing reef coasts; Patch reef coasts; and inlets, estuaries and creeks associated with the primary coastal types (R.S. Arthurton in Kairu and Nyandwi, 2000). The component facies for each of the coastal type, their main characteristics as well as some of the areas where they found are indicated in **Tables 2 and 3**.
Around Mauritius dune and ridge complexes characterise most of the beaches and the beach width varies from a few metres in the Eastern and Southern regions to about 25 m in the north. In general the sediments are coralline except at the mouths of rivers where they are muddy with a large component of silt and clay. In many places and in particular in the southern regions there are scattered low-lying basaltic rocks on the shoreline.

The coastline of Mozambique is characterised by a strip of beaches, recent dunes and inland lagoons in the south; by mangroves, swampy depressions and series of low beach ridges in the centre and mangroves, small dunes alternating with cliffs in the north. In Mozambique, for approximately 850 km, from Ponto do Ouro (26°50'S) at the Mozambique/South Africa border to the Bazaruto Archipelago at 21°10'S (Tinley 1971, Hatton & Munguambe 1998), the coast is characterised by high parabolic dunes and north-trending capes and headlands, with coastal barrier lakes behind the dunes.

Table 2. Primary coastal types and their main characteristics and some areas where they found (Kairu and Nyandwi, 2000)

Primary coastal type	Main characteristics	Examples
Exposed low-lying sandy coasts	• Associated with the outflows of rivers • Unprotected from ocean waves • Generally associated with a broad continental shelf • Beaches extend over many tens of kilometers without interruption	Southern (e.g. Macaneta) and central central Mozambique (southern Nampula province)
Exposed rocky coasts	• Associated with strong wave energy • Present in both broad and narrow continental shelf • Occur more in some of island states and is somewhat rare on mainland coast	Grande Comores (Comoros); north-eastern part of Madagascar; western coast of Mahe(e.g. Anse Intendance) (Seychelles); Vuma, south of Mombasa (Kenya) and northern coast of Mozambique
Fringing reef coasts	• Flat-topped reef bar, which forms a breaker zone for ocean waves • Backreef platform provide a substrate foe coral gardens, *Halimeda* thickets and seagrass meadows • The landward part of backreef platform overlaid by a sand beach and a beach plain. In Seychelles such beach plains are known as "coastal plateaux" • Bounded to landward by low rock cliffs of fossil reef limestone	Coast extending from Watamu to Chale Point (e.g. Nyali, Diani) (Kenya); parts of Zanzibar islands (e.g. Nungwi); southern Tanzania coast; south-eastern coast of Mahe (Seychelles); much of Mauritius; western coast of Madagascar; and parts of the Comoros
Patch reef coasts	• Interface directly with bathymetrically varied shelf sea waters, with complex shoals, patch reefs and islands • May be partially sheltered • Rock cliffs have only limited platform development • Intertidal flats have mangrove stands and seagrass meadows • May be interrupted by tidal inlets and creeks	South of Chale Point (Kenya), along most most of Tanzania mainland shore (between the border with Kenya to the Songo Songo island in south Tanzania), around much of the western coasts of Unguja and Pemba islands, and northern northern coast of Mozambique
Inlets, estuaries and creeks associated with primary coastal types	• Hosted in all above primary coastal types except exposed rocky coasts • Exposed low-lying sand coast, the inlets occur as river estuaries or deltaic distributaries • Fringing reef coasts, the inlets occur as deep channels, flanked by rock platforms and cliffed terraces • Patch reef coasts, the inlets are flanked by limestone terraces	Exposed low-lying sand coast – central Mozambique, Fringing reef coast— the creek inlets of Mombasa, Mtwapa and Kilifi (Kenya) Patch reef coast— Dar es Salaam harbour

Table 3. Primary coastal types of the WIO region and their component facies in relation to their resource implications and susceptibility to physical change (based on R.S. Arthurton in Kairu and Nyandwi, 2000)

Primary coastal type	Component facies	Resource implications	Susceptibility to physical change
Exposed low-lying sandy coasts	Sand beaches including spits and delta barriers	Tourism, recreation, sand mining	Shoreface erosion/accretion
	Sand dunes	Groundwater, minerals, coastal defence	Beach head erosion/accretion, Aeolian deflation/construction, degradation by man
	Beach plains, delta plains and hinterland	Agriculture, settlement, tourism	Beach head erosion/accretion
Exposed rocky coasts	Pockets beaches	Recreation	May be ephemeral
	Rock shores/platforms		Resistant
	Rock cliffs	Coastal defence	Resistant except where soft/weathered
	Hinterland	Maybe groundwater	Resistant except where soft/weathered
Fringing reef coasts	Forereef and reef apron	Coral reef ecosystem	Dynamite fishing, bleaching, pollution and and siltation affecting coral growth, storm damage
	Reef bar	Reef ecosystem, eco-tourism & coastal defence	Tourism-related damage, sea-level rise
	Backreef lagoons	Reef ecosystem, eco-tourism	Tourism-related damage, sea-level rise
	Backreef platforms with sediment veneer	*Halimeda* thickets, seagrass meadows, seaweed culture	Sediments may be ephemeral, especially in landward parts; pollution, eutrophication
	Backreef rock platforms		Resistant to erosion
	Beach-rocks	Coastal defence	May be resistant to erosion
	Sand beaches	Tourism, recreation, sandmining	Shoreface erosion and accretion
	Sand dunes	Coastal defence, groundwater	Beach-head erosion and accretion, aeolian deflation and accretion/construction
	Beach plains	Agriculture, settlements, tourism	Beach-head erosion and accretion
	Rock cliffs	Coastal defence	Resistant except where soft or weathered
	Hinterland, limestone terraces	Groundwater, tourism infrastructure	Resistant except where soft or weathered
Patch reef coasts	Offshore patch reefs	Coral reef ecosystem	Dynamite fishing, bleaching, pollution
	Intertidal flats (sediments)	Mangrove stands, seagrass meadows	Sediments may be ephemeral, erosion exacerbated by mangrove clear felling
	Rock platforms		Resistant
	Beach rocks	Coastal defence	May be resistant
	Sand beaches including spits	Tourism, recreation, sand mining	Shoreface erosion/accretion
	Beach plains, delta plains	Agriculture, settlements, tourism	Beach head erosion/accretion

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Primary coastal type	Component facies	Resource implications	Susceptibility to physical change
	Rock cliffs	Coastal defence	Resistant except where soft or weathered
	Hinterland, reef limestone terraces	Groundwater, tourism, infrastructure	Resistant except where soft or weathered
Inlets, estuaries and creeks (associated with primary coastal types)	Swamps and marshes	Mangroves stands	Erosion exacerbated by clear felling
	Channels, tidal inlets	Ports, industry, urban development, aquaculture	Possible lateral channel migration
	Rock platforms		Resistant
	Rock cliffs	Coastal defence	Resistant except where soft or weathered
	Older beach plains and dunes	Agriculture, mineral, groundwater	Erosion due to channel migration

Seychelles comprises of 41 granitic islands and 74 coralline islands. The granite islands are typically rugged and hilly while the coral islands are low sand cays (Bird and Denis islands) and elevated reef limestone (the Aldrabra). Granitic islands are characterized by pocket beaches known as "anses", and coastal plateaux, which rarely rise above 2m above sea level. The plateaux consist of calcareous reef material, which builds up as sand dunes.

In Tanzania, the most prominent features along the coast include: fringing platforms, limestone cliffs, sandy ridges and beaches, and mangrove forests in the riverine estuarine and deltas. Dunes are limited and only found in southern Tanzania, south of Mtwara town and are covered by sparse vegetation (Francis and Mahongo, 2001). According to Abuodha (1994) the major morphological features of Kenya's coastline are: Sandy beaches (e.g. Kikambala, Kanamai, Bamburi-Kenyatta, Nyali, Tiwi & Diani); rocky shores (Shanzu, Kenyatta, Iwetine and Galu); Cliff coasts (Kanamai, Shanzu, Likoni & Black Cliff Point); Coastal dunes (Shanzu, Bamburi, Malindi & Mabrui) and shore platform and lagoons.

Mangrove forests occur on the mainland and island coasts of the region in sheltered bays with alluvial deposits, especially in the mouths of large rivers. Mangroves constitute one of the most extensive and widespread natural communities in the region. A total of eleven species of mangrove are known to occur in the region. Although estimates vary, Madagascar, Mozambique and Tanzania have the largest areas of mangrove forests in the region.

3. GENERAL DESCRIPTION OF THE SHORELINE CHANGE PROBLEM IN THE WIO REGION

Shorelines are generally more or less in dynamic equilibrium. Their evolution due to changes in winds, waves, currents, and sediment transport, is rather seasonal, characterized by alternate erosion and accretion. Additional changes occur when perturbations are introduced by anthropogenic factors/activities.

Shoreline change is a natural process of evolution of coastal areas. It may occur on different scales of time, from a single tidal event, to decades or centuries. However, three time scales of shoreline change evolution can be distinguished (Abdel-Aal, 1993):

i) **Geological evolution.** Takes place over centuries and affects a large area
ii) **Long-term evolution.** Annual to decadal shoreline changes affecting a limited stretch of the shoreline
iii) **Short-term evolution.** Seasonal variations of shoreline at the local scale

Shoreline change, particularly coastal erosion, is one of the most prevalent environmental problems in the WIO region. Coastal erosion occurs in the most of shorelines of all the countries of the WIO region. The problem of shoreline change in the WIO region has been studied and reported widely for some countries than others (IOC-UNEP-WMO-SAREC, 1994 & Kairu and Nyandwi, 2000). Table 4 lists some examples of eroding/accreting shorlines in the WIO region.

In Kenya, coastal erosion is severe in a number of sandy beach areas such as north and south of Mombasa and Malindi – Mambrui area, while in areas around Mambrui village, rapid accretion is occurring (KMFRI, 2003). Before 1976 Malindi was experiencing loss of land, but from 1976 to date, the beach at Malindi has prograded by about 500m (Kairu, 2003). Coastal erosion is also prevalent along the cliffs beaches at Kanamai, Shanzu, Ivwetine, Nyali, Likoni, Black Cliff Point, and Tiwi (Aboudha, 2003).

Coastal erosion is observed in many areas on both east and west of Madagascar. These areas include: Morondova, Toamasina and Manakara. In Mauritius, erosion has been documented in Flic en Flac, Le Morne, Pomponette-Riazmbel, Belle Mare and Grand Baie (Joottun, et. al., 1994)

Areas experiencing severe coastal erosion in Mozambique included Beira, Macaneta Penninsula and Maputo bay (Lundin and Linden, 1996 & Kairu and Nyandwi, 2000). For the past 40 years, the Zambezi delta has been experiencing accretion of about 1 m per year (Kairu and Nyandwi, 2000).

In the Seychelles coastal erosion has been detected in most of the beaches though it is more pronounced on the island of La Digue, Bird Island and Praslin as well as the East Coast of Mahe Island (Shah, 1994).

In Tanzania coastal erosion problems have been reported in most parts of the coastal section from the southern end of the coast to its northern end and also in Unguja island (Shaghude et al. 1994; Mohammed &

Table 4. Examples of eroding/accreting shorelines

Site	Geology	Comments
Comoros		
Grande Comoros	Low volcanic rock cliffs and narrow coastal lowlands	Removal of sands for construction has resulted in existence of few beaches (Kairu and Nyandwi 2000)
Kenya		
Malindi		Major beach accretion of micaceous sand has occurred since the 1960s
Madagascar		
Morondova	Wide low-lying area	In 1953, the Morondova city lost 100m of shoreline due to the swell and storm events (Kairo and Nyandwi, 2000)
Mauritius		
Flic en Flac	Sandy beaches are the most common and exposed basaltic cliffs in the northern end	Between 1980–1994, the position of high water mark at Flic en Flac moved by a distance of 8 m (Jootum, et. al., 1994). The ridge complex zone which runs parallel to the shoreline, stretching over 600m and attaining 5m high in some regions, complex has been mined for its good quality sand.
Belle Mare	Sand beaches	Receded to about 5m in 1988 due to tropical cyclones (Jootum, et. al., 1994).
Mozambique		
Beira	Sandy beaches, and coastal swamps	According to Lundin and Linden (1996), apart from natural causes, coastal erosion could be attributed to: inadequate maintenance of the buttress and sand retention wall; destruction of the dunes; mangroves and casuarinas; removal of sand for construction; and building on beach
Seychelles		
Bird Island	Low-lying coralline island	Its south-western shoreline shift and recede naturally while, north-eastern shoreline is accreting (Shah, 1994)
Tanzania		
Mwambani, Tanga	Cliff erosion	Mwambani shoreline is characterized by a fringing reef platform bordered by a line of cliffs. The stretch is a high wave energy environment and fine sediment is lacking.
Maziwi Island	Sandy island	Disappeared in 1977/1978 and its disappearance is attributed to sea level rise (Fay 1992) and clearance of all vegetation on the island (Shaghude, in press).
Nungwi, Zanzibar	Sandy beaches	An erosional regime that threatened the village of in the early 1990s has been replaced by accretion

Betlem, 1996). The most seriously affected sites include Dar es Salaam coast (Msasani to Kunduchi); Tanga (Mwambani, Kigombe and Pangani delta); Mtwara (Mikindani) and Unguja (Jambiani – Bwejuu, Maruhubi).

The shoreline change problems have been found to affect shores consisting mainly of unconsolidated and semi-consolidated sediments, particularly sand beaches, beach plains and sand dunes.

Places like Sea View and Msasani Bay and Shangani area in Mtwara (Tanzania), which are largely made of raised reef limestone, are experiencing cliff erosion. Since the cliffs are made of relatively strong limestone, the shoreline recession rates are slow.

It is therefore evident that the susceptibility of shorelines to erosion varies from place to place, but it is generally influenced by the geology and other physical parameters such as wave and current dynamics, sea level rise, etc.

4 CAUSES OF SHORELINE CHANGE IN THE WIO REGION

Shoreline change is caused by a complex interaction of various natural processes and in most cases is intensified by human activities. The natural processes include among others: the combined action of waves, low coastal topography and nature of sediments, tides, winds and currents, variations in the sea level, tectonics and storms. Human activities that could intensify beach erosion include: manipulation of hydrological cycles through mainly dam construction; building on beaches; coastal structures such as harbours, beach protecting structures and jetties; and mining of beach sand and live coral. Others include: destruction of protective coral reef systems; and destruction of coastal vegetation

4.1 Natural causes and conditions

Natural processes and climatic conditions are important in determining the nature of wave impacts responsible for the erosion of reefs and beaches, and sediment transport.
Natural processes are constantly changing resulting in alternating periods of accretion and periods of erosion and inundation. These processes are influenced not only by daily or hourly changes in tides, etc, but also over longer timescales as sea level and climate change.

Erosion and inundation brought about by river flows, tides, winds and rain are among the most important natural processes which determine the shape and dynamic character of the coastline. Coastal features such as sand dunes and beaches, mangroves, and mudflats are formed by the deposition of sediments. Throughout most of the region reef, growth and its related biogenic sedimentary processes have been and are some of the principal contributors to the coastal geomorphology.

In the WIO region, terrigenous sediments are introduced to the beaches of mainland fringing reef and patch reef coasts, and some of those of the larger islands where older rocks crop out through:

- Quartz sand derived directly or indirectly from hinterland through rivers and streams discharging at the coast and transported along the coast by the processes of longshore drift and wind deflation
- Erosion from beach heads, including the temporary coastal and sand stores of dunes and beach plains, by extreme wave impacts

At places such as the eastern coasts of Zanzibar's islands, where the discharge of terrigenous sediments is non-existent, the beach is almost exclusively of biogenic calcium carbonate sand (Mohammed and Betlem 1996).

Any of these sources may be subject to variation on long- or short-time scales due to sea-level change, climate variations, or land use changes. Losses of beach sediment are similarly subject to variation with time, being exacerbated by coastal storms and inappropriate shoreline protection measures. Variations in the direction of longshore drift is an important factor to be considered in the context of sediment loss from beaches of the WIO region (Arthurton, 1992; Kairu and Nyandwi, 2000).

Mauritius offers some of the illustrative examples of shoreline change in the WIO region which could be attributed to the natural processes.

Mauritius is often under the influence of tropical cyclones and anti-cyclones. A typical cyclone could cause a rise in water level with low pressure and gusts of 225 to 250 km per hour often raises the water level to 2.50 m and the wave uprush to 50m in many parts of the Island coastline (Joottun, 1994). If waves generated by these gusts or swells generated by strong winds coincide with spring tides, they will cause a significant storm surge. This is recognised as a contributing factor for coastal erosion. Cyclones such as

Carol of February 1960, Gervaise of February 1975, Claudette of December 1979 and Hollanda of February 1994 caused widespread damage to coral reefs, the shores and infrastructure (Ragoonaden, 1996 and Dubi, 1998).

Another important cause of the coastal erosion is the shortage of sediment. The Indian Ocean Commission publication *Manuel de Suivi et de Traitement de L'Erosion Cotiere* (2002) clearly emphasises that the present shortage of sediment on the shoreline due to natural reasons is one of the causes of erosion in the islands of the Indian Ocean. The Mauritian beaches are mostly coralline and receive a very low supply of sediment from the hinterland. The above-mentioned manual suggests that since 10,000 years ago there was a period when the different beach morphologies were formed due to an abundance of sediment (sand) of coralline origin. However, the contrary is now happening, whereby there is a natural shortage of sediment. This is making the sandy beaches more vulnerable to erosion (Mooloo and Luximon, 2003).

4.2 Human-induced causes

Generally, although the relative contribution of human-induced coastal erosion to all observed coastal erosion in the Region is not thoroughly investigated, the few studies reported in some countries within the Region show that the contribution of anthropogenic coastal erosion is quite significant. For instance in Seychelles, it is reported that, out of 40 coastal erosion cases cited, only 11 were attributed to natural causes, such as sea level changes, topography and marine hydrology factors, while in 29 others erosion was mainly attributed to human activities (Societe CMPI, 1987).

The anthropogenic activities contributing to shoreline change could broadly fall into four main categories as described below.

i) **Obstruction of sediment supply or modification of water flow.** Reduced sediment supply (caused by offshore extraction, protection of eroding shoreline and damming of sediment-rich rivers) has contributed to the further loss and degradation of coastal habitats including beaches and mangroves. The construction of coastal structures such as groynes and jetties may interfere with the process of longshore drift, modifying the sediment budget and exacerbating erosion of the adjacent beach or beach head in a down drift direction. The construction of dams on rivers leading to the ocean have reduced sediment supply to the coast through trapping. Preliminary data shows that damming of the Tana river in Kenya reduced the sediment load from 10 x 10^6 tons per year (during 1950s) to 4.9 x 10^6 at present (KMFRI, 2003).

ii) **Removal of beach material.** Though banned in most of the countries in the region, beach sand is still being mined for construction. Before the banning of sand mining in Mauritius in October 2001, about 800,000 tonnes of sand were being mined from the lagoon annually by 25 cooperative associations using 310 boats and employing nearly 1,000 people. In Tanzania, a field survey was conducted by Griffiths (1987) to estimate the extent of sand extraction along the four main streams (Tegeta, Mbezi, Mlalakuwa and Kijitonyama) which drain the hinterland of Kunduchi beach, found that at least 100,000 m^3 of sand were extracted annually from the four streams. This means that the sand being brought in through these streams does not reach the beach.

iii) **Removal of protection against wave battering and beach protective vegetation.** There are several examples that could be attributed to this impact:

- **Dynamite fishing.** Though reduced significantly in Tanzania in recent years (in the 1980s), dynamite fishing (due to its destruction of coral reefs), was considered by some experts to be one of the main causes of coastal erosion. However, other experts dispute this arguing that in some areas such as Kunduchi, coastal erosion was already a serious problem even before dynamite fishing started.
- **Clearing of vegetation.** In some areas of Tanzania such as Bagamoyo, Litingi, Mtwara and Kilwa Kivinje, erosion is taking place where mangroves have been removed. For

instance, the management of Makonde Beach and Resort in Mtwara, Tanzania, for the purpose of getting a better view of the ocean, cleared a mangrove forest behind the resort. Ever since, the resort is seriously threatened by erosion and the seawall built is proving to be ineffective (Francis et al., 1997). In the Macaneta Peninsula in Mozambique, cutting/clearing of trees that normally protect the sand dunes is also contribution to the erosion problems experienced there (Hoguane, et. al., 2003).

- **Mining of corals.** Coral mining, for lime production used for both local and commercial construction requirements is widely practiced in some parts of Tanzania (Muhando et al., 2001). The mining of live corals, amongst others, removes barriers protecting the coastline against wave attacks.

iv) **Poor planning.** Existing policies and practices can also increase the coastal zone's vulnerability to shoreline change. These practices include: investments in potentially hazardous zones; inappropriate coastal defence schemes and coastal habitat conversions. In most of the countries in the region, tourist infrastructure has been built right on the shoreline, which in some cases is interrupting the natural sedimentary cycle.

These activities, individually or in combination, may alter the equilibrium of a coastal section and therefore result in shoreline change (erosion or accretion) mainly through altering the supply of sediments.

5 SOCIAL AND ENVIRONMENTAL IMPACTS OF SHORELINE CHANGES IN THE WIO REGION

The main social, economic and environmental impacts of shoreline change are reflected in a number of ways including: loss of beaches; loss of arable and buildable land; damages to coastal property and infrastructure; and destruction of habitats such as mangroves and coastal forests.

Examples of social, economic and environment impacts of shoreline change include:

i) **Disappearance of Maziwi Island.** Maziwi Island was one of the most important nesting sites in the WIO region for three species of marine turtles, namely olive ridley, green and hawksbill turtle. The Island disappeared in 1978 apparently due to erosion.

ii) **Disappearance of settlements.** Maritime trade and easy communication considerations were the main driving forces in establishment of the earliest settlements in the eastern Africa coast. These settlements, which some of which date back to between 8th and 18th Century, included: Lamu, Malindi, and Mombasa (Kenya)(Kairu, 2003); Bagamoyo and Kilwa (Tanzania) and Pemba (Mozambique). Settlements located on limestone terrain survived and are still in existence today, while those located on unconsolidated sand deposits such as several localities in Lamu and Ungwana bay areas have disappeared (Okemwa, et al., 1994).

iii) **Modification of habitats.** In Anjuan Island, Comoros, the removal of sand and coral heads for the building industry has transformed beaches and beach plains, reef areas, and lagoons into mud flats, with sediments from the bare slopes of the central mountains of the Island (Kairu and Nyandwi, 2000). In Tanzania, between 1981 and 2002 shoreline erosion destroyed about 1 acre of mangroves in the area between Southern Kunduchi and Manyema Creek (Makota and Salema, 2003).

iv) **Damage to property and infrastructure.** Most of the beach fronts of the hotels along the beaches in Tanzania and Kenya are eroding. For example, Hotel Africana which was built on a dune had lost more than 50% of its residential huts by the late 80's (Nyandwi, 2001). The Hotel was later abandoned when a larger part of the hotel area was eroded.

v) **Expenses associated with maintaining beach protection structures.** A great deal of money is spent on maintaining what is, in many areas, poorly designed coastal structures built to protect properties against erosion. For example, Kenya experiences increased costs of coastal protection against shoreline erosion and flooding from major river systems. Many sea walls have been erected at major tourist development centres to protect them from shoreline erosion that has been threatening many of the coastal developments. This impact is most felt at north and south of Malindi Bay, Mombasa and Diani, Malindi/Watamu Marine Park and Biosphere Reserve, and Ngomeni Mangrove Swamps. The

Bamburi Beach Hotel administrators reported high cost of seawall maintenance. The seawalls are estimated to cost between Kshs. 2–5 million (US$ 27,000– 67,000) to erect. It costs a further US$ 10,000–14,000 p.a. to maintain the seawalls due to the undercutting of the waves (Aboudha, 203). In Mauritius, between 1995 and 2002, the Ministry of Environment carried out some 3500m of coastal protection works (in the form of gabions and groynes) in different parts of the Island. These are: Grand Bay (200 m); Riviere des Galets (800 m); Cap Malheureux (100 m); Flic en Flac (700 m); La Prairie (300 m); and Riambel (1400 m) (Mooloo and Luximon, 2002).

vi) **Degradation of aesthetic qualities by construction of beach protection structures.** Coastal protection structures, like seawalls, gabions and groynes, reduce the recreational beach area and its aesthetic appeal, prevent easy access to the sea and add to the cost of maintaining the beaches.

6 MEASURES/STRATEGIES UNDERTAKEN TO ADDRESS PROBLEMS CAUSED BY SHORELINE CHANGE

Various measures, strategies and methods have been applied to address shoreline change and especially shoreline erosion in the WIO region. Coastal protection methods in the WIO region are varied and take many different forms. A method of protection can comprise one or more options that fall broadly under three categories, namely, 'protect', 'retreat/advancing' and 'accommodate' (Table 5).

6.1 "Protect" options

Coastal protection and sea defense options are further sub-divided into:

i) **"Hard" engineering techniques.** These techniques, which include groynes, breakwaters, seawalls, and revetments, involve the construction of solid structures designed to fix the position of the coastline.

- **Offshore breakwaters.** These are built to protect the beach by reducing the amount of wave energy reaching the beach area. In Zanzibar Town, a breakwater was constructed in the 1920s to protect the harbour and is still intact to date. In Wolmar, Mauritius, segmented breakwater made of rubble-mound has been constructed to reduce the amount of wave energy reaching a coastline during cyclones and stabilize the replenished beach (Figure 2) (Mooloo and Luximon, 2003). In 2002, one of the beach hotels along Bamburi beach, Kenya sank an old ship into the sea opposite

Table 5. Examples of coastal protection, retreat/advancing and accommodative strategies (Modified from Dubi, 2000)

	Technology		
Application	Hard structural options	Soft structural options	Non-traditional options
Protect	• Seawalls, revetments • Groynes • Breakwaters	• Beach nourishment • Dune restoration and creation • Wetland restoration and creation • Afforestation	• Coconut-leaf walls • Coconut-fibre stone units • Wooden (Mangrove) stakes walls • Stone walls • Sand bags
Retreat/ Advancing	• Phased-out or no development in susceptible areas • Advancing the existing defence line • Relocating threatened infrastructure		
Accommodate	• Legislative framework including Environmental Impacts Assessment • Emergency planning • Modification of building styles and codes • Regulations of hazard zones		

to it. This ship is supposed to act as an artificial breakwater. The hotel has not constructed a seawall. Already, the beach ridges that have formed are colonised by creeping plants(Aboudha, 2003).

- **Seawalls**. These are built to protect high value property situated along the coast. There are many designs of seawalls built using different materials. Different types of seawalls exist in the region. Examples include (a) concrete seawalls at Ocean Road, Dar es Salaam and near Zanzibar Harbour, Tanzania; (b) stone-filled wire gabions (Figure 3) at Rivière de Galets and Cap Malheureux, Mauritius (Mooloo and Luximon, 2003) and (c) rock armouring (Figure 4) at Anse Kerlan, Seychelles (Quatre, 2003).
- **Groynes**. These are structures built perpendicular to the shoreline to trap long-shore sediment transport with the intention of reducing erosion on the existing beach (Abdel-Aal, 1999). Groynes have been constructed using coralline limestone blocks (Kunduchi Beach area, Tanzania & Shanzu, Kenya) and quarried granite (Praslin, Seychelles)(Figure 5) (Quatre, 2003).

ii) **"Soft" engineering techniques.** These include artificial replenishment of sediment supply, dune restoration and creation and wetland restoration. They focus on the dynamic nature of the coastline and seek to work with the natural processes, accepting that its position will change over time.

- **Beach nourishment.** Sand is transported by truck or barge from a remote borrow area and placed on the shore to stabilise an eroding beach. Beach nourishment has been used to reinstate an important beach following extreme event related degradation. In Mauritius, after cyclone Dina (January 2002), a number of hotels used about 8 000 tonnes of sand for beach nourishment of the areas in front of their hotels (Mooloo and Luximon, 2003). At the White Sands Hotel, Dar es Salaam, Tanzania, the beach is maintained by refilling it on a daily basis.
- **Afforestation.** Mauritius has embarked on tree planting along the coastline to create a barrier for the gust winds and even storm waves. At Anse Kerlan, Seychelles, vegetation has been planted on the sand dune to reduce erosion (Figure 6) (Quatre, 2003). In a place near Mtwara Beach Hotel and Resort, Tanzania, a combination of mangrove reforestation, embankment and a wooden seawall has been used to protect salt pans (Francis, et. al., 1997).

iii) **Non-traditional engineering techniques.** Coastal communities in various parts of the region, have used different materials that are easily available within their areas to build structures to protect their coasts. Materials used include: coconut-leaf, coconut fibres, and mangroves poles.

- **Mangrove poles.** In Bamburi beach in Mombasa, Kenya, some of the private property owners have used mangrove poles for protection of their properties. These poles, which are one–foot in diameter and one-metre high, are much cheaper compared to the limestone boulders (Aboudha, 2003).
- **Sand bags and used tyres.** In Ile aux Sables, Rodrigues, Mauritius, used tyres coupled with sand bags placed along the shore have proved to be effective in dissipating the incident energy and promoting accumulation of sand. In the absence of any materials like sand bags, or used tyres, tree logs may also be used as a temporary measure for shore protection against erosion (Figure 7).

6.2 "Retreat/advancing" options

These options include:

- **Phased out or no development in susceptible areas.** Wherever other options are not possible/ feasible, it would be wise to retreat or prohibit any development activities in the area. In Mauritius in 1996, a ministerial committee recommended that sand extraction from lagoon be phased out over the period 1997 to 2003. However in 1997, Government decided to phase out sand extraction in October 2001. Peoples who were involved in sand mining were financially compensated and alternative jobs including training facilities were offered.
- **Relocating threatened infrastructure.** When coastal erosion at Anse Kerlan was posing a threat to the main road running alongside the beach, the road was diverted further inland by several meters. With the application a 15-m-wide rock amour along the eroding beach, the diversion created more

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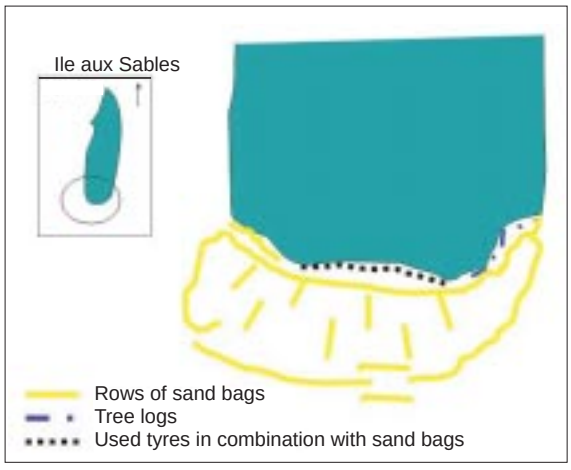

Fig. 2. Segmented breakwaters in front of the Hotel, near Wolmar, Mauritius (Mooloo and Luximon, 2003) Fig. 3. Gabion works at Cap Malheureux, north of Mauritius, to protect a cemetery (Mooloo and Luximon, 2003. Fig. 4. Rock armouring at Anse Kerlan, Seychelles (Quatre, 2003) Fig. 5. Some of the groynes constructed to protect Anse Kerlan (Quatre, 2003) Fig. 6. Planted vegetation on the coast of Anse Kerlan (Quatre, 2003). Fig. 7. Protection of the beach at Ile aux Sables, Mauritius using sand bags, used tyres and tree logs (@N. Soogon)

space for accretion (Quatre, 2003).

- **Advancing the existing defence line.** In 1997/98, the Kunduchi Beach Hotel implemented a land reclamation project that resulted in increasing the width of the beach by 30 to 40 m, providing expanded recreational opportunities and improved protection for hotel's properties. The Hotel was only 2m away from the encroaching sea before reclamation was carried out.

6.3 "Accommodate" options

Although there is no country in the WIO region with a set strategy (policies, legislation and regulations) specifically geared towards addressing shoreline change, there are a number of national policies/ regulations with aspects relevant to shoreline change. As shown in Table 6, Seychelles and Tanzania do have a number of policies/legislation/regulations that are geared towards addressing some aspects of relevance to the shoreline change issues.

However, the legal framework of countries such as Kenya does not take into account problems related to coastal erosion especially those related to development of vulnerable environment. Construction of coastal defense structures, which are considered under minor improvement works, is not regulated.

The other options include:

- **Setback lines/zones.** Setback lines involve the restriction of development of certain types within a prescribed distance from the shoreline. Facilities and infrastructures in the coastal zone should be located at an appropriate distance and position. Under ideal situation, the setback should be site-specific taking into consideration slope, altitude and sensitivity of the areas. Mozambique has its setback lines 100 metres from the high water mark, while Kenya has set its setback line at 37.7 metres. Tanzania originally set its setback line at 100 metres, but changed it 1992 to 60 metres. There are numerous examples where the setback lines have been ignored.
- **Environmental Impacts Assessments (EIAs).** In Mauritius, in an attempt to address problems related to shoreline change, since 1992, a number of coastal activities are regulated through the EIA mechanism. These are: construction of coastal hotels; construction of breakwaters, gryones, jetties, revetments and seawalls; construction of marinas; lagoon dredging and reprofiling of sea beds including creation of bathing areas; modification of existing coastline such as beach reprofiling; and coastal protection works and removal of basaltic and beach rock, are offshore sand mining
- **Emergency planning which includes establishment of early-warning systems.** Since 1965, the state of coastal erosion of Flic-en-Flac and Pomponette in Mauritius have been monitored (Ragoonaden, 1996).
- **Modification of building styles and codes.** This option include the switch to building material alternative to beach sand. Following the ban of sand mining from lagoons in Mauritius in 2001, sand is now mined from two inland sites.
- **Regulation of hazard zones.** In Tanzania, the National Integrated Coastal Management Strategy approved by the Cabinet in December 2002 provides for the establishment of Special Area Management Plans (SAMPs). SAMPS shall be developed for geographic areas of concern, including "areas at high environmental risk from the effects of erosion and flooding".

7 LESSONS LEARNT

Based on case studies and other sources of information, a number of lessons have been learnt. These lessons are summarised below.

Engineering techniques

- Beaches are very dynamic geomorphic features, and any development activity should take that fact into consideration. In this respect, setback lines should be site-specific taking into consideration, among others, geomorphology and sensitivity of the area.
- There are many examples of individual attempts by either hotel owners or residents to control coastal erosion. However, there are no unified attempts or approaches to coastal protection that have been

Table 6. Some of the existing policies/legislation in Seychelles and Tanzania their relevance to shoreline change

Country	Legislation/Policy	Implied Objective
Seychelles	The Town and Country Planning Act 1972 (Cap 237,TCPA)	Permission is required for the development of any land, including the coastal plateau for tourism purposes. Building operations must comply with the rules and codes of practice laid out in sections 7 to 83 of the Regulations
	The Environment Protection Act 1994	provides, *inter alia*, for the environmental impact assessment process, the establishment of sensitive areas, coastal zone management, waste management, standards and makes provision for prevention, control and abatement of environmental pollution. The Act provide powers to the responsible authority to prepare coastal zone management plans (Section 11) which includes evaluation of coastal ecosystem state and areas of scenic and outstanding beauty, an evaluation of the impact of coastal erosion and causes and sources of coastal pollution and degradation.
	Environment Protection (Impact Assessment) Regulations, 1996	Act specifies the preparation an impact assessment report for any project or activity such as mining, the hotel industry (hotels, restaurants and tourism activities), roads and coastal defences; land reclamation; and housing development. The regulation also provides limits to development with a protected area or an ecologically sensitive area such as beaches and intertidal zones, coastal strip, small and outlying islands and unique natural habitats not protected as protected areas.
	Beach Control Act, 1971 and Subsidiary regulations, 1991 (Cap 14)	Makes specific provisions for the regulation of use of pleasure boats and limits to water sports within the 'inshore waters' and gives powers to the designated authority to specific areas of the beach to allow several activities to be permitted without endangering the environment or public safety. To date two areas (Beau Vallon and Port Launay) have been zoned in accordance to these regulations
	Removal of Sand and Gravel Act 1991 Chapter 203	Act regulates the removal of sand and gravel from rivers, streams and coastal areas.
Tanzania		
	National Integrated Coastal Management Strategy	Provides for establishment of an integrated planning and management mechanism for coastal areas of high economic interest and/or with substantial environmental vulnerability to natural hazards
	Mining Act, 1998	Regulates issuing of renewable mining licenses for minerals and gemstones, including building materials (sand, soil & stones)
	Marine Parks & Reserves Act, 1994	Prohibits any construction or any activity within a marine park without first undertaking EIA as well as mining in a marine park unless permitted under general management plan or regulations
	National Land Policy, 1995	Encourages optimal use of land resources. Provides specifically that sensitive areas to be protected and not to be allocated to individuals and stipulates that all beaches shall be public and waterfront development shall be regulated. Construction of tourist hotels, residential buildings & recreational activities along the coastline/islands shall be regulated to prevent coastline erosion & ensure public access. Coastline development shall be done after EIA study has been carried out. A Coastal Zone Integrated Development and Management Programme will be prepared for conservation of both land and aquatic environments.
	The Town and Country Planning (Public Beaches Planning Area) Order, 1991, GN 76 published on 25/5/92 and deemed to have into operation on 24th November for 1989	- Schedule: All that land lying within 250 meters and forming shores beaches of Indian Ocean is a planning area. - Rule 2: A planning scheme for a planning area fronting ocean must reserve strip of land of a width of not less than 60 meters from the high water mark exclusively for conservation and strictly water-related human activities

undertaken to protect a relative large area. The priority is always to protect a house or a hotel or infrastructure regardless of its implications on adjacent areas. There are also no set standards/ guidelines for constructing coastal structures to address shoreline change.

- To maintain the function of hard engineering structures such as seawalls, groynes, and breakwaters, geological and hydrodynamic conditions of a given location must be known. Their proper planning and designing requires reliable information on these conditions.
- Structures built along some parts of the shoreline have accelerated erosion because of inappropriate design and construction of coastal protection measures as well as non-uniformity in protection measures undertaken. For example, some beach hotels have seawalls while their neighbouring private homes do not, or have different types of protection structures. There are no standards/guidelines for such coastal structures as groynes and seawalls.
- Once constructed, engineering structures are not maintained regularly, resulting in their failure or collapse within a relatively short period of time.
- Groynes are only effective where there is substantial longshore sediment transport. Building them where there is limited supply of sand to attract may end up attracting volumes of seaweeds onto the beach which is a nuisance and unattractive.
- A combination of at least two or three mitigation approaches has been found to be effective in controlling erosion. The hotel in the Wolmar area, Mauritius used rubble- filled Reno mattresses, beach nourishment and segmented rubble-mound offshore breakwater.

Legislative framework

- Although some progress has been made in the management of beaches over the years, in most of the countries, the beaches are still largely unmanaged, resulting in illegal sand mining, dune destruction, and the removal of coastal vegetation. Management initiatives are only instituted when the erosion problems become severe. Also there is no country in the region with a legal framework specifically designed towards overall beach management. Indeed, beach management is fragmented into several legislations and regulations, and often shared among different government ministries and agencies, making enforcement difficult.
- There are no examples of appropriate use of existing laws to zone sensitive areas such as beaches. Also there is absence of regulations/by-laws guiding the construction of coastal protection measures.
- In most of the countries in the region, beaches are not given the same level of importance as other sensitive ecosystems such as wetlands, mangrove forests, and coral reefs. This has resulted in lack of provision of proper legal recognition and protection of the beaches.
- Coastline development such as construction of tourist hotels, residential buildings & recreational activities along the coastline/islands is unregulated and done without environmental impacts assessment (EIAs). Of more concern is that EIA procedures and guidelines are not legally recognised.

8 RECOMMENDATIONS

Shoreline change is a natural process of evolution of coastal areas and is caused by a complex interaction of various natural processes and in most cases is intensified by human activities. It may occur on different scales of time, from a single tidal event to decades or centuries.

Although coastal areas of the region are increasingly attracting a wide range of developments such as construction of major settlement centers and tourism infrastructures, in some areas, the shoreline is threatening the sustainability of these activities. As discussed in the preceding sections, shoreline change has affected several areas along the coast of the WIO region, causing significant social, economic and ecological impacts. These include: loss of beaches, arable and buildable land; damages to coastal property or infrastructure; and destruction of important ecosystems.

As also discussed in the previous sections, different strategies have been applied to address the problems caused by shoreline change. Some of these strategies have succeeded while others have failed and a number of lessons could be drawn as discussed in the previous section.

Participants to the Regional Coastal Erosion Workshop, held from 27-29 November 2002 in Nairobi, Kenya made several key recommendations that if implemented will go a long way towards addressing some of the issues highlighted in this report. These recommendations are attached as Annex I. In addition to

these recommendations, further comments are made below based on the review of the case studies as well as other sources of information on shoreline change.

- Detailed knowledge of both of the socio-economic and environmental processes in a specific area involved, and of the spatial and temporal scales over which those processes occur, is an essential prerequisite to understanding the shoreline change affecting the area and management responses to be adopted. Information on the following parameters is important for this purpose:

Physical

Elevation and bathymetry
Hydrodynamics (wave regimes, sea level, tides, etc.)
Geology and geomorphology (classification of coasts)
Current evolutionary trends
Meteorological information (wind, storms, etc.)
River and coastal sediment dynamics (including river discharges)

Policy and institutional

Land ownership (e.g. state-owned, private, etc.)
Zoning and regulations (e.g. existing setback lines, etc.)
Responsible Institutions, level of devolution, and capacity
Budget allocated to coastal erosion management

Technical and engineering

Type of coastal defence works: hard engineering, soft engineering

Social and economical

Demography
Coastal livelihoods (e.g. fishing villages)
Land cover and land use
Highly valuable areas (both ecologically and culturally)

Public perception

Perception of risks and hazards

Information

Availability and accessibility
Information exchange and dissemination practices

- Coastal defense measures should be based on detailed knowledge of coastal geomorphology and ecological processes and assessment of their effectiveness in addressing erosion problems in a specific area.
- The selected coastal defence measures need to be environmentally sensitive and affordable over the long-term and developed within the context of national policies for integrated coastal management and river basin management.
- Monitoring programmes to assess effectiveness of the structures constructed in addressing erosion problems should be initiated. Such programmes are also important for identifying any unforeseen effects. Based on their findings, a maintenance programme could be initiated at the appropriate time.
- Setback strategies involve the restriction of development of certain types within a prescribed distance from the shoreline. In order to regulate development in the coastal zone, it is important that environmental sensitivity maps with guidelines on the nature and type of development that may be allowed in such areas be prepared. The coastal classification map and its derivative susceptibility assessment provide important guidance in the placing of setback limits.
- According to Swart and Horikawa, (1986), to prolong the effective life of the sand nourishment and avoid any major interruption in the supply of sediment to the downdrift beach, groyne fields should be combined with sand nourishment. The groyne field is filled with sediment to their impoundment capacity from an external source at the time of construction.
- Countries such as Comoros, which relies on beach sand for construction, should be assisted financially

and technically to find alternative sources of sand.

- Involvement of community members, students, and the private sector in coastal monitoring programmes and beach clean-up campaigns, is important as it heightens their sense of coastal stewardship. The potential exists to involve the private sector, especially hoteliers, in monitoring beach changes. These changes have obvious implications for hotel operations.
- Re-vegetating beaches and dunes with native vegetation has been proven effective in preventing their further erosion.
- Under the auspices of the Nairobi Convention, there is the need to develop Regional Guidelines/Code of Conduct for shoreline change, with precise recommendations, practical and realistic principles as well as rules for good practice for local, regional and national authorities and other key stakeholders. The Guidelines/Code of Conduct should contain such information as the status and trends of coastal defense measures applicable to the region and the potential impacts of different measures.

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ANNEX I: RECOMMENDATIONS OF THE REGIONAL COASTAL EROSION WORKSHOP, 27-29 NOVEMBER 2002, NAIROBI, KENYA

Participants to the Regional Coastal Erosion Workshop, 27–29 November 2002, Nairobi, Kenya, recognised the following:

- Shoreline changes is a serious problem in the region with social, economic, cultural and environment impacts.
- Monitoring and assessment of shoreline changes are widely inadequate across the region and is often Inconsistent and irregular
- Different mitigation and restoration measures have been used to address the problems of coastal erosion, but many of them have failed miserably due to the fact they were applied without the support of long-term information on erosion processes and rates, or adequate technical support.
- A number of assessment and monitoring have been conducted in different countries providing some useful information on the status of shoreline change in the region as well as drawing lessons and experiences for dissemination within and outside the region
- Addressing shoreline change is challenging and complicated particularly for countries with limited financial and human resources and weak institutional framework

In this respect, the participants recommended the following actions:

Assessment and Monitoring

- Conduct assessment of extent and magnitude of shoreline change in the region and using the EUROSION model as a basis, prepare a coastal vulnerability atlas in GIS format.

Mitigation

- Document successes and failures of mitigation measures for the purpose of sharing and exchanging information on lessons learnt.

Restoration

- On the short-term conduct environmental audit to identify priority sites that may need restoration and on the long-term strive to implement restoration measures on selected areas as well as monitor the status of restored habitats

Capacity building

- Building and strengthen scientific and technical capacity in the region for conducting assessment and monitoring, mitigation and restoration.
- Enhance regional and international collaboration and promote the exchange of staff. Such programmes have been found to provide appropriate mechanisms for technology transfer necessary for addressing shoreline change in the region.

Awareness and information dissemination

- Create awareness among stakeholders to ensure that key concepts/aspects of shoreline change are understood and the public is widely and constantly informed of where they can get information on shoreline change.
- Set-up a roster of experts, institutions and interested partners within and outside the region dealing with shoreline change. Develop an awareness of existing expertise in the region.
- Set up an email-based discussion group for shoreline change experts.
- Post information on existing websites as a mean to disseminate information on assessment and monitoring; mitigation and restoration and maintenance of contacts among experts involved in coastal erosion.

Updating existing guidelines and developing new ones

- The IOC-UNESCO guideline on assessment and monitoring should be updated to reflect the current realities. It was also recommended that the guideline should continue to be in generic form for a wide application at the regional level. Once the guidelines have been revised, it is important that deliberate efforts are made to promote their use by the public.
- Develop management tools and instruments, such as guidelines, highlighting best practices in application of restoring areas affected by shoreline changes, as a priority

Legal frameworks and analysis

- Strengthen relevant legislation, making it mandatory to conduct environmental impact assessment (EIA) for activities (including beach restoration and mitigation techniques) that have potential to affect shoreline stability.
- Identify gaps in the legal framework regarding standards for restoration and mitigation of affected shorelines.

Collaboration and partnership

- Identify areas for collaboration between Nairobi Convention and partners such as RIKZ-CZMC for the purpose of sharing experiences and lessons learnt. UNEP as the Secretariat of the Nairobi Convention was requested to take the initiative to approach the RIKZ-CZMC for initiating joint activities.
- Establish an effective coordinating/harmonizing mechanism of all the initiatives dealing with shoreline changes. Some of the existing initiatives include African Process, GOOS (GOOS Africa and IOGOOS), IOCINCWIO and WWF-EAME.
- In light of the close linkage between Coastal Erosion and the Physical Alteration and Habitat Destruction activities, the possibility for establishing a working group within the framework of the Nairobi Convention, bringing together the two groups should be explored.

Follow-up activities

- The Meeting agreed on the steps to be followed with regard to the development of case studies proposal:

a) Invitation of additional suggestions on potential case studies
b) Selection of priority case studies
c) Preparation of detailed write-up on each selected case study
d) Presentation of case studies in a Regional Workshop on Physical Alteration and Habitat Destruction
e) Finalization of a regional proposal.