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KENYA

National Marine Ecosystem Diagnostic Analysis (MEDA)

Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project

ASCLME
Agulhas and Somali Current
Large Marine Ecosystems Project

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE
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PREAMBLE

The Kenya National Marine Ecosystem Diagnostic Analysis (MEDA) was prepared by coastal and marine experts in Kenya. The MEDA presents essential data and information relating to the dynamic biophysical and socio-economic processes in Kenya that define the Large Marine Ecosystem (LME). It also identifies areas of concern that will feed into the Transboundary Diagnostic Analyses (TDA) and the Strategic Action Programme (SAP) for the Agulhas and Somali Current LME.

In the process of preparing MEDA for Kenya, an effort was made to collect and analyze the most current data and information on the various coastal and marine ecosystems and resources. This was with a view of presenting the most up to-date information on the trends in the exploitation, development and protection of the coastal and marine environment in Kenya. The report also includes information on key issues of concern and challenges for sustainable coastal development. The key gaps in data and information that need to be given special consideration in future research investigations, are also discussed.

While the information presented in this report was intended to feed into the process for the preparation of the regional TDA and SAP for the Agulhas and Somali Current Large Marine Ecosystems, the findings of the report are also useful in the overall management and conservation of coastal-marine environment in Kenya. As such, the report will aid policy makers, decision–makers, scientists, students as well as community members.

EXECUTIVE SUMMARY

The coastline of Kenya extends for a length of about 600 km and is characterised by distinctive coastal ecosystems such as coral reefs, seagrass beds and mangroves. It includes distinct geomorphic features such as sandy beaches, archipelagos, coral islands, intertidal reef platforms, cliffs, sand dunes, creeks and estuaries. The distinct geomorphic features affect the diversity and productivity of mangroves, sea grass beds and coral reef ecosystems. Kenya's continental shelf is relatively narrow, generally ranging between 5 and 10 km. The water depths off the coast drop below 200m within less than 4km. However, the continental shelf widens significantly in Ungwana Bay where in some places it exceeds 15km. The region enjoys a modified equatorial type climate with double rainfall maxima influenced by the Inter-Tropical Convergence Zone (ITCZ). There are two rainy seasons. The long rainy season occurs in the period between March and May and the short rainy season is experienced in the period between October and November. The mean annual rainfall is 1000-1200 mm while the mean monthly temperature and humidity are 27˚C and 80% respectively. Rainfall patterns have shown distinct changes in the recent past and the frequency of extreme events has increased. The predominant coastal types include the fringing reef shoreline of southern Kenya, the deltaic shoreline of Ungwana Bay and the ancient deltaic shoreline of the Lamu Archipelago. There are two major river systems draining into the coastal region of Kenya. These are the Tana and Athi-Sabaki rivers which drain into the Indian Ocean in the northern region of the Kenya coast. Other small semi-permanent rivers draining into the Indian Ocean include the Ramisi, Umba, Mwache, Mkurumuji, Rare and Kombeni. Increased sediment loads in estuaries and creeks are causing the degradation of mangrove forests, coral reefs and seagrass beds. However, the decreased sediment loads in the Tana Delta is causing an increase in the erosion of the delta, and increased salt-water intrusion, leading to a reduction of downstream habitats.

The Kenya coast experiences semi-diurnal tides with a tidal range of 3m during spring tide and 1m during neap tide. The lowest tides of about 1m occur during the northeast monsoon with 80% of the swells reaching maximum significant height of 6m. The surface currents that impact the Kenya coast are the East Africa Coastal Current (EACC), the seasonally reversing Somali Current (SC) and the Equatorial Counter Current (ECC). The East African Coastal Current (EACC) flows northward throughout the year and the Somali current is a typical seasonally reversing current with the current flowing northward during the south east monsoon at a maximum speed of about $2ms^{-1}$. The mean SST have increased from 27.2˚C to 28.2˚C since 1980. The SST generally varies from 27 to 28˚C during the northeast monsoon. However, during the south east monsoon, the temperatures are generally relatively lower ranging between 24.5 and 25.8ºC. Salinity variations are influenced by the water masses associated with the ocean currents as well river discharge. Low salinity occurs in the bays and creeks where the influence of river runoff is greatest during rainy season.

Bays, creeks and inshore waters receive nutrients via river systems that drain from various catchment areas that extend into the Kenya Highlands. Along north Kenya (towards the Somali border), there is also significant upwelling of the bottom nutrient rich waters. However, low nutrient levels in offshore waters of Kenya explain the generally low fisheries productivity. High productivity occurs in areas that are influenced by river discharges such as Ungwana Bay and Funzi-Shirazi Bay. However, high productivities have been reported at the thermocline depth where a high biomass of phytoplankton is present.

Mangrove forests in Kenya are estimated to cover 54,000ha with nine mangrove species. *Rhizophora mucronata* and *Ceriops tagal* are the dominant species represented in almost all mangrove formations. Rare species include *Heritiera littoralis* and *Xylocarpus moluccensis*. Mangroves have been impacted by human activities particularly through removal of wood products, land clearing and conversion to other uses and pollution. Recent estimates indicate a 20% decline in mangrove area over the last two decades. Another important ecosystem, seagrass beds, cover a surface area of about 3,400ha. There are 12 species and the dominant one is *Thallasondendron ciliatum*. Seagrass beds provides habitats for commercial fisheries as well as serving as important foraging grounds for endangered marine species such as dugongs and turtles. The most important sites are Kiunga, Malindi, Mombasa, and Diani-Challe. Seagrass degradation in Kenya is usually as a result of physical dragging of fishing nets, pollution, herbivory by sea urchins, smothering by high sediment load and low salinity.

Kenya's coral reefs cover a surface area of about 63,000ha, and are made up of at least 220 coral species. Dominant coral species in Kenya include *Porites lutea*, *Galaxea astreata*, and a broad diversity of species in the genera *Acropora*, *Pocillopora*, *Favia*, *Favites*. The best reef development is found in the fringing reefs in the southern part of Kenya coast at Diani-Chale and Kisite-Mpunguti MPA. Reduced reef development in the northern part of the Kenya coast is attributed to the large areas of loose sediment and significant fresh water inputs from Tana and Athi-Sabaki rivers. Fringing reefs are also found off Lamu Archipelago and along many of the barrier islands to the north. Coral reefs' high biodiversity, high productivity and ability to protect the coastline from ocean waves make them highly valuable ecosystems. Coral reefs also support the artisanal fishery dominated by local and migrant fishers.

Marine mammals found in the Kenyan waters include cetaceans and sirenians. The indo-pacific bottlenose and humpback dolphins are the most common dolphin species found in Kenya while the humpback whale is the most common among the whale species. Dugongs (*Dugong dugon*) are found in Malindi Marine Parks, Kipini, Lamu archipelago, Gazi, Msambweni and Kisite marine parks. Dugong populations in Kenya have declined rapidly from a herd of 500 individuals reported at the south coast in 1967 to only 6 in 1996. There are five key bird habitats along the coast, namely the Sabaki estuary Mida Creek, Chale Island, Malindi-Watamu area, Kisite Island, Kiunga Marine National Reserve and the Tana Delta.

The coastal region of Kenya has about 2.5 million people with a population density of 77 per km^2. The coastal population constitutes 8% of the total national population in Kenya. The population increase in the period between 1989 and 1999 was 54%. Most of the population is concentrated in areas which are located along the coastline. Concentration of populations in these centres places significant pressure on the coastal environment and its resources due to over exploitation of natural resources and generation and discharge of waste into the marine environment. Most of the pollution hotspots are located near urban centres. The urban centres have higher population densities, attributed to rural-urban migrations driven by the better economic opportunities and social amenities in urban areas such as Mombasa, Malindi and Kilifi.

The small-scale fishery in Kenya is an important source of livelihoods as it employs 12,000 people and supplies 95% of the country's total marine catch, generating an estimated US$ 3.2 million per year. The marine fish production potential has been estimated by the Fisheries Department to be 150,000 tonnes per year. Of the 736 marine fish species reported for Kenya, 127 species are commercially exploited, 193 are ornamental, 26 are threatened. However, only about 45 species have been studied. The landing from artisanal fisheries ranges from 5,000 - 8,000 tonnes per year which is about 95% of the total marine catch. In the year 2007, the marine artisanal fish production was 7,467 tonnes with an ex-vessel value of Ksh. 610,865,000. The sub-sector also accounts for between 2% and 6% of total fish production in the country. While the entire fisheries sector only contributes 0.5% to national GDP, it is nevertheless a vital component of economic activity in the coastal region of Kenya. Population growth, along with high levels of poverty in the coastal region, has contributed to increases in the number small-scale fishers, with a 34% increase in the period between 2004 and 2008. This has, in turn, placed great strain on fish stocks along the coast, resulting in the over-exploitation of fish resources. Destructive fishing techniques such as trawling, as well as the use of seine nets and spear guns, have led to the decline in fish resources.

The 200 nautical mile EEZ is believed to have vast fishery resources that are under-exploited. The EEZ is mainly exploited by foreign flagged vessels due to lack of appropriate fishing vessels, fishing gears and safety gear to venture into the open waters among the local fishermen. With an estimated potential of between 150,000 to 300,000 metric tonnes per year, the Kenyan EEZ is currently being exploited by Distant Water Fishing Nations (DWFN) whose main target are tuna and tuna-like species. During the year 2007 a total of 33 purse seiners and around 30 long liners operated in the EEZ and transshipped a total of 16,564 metric tonnes of tuna and tuna-like species through the port of Mombasa.

Tourism is an important source of livelihood in the coastal region of Kenya, despite the fact that only between 2% and 5% of tourism receipts actually trickle down to local communities. The major tourism attractions are beautiful sand beaches, the sun, wildlife, historical sites and local culture. The sector has been strong in recent years, with arrivals increasing from 814,000 in 1990 to over 2 million in 2007 and revenue increasing from US$864 million (Kshs 56.2 billion) to US$ 1 billion (Kshs 65.4 billion) between 2006 and 2007, representing an 11.6% growth rate. It is estimated that 60% of the revenues generated by the tourist sector in Kenya are due to coastal tourism.

Kenya has the some of the oldest marine protected areas in the WIO Region. There are 4 marine parks and 5 marine national reserves. The total area of the parks is estimated at 54 km^2, while that of reserves is 898 km^2 representing approximately 8.7% of the Kenyan territorial waters. In addition, there are a number of community protected areas located in Wasini, Kuruwitu, Bureni, Trade-Winds, Kibuyuni and Kiweni. However, conflicts have been observed in these protected areas particularly where local fishing communities harbour negative attitudes towards establishing new government managed MPAs, creating an impediment to government commitment to increase MPA coverage. Local resource users are still concerned about being denied access and control over the resources in marine parks and reserves.

Environmental degradation and over-exploitation of natural resources are challenges that Kenya is facing with regard to the management of coastal and marine environment. In the small-scale fishery, the use of destructive fishing techniques, poverty and rapid population growth all continue to strain resources on the coast. Also, lack of capacity for effective management and enforcement of regulations is constraining sustainable management of the coastal region. There are however strengths and opportunities that can be utilized to promote sustainable management and development in Kenya's coastal region. There are a number of opportunities that have the potential to generate alternative forms of employment, which could potentially reduce the strain being placed on coastal ecosystems. Creating alternative streams of income could reduce pressure on the marine ecosystems and counter the cyclical relationship between poverty and natural resource exploitation. Kenyan government has not only recognized the causal links between poverty and natural resource exploitation, but has formulated policies, strategies and plans for integrated coastal zone and fisheries management. The emphasis is being placed on training, management, alternative employment and the sustainable use of marine resources.

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LIST OF ACRONYMS

ASCLME:	UNDP-GEF Agulhas and Somali Current Project
CBO:	Community Based Organisation
CDA:	Coast Development Authority
CORDIO:	Coastal Oceans Research and Development in the Indian Ocean
DoF:	Department of Fisheries
EEZ:	Economic Exclusive Zone
EIA:	Environmental Impact Assessment
EMCA:	Environmental Management and Coordination Act (1999)
EMP:	Environmental Management Plan
ENSO:	El Niño–Southern Oscillation phenomenon
FAO:	Food and Agriculture Organization
GDP:	Gross Domestic Product
GIS:	Geographic Information System
GMDSS:	Global Maritime Distress Signalling System
GOK:	Government of Kenya
GOOS:	Global Ocean Observing System
HABs:	Harmful Algal Blooms
HEP:	Hydro-Electric Power
IBAs:	Important Bird Areas
ICZM:	Integrated Coastal Zone Management
ISSG:	Invasive Species Specialist Group
IOC-UNESCO:	Inter-Governmental Oceanographic Commission of UNESCO
IOD:	Indian Ocean Dipole
IOTWS:	Indian Ocean Tsunami Warning System
ITCZ:	Inter-Tropical Convergence Zone
IUCN:	The World Conservation Union
JMA:	Japan Meteorological Agency
KDCP:	Kenya Coastal Development Project
KMD:	Kenya Meteorological Department
KMFRI:	Kenya Marine and Fisheries Research Institute
KPA:	Kenya Ports Authority
KWS:	Kenya Wildlife Service
LOTCO:	Lamu Old Town Conservation
MPAs:	Marine Protected Areas
MCS:	Monitoring, Control and Surveillance
MOTCO:	Mombasa Old Town Conservation
NDOC:	National Disaster Operation Centre
NWC:	National Warning Centre
NEMA:	National Environmental Management Authority
NGO:	Non-Governmental Organisation
NOC:	National Oil Corporation of Kenya
NPA:	National Programme of Action
PTWC:	Pacific Tsunami Warning Center
PCU:	Project Coordination Unit (of ASCLME Project)
POPs:	Persistent Organic Pollutants
SADC:	Southern African Development Community
SST:	Sea Surface Temperature
SWIOFP:	World Bank-GEF South-West Indian Ocean Fisheries Project
SWOT:	Analysis of Strengths, Weaknesses, Opportunities and Threats
UNDP:	United Nations Development Programme
UNEP:	United Nations Environment Programme
UNESCO:	United Nations Educational, Scientific and Cultural Organisation
VTMS:	Vessel Tracking Management System
WCS:	World Conservation Society
WIO-LaB:	UNEP-GEF Project Addressing Land-Based Sources and Activities in the WIO
WIO:	Western Indian Ocean
WWF-EAME	World Wildlife Fund- Eastern Africa Marine Ecoregion

1. COUNTRY OVERVIEW

The Republic of Kenya covers a total area of 582,650 km2 with a population of approximately 37.5 million people (GOK 2007). The country's GDP is US$ 31.42 billion, and the GDP Per Capita is US$1,600 (World Bank 2007). The country experienced remarkable economic growth in the period 2003–2007 with the GDP growth rate reaching 7.1% in 2007. Kenya's GDP is heavily supported by the agricultural sector which contributes over 23%, followed by manufacturing industry sector which contributes about 17%. The services sector contributes over 59% (GOK 2009). Figure 1 shows the geographical extent of the country.

The Kenyan coast is endowed with rich natural resources that support the local and national economy. Some of these resources include fisheries, mangrove forests, coral reefs, terrestrial forests, sandy beaches and seagrass beds. Approximately 65% of Kenya's coastal population live in the rural areas and are engaged primarily in fisheries, agriculture and mining for their livelihood. The main economic activities in the coastal region are tourism (45%), maritime activities especially port and shipping (15%), agricultural industry (8%), fisheries (6%), agriculture (5%), forestry (4%), and mining (2%) (UNEP/FAO/PAP/CDA 2000).

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Figure 1: Map of Kenya showing bordering countries

2. BIOPHYSICAL ENVIRONMENT

2.1 The coastal region and its distinctive features

The Kenyan coast has a total length of approximately 600 km. The Exclusive Economic Zone (EEZ) extends to 200nm from the coast (Figure 2). The distinctive features found along the coast include semi-continuous fringing coral reef system, the Lamu archipelago, sandy beaches, bays, estuaries, tidal creeks as well as coral islands. In other places the coral reefs occur as platforms on the intertidal flats and as backshore raised reef limestone, forming cliffs which are 12- 15m high. There are also mangroves, sea grass beds and intertidal reef platforms and coral reefs, which are vital for the diversity and productivity of marine ecosystems (UNEP 1998).

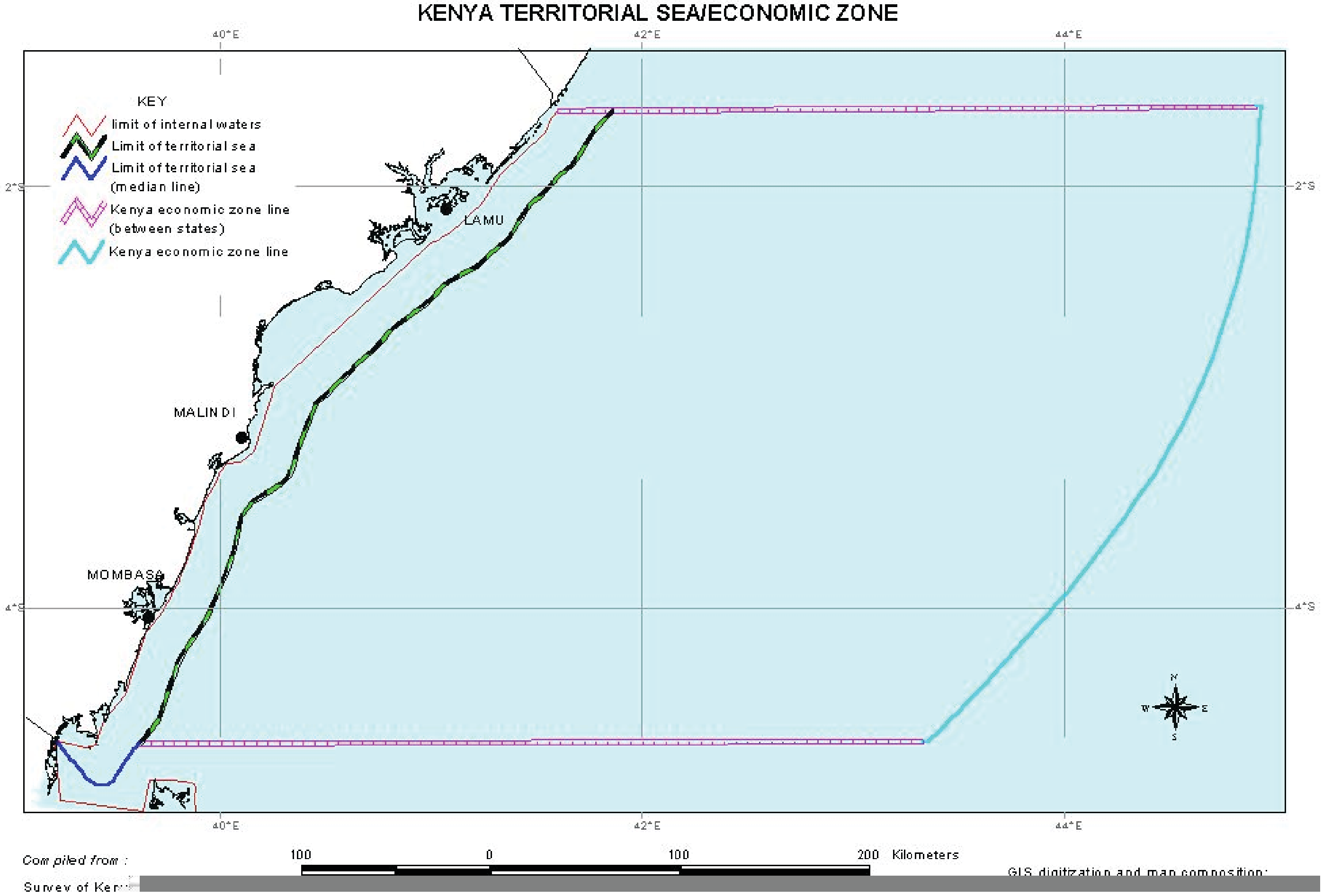


Figure 2: Kenya's territorial waters (source: Survey of Kenya map series SK 74)

On the northern coast of Kenya, sand dune ridges are characteristic. In some places at least two generations of dune ridges are found, the older being of Pleistocene age and the younger located close to the sea being of Holocene age (Abuodha 2003). On the southern coast, steep cliffs formed by wave action on coral limestone rocks and raised shorelines are the most prominent features. However, where rivers discharge, deep creeks are found such as Port-Reitz and Tudor Creeks found in Mombasa. Mangrove swamps are common in muddy areas where freshwater enters the coast (Abuodha 1992). Mangrove areas along the Kenya coast include the Lamu Archpelago, Tana Delta, and Funzi-Shirazi Bay.

Kenya's continental shelf is relatively narrow, with width generally ranging between 5 and 10km. The water depths off the coast drop below 200m within less than 4km. However, the continental shelf widens significantly in Ungwana Bay where in some places it exceeds 15km. The shelf is sedimentary in nature, dominated by fine sands, silt and mud derived from terrigenous sources (Obura 2001). Beyond the shelf the seabed slopes away to depths in excess of 4,000 m (UNEP 1998).

Actions to improve the state of knowledge include (i) conducting an analysis on the vulnerability of the Kenya coast to inundation due to sea level rise and potential tsunami episodes, (ii) transboundary mapping of fish shoals and migratory paths, (iii) preparation of national hydrographic and bathymetry charts to be used for navigation, and (iv) modelling of water circulation to support sewage disposal in the coastal waters.

2.2 Climate

The climate of the Kenyan coast can be categorized into three main variability modes, namely inter-annual, seasonal and intra-seasonal (Ogallo *et al*. 1988). The interannual variability of rainfall results from complex interactions of forced and free atmospheric variations which include interactions between sea surface temperature (SST) forcing, large-scale atmospheric patterns, and synoptic scale weather disturbances (Camberlain and Wairoto 1997).

The coastal region experiences a modified equatorial type climate with a double rainfall maxima controlled by Inter-Tropical Convergence Zone (ITCZ). The short rainy season is experienced in the period between March and May, while the long rainy season is experienced in the period between October and December. Annual rainfall ranges from 1000 to 1200 mm. Annual rainfall varies from south to north and east to west. The south receives more rainfall than the north due to the inclination of the coast and the east receives more than the west. The short rainy season tends to have stronger interannual variability and a substantial association with the El Niño–Southern Oscillation (ENSO) phenomenon (Nicholson and Kim 1997). Mean daily temperature is approximately 27°C while humidity averages about 80% (Okoola 1999).

2.3 Marine and coastal geology and geomorphology

Geology

The Kenyan coast is a passive continental margin fault with NE-SW trends generating the majority of the coastal depositional basins (Figure 3). Thick sedimentary deposits of Permo-Triassic to recent age cover most regions of the coast. The lowest sector of the coastal plain consists of Pleistocene to recent geology, particularly in Malindi and Mombasa-Kwale area. Pleistocene limestone and Holocene to recent beach rock forms the basal geology of the coastline and the intertidal platform (Abuodha 2003).

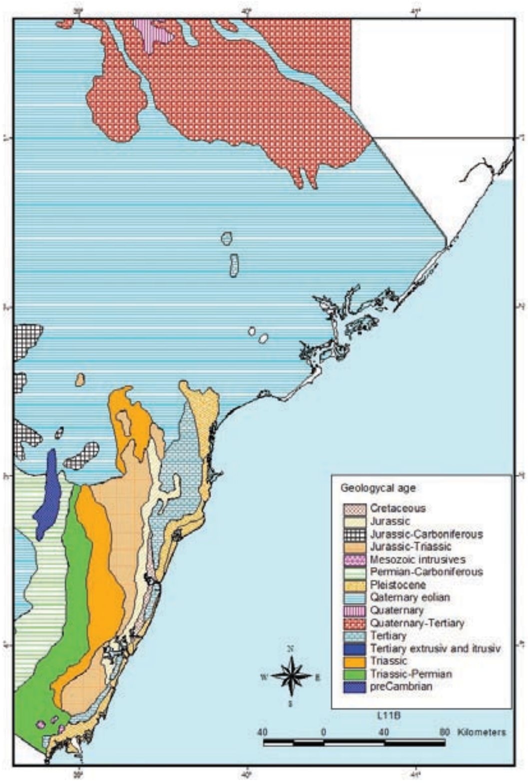


Figure 3: The geology of the coastal region of Kenya (Kenya Soil Survey 2011)

The coast is formed largely of Pleistocene limestone, characterised by undercut cliffs and associated wave cut platforms which are commonly more than 1 km wide in some places. Where they are not masked by the deposits of beach ridge plains, the platforms coincide with the contemporary intertidal zone. The platforms are mid to late Holocene products formed since the post to late Weichselian glacial sea level attained in its current level (Arthurton *et al*. 1999).

Geomorphology

The terrestrial zone of the Kenya coast region is comprised of the following physiographic features which are closely related to the geological characteristics of the area: the Coastal Plain, the Foot Plateau, the Coastal Range and the Nyika. The Coastal Plain bordering the coastline is generally narrow (with the exception of Tana Delta zone) and its elevation is less than 45 m above sea level. In the southern section, the Coastal Plain is 3 - 6 km wide and attains elevations of up to 50 m above sea level. Its landward boundary is marked by the Foot Plateau, whose elevations range from 60 to-140 m above sea level. The coastal zone has been subjected to marine regression since the Jurassic period. During the Pleistocene, sea-level fluctuations associated with glacial and interglacial phases resulted in well developed raised platforms and beaches.

Three different coastal types are recognized along the Kenyan coast. These include the fringing reef shoreline of southern Kenya, the deltaic shoreline of Ungwana Bay and the ancient delta area of the Lamu Archipelago (Kairu 1997). Inland, behind the coral limestone rocks, low-lying clays and shales are found which filled what must have been lagoons in front of the barrier reefs.

Other important geomorphological features include sandy beaches, sand dunes, tidal creeks, mud-flats and rocky shores bordered by cliffs (Abuodha 1992, 2003). The foreshore area between Malindi and Mambrui consists of wide low-gradient extensive beaches, bordered landward by sub-horizontal berms and seaward by runnel and swash bars. These are succeeded inland by an array of complex dune ridge systems of up to 50m in height (Ase 1978). The beach ridges, closely associated with the dunes are of variable Holocene age.

Coral rocks characterize the coastline and sandy beaches are protected from the open ocean by patch and fringing reefs. Except for the interruption of the reefs at the mouths of creeks due to the outflow of fresh water from rivers, the reefs run parallel to the entire shoreline at a distance of 1-2 km (Abuodha 1992). Cliffs formed by wave erosion with raised shorelines are the most prominent feature indicating an emerging shoreline.

2.4 Freshwater resources and drainage

River discharges

There are two major river systems in Kenya that drain into the Indian Ocean. These are the Tana and Athi-Sabaki rivers (Figure 4). The Tana River is Kenya's longest river with a length of 850 km with its source in the Central Kenya Highlands including Mt. Kenya. The river drains a catchment area of about 126,828 km^2 and its discharge has been estimated to be 9 billion m^3. The sediment load has being estimated to be in the order 6.8 million tonnes, although it is varies seasonally. The peak flow occurs in the period April - June during the long rains and in the period November-December during the short rains (Kitheka *et al*. 2003, 2005). Several hydroelectricity power (HEP) generation dams have been constructed on the Tana River. These include Masinga, Kindaruma, Kamburu and Kiambere. These dams have modified the flow of the river as well as its annual sediment load (Kitheka *et al*. 2002, 2003).

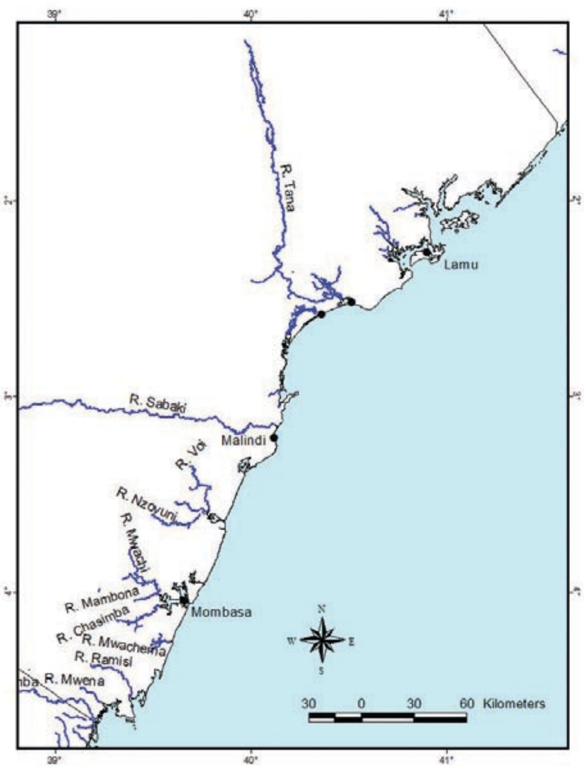


Figure 4: Major rivers draining into the Indian Ocean (KMFRI GIS Database 2011)

The Athi-Sabaki River is the second largest river with a total length of 650 km. The river originates from the Ngong hills and Aberdare mountain range in central Kenya Highlands. The total catchment area of the river is about 70,000 km^2. The river is not dammed and the sediment load is very high, estimated to range between 5 and 13 million tonnes per year (Kitheka *et al*. 2003, 2005).

There are a number of other important semi-perennial rivers found within the coastal region of Kenya. These include Ramisi, Umba, Mkurumuji, Pemba, Mwache and Kombeni (UNEP 1998). The Umba has its source in the Usambara Mountains in Tanzania and discharges into the Funzi Shirazi Bay. The alteration of the natural river flow is common in some of the major rivers draining into the coast. This is mainly due to increased abstraction of water (e.g. for irrigation, urban and rural water supply), damming, and wetland conversion in the catchment areas (Crafter *et al*. 1992). A number of factors, such as changing climate, land-use practices and dam construction, have also led to changes in the sediment load of the rivers draining into the coast.

Coastal Lakes

Lakes found in the Coastal region of Kenya include oxbow lakes such as Lake Bilisa and Lake Shakababo in the Tana Delta. Some oxbow lakes are actually wetlands, e.g. Lake Mahe in Umba flood plain, and Ziwa la Chakamba and Ziwa la Ndovu in Tana flood plain (Kitheka 2002). The other important lakes include Lake Jipe (length 12 km and area 28 km^2) and Lake Chala (length 2.2 km and area 5 km^2) which are found in the lower parts bordering Mt Kilimanjaro. Lake Jipe is threatened by heavy discharge of sediments from rivers draining into it. Due to their location in a region characterised by low population density and limited anthropogenic pressures, the two lakes experiences relatively low levels of pollution (Munga *et al*. 2006).

Deltas and Estuaries

Deltas and estuaries found in the coastal region of Kenya include the Tana delta and Sabaki Estuary in Malindi. The Tana Delta presents true features of a typical delta as it is characterised by several distributaries that discharge turbid water into Ungwana Bay. The distributaries within the Tana Delta such as Kipini and Mto Kilifi are also estuaries in their own right (Kitheka *et al*. 2003). Other well developed estuaries along the Kenya coast include those found at the mouths of Mwache, Kombeni, Ramisi and Umba. The shores of deltas and estuaries are characterized by the presence of mangrove forest ecosystem (Kokwaro 1985).

I) ISSUES

- Climate change and variability is already influencing rainfall patterns and subsequently the flow patterns of rivers, impacting on floodplains, deltas and coastal ecosystems.
- Land and water-use practices in the catchment areas are leading to alteration or modification of river freshwater flow and sediment budget. This is impacting creek, deltas and estuaries leading to the degradation of coastal ecosystems.
- Shoreline changes (erosion and accretion) due to changes in sediment loads from rivers, increased wave climate and coastal development.
- Rapid and unmanaged development along the coast and subsequent loss of critical habitats that provide essential ecosystem goods and services.
- Increasing levels of pollution resulting from the discharge of municipal, domestic and industrial effluents into the inshore waters threatening human health and ecosystem integrity.
- Weak policy, legal and institutional structures for effective management of the coastal and marine environment, and a lack of capacity in institutions and regulatory bodies.
- Gaps in the knowledge base and inadequate awareness of the value of ecosystem goods and services provided by coastal and marine environment.

II) GAPS

- Limited knowledge and information on the hydrological functions of coastal wetlands (both deltas and estuaries).
- Inconsistency in the acquisition of data on the exploitation and management of marine resources.
- Inadequate data and information on the hydrology of coastal rivers including streamflow, groundwater recharge and the total freshwater discharge in estuaries and deltas.

Recommendations

- Ensure effective enforcement of legislation in order to control over-exploitation of marine natural resources and therefore minimize degradation of the coastal - marine environment.
- Develop sustainable approaches for dam construction and operations including the management of freshwater abstraction in rivers and groundwater aquifers.
- Promote inter-institutional cooperation in management, protection and development of coastal and marine natural resources.

2.5 Physical Oceanography

2.5.1 Coastal hydrodynamics and offshore current systems

In shallow inshore zones, water circulation is driven by tidal currents (Figure 5). Tidal currents have been mostly studied in creek and estuarine systems such as Port-Reitz, Tudor, Sabaki Estuary, Tana Delta, Mida Creek, Mtwapa, Kilifi and Gazi (Norconsult 1975, Nguli 1994, Magori 1998, Kitheka *et al*. 2002, 2003, 2005,

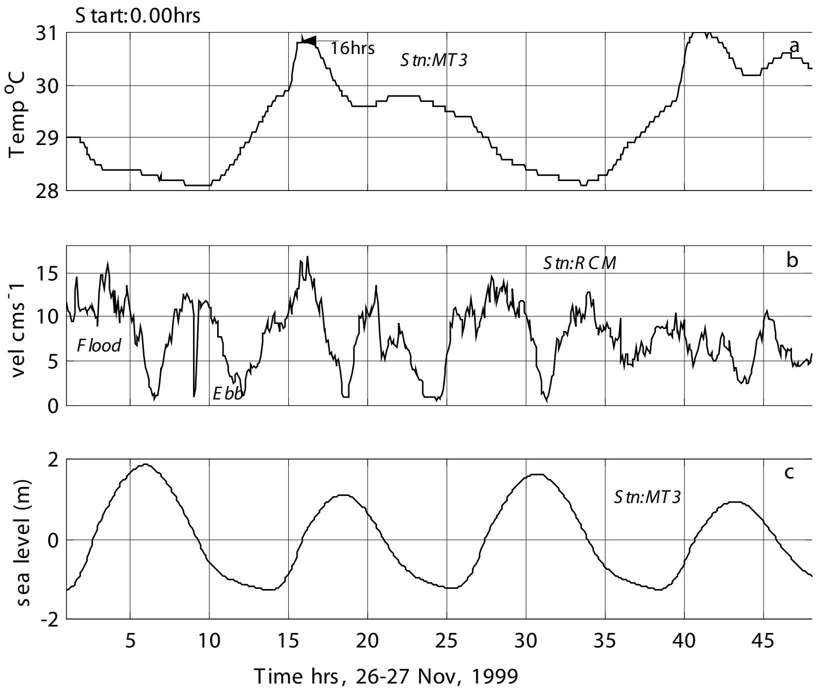


Figure 5: Tide, tidal current and temperature variation in Tudor Creek (Nguli 2006)

Nguli *et al.* 2009). In most of the coastal systems, the mean spring flood and mean ebb currents show significant differences with the ebb tides being more dominant (Odido 1994, Nguli 1994, 2006, Kitheka 2002, Kitheka *et al.* 2002, 2003, Magori 1998). The tidal currents rarely exceeded 1ms^{-1} in the main channels. Flows during the long rainy seasons may in certain instances exceed this value due to freshwater input which reinforces ebb flow.

The offshore current system off the Kenyan coast is part of the alternating cycle of the southeast monsoon and the northeast monsoon (Knox and Anderson 1985, Schott and McCreary 2001). The cycle is caused by alternating high and low pressure systems over central Asia and south of 20°S latitude (Okoola 1999). The predominant monsoon-driven surface currents are the East Africa Coastal Current (EACC), the Somali Current (SC) and the Equatorial Counter Current (ECC). The East African Coastal Current (EACC) flows northward throughout the year. On the other hand, the Somali current is a typical seasonally reversing current with the current flowing northward during the south east monsoon at a maximum speed of about 2ms^{-1} (Swallow *et al.* 1991). During the northeast monsoon the Somali current flows southward at a speed of 1.5-2 ms^{-1}. The reversed Somali Current meets the EACC at latitude 2.25°S (Düing and Schott 1978, Johnson *et al.* 1982) to form the eastward flowing Equatorial Counter Current (Figure 6) which flows as an undercurrent (Leetmaa and Stommel 1980). The width of EACC is 160-200km with its maximum depth at about 400m. It has an annual mean velocity of about 0.8ms^{-1} and its volume flux is of the order 19.8-4.8Sv (Swallow *et al.* 1983, Schott and McCreary 2001).

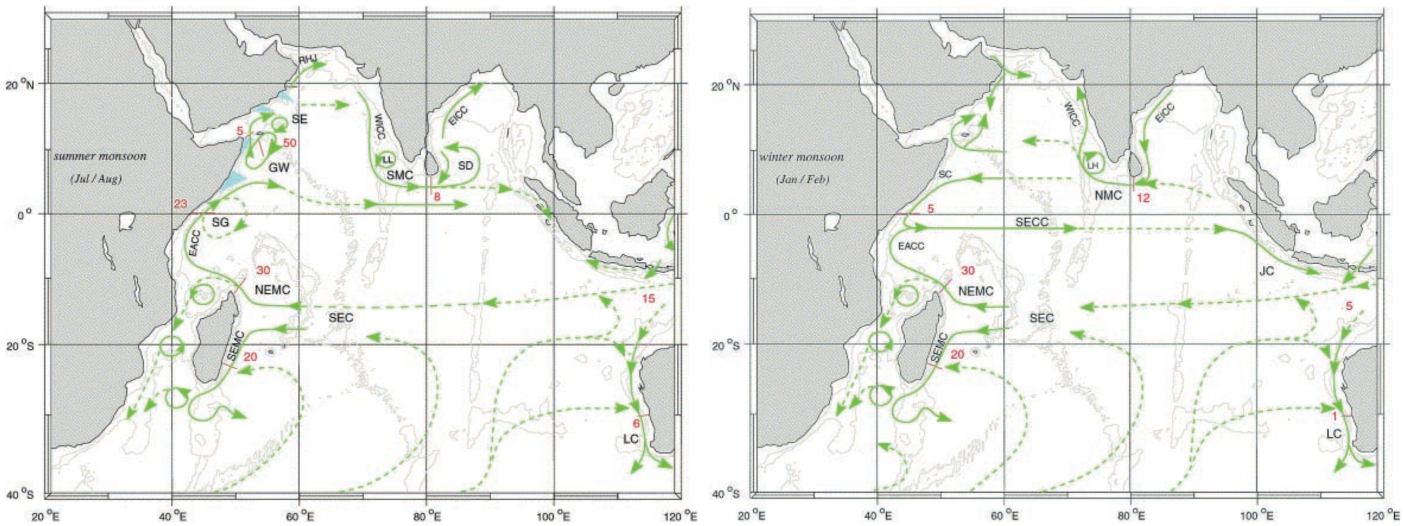


Figure 6: Offshore currents in the WIO Region (Schott and McCreary, 2001)

2.5.2 Tidal regime and waves

The inshore waters of Kenya experience semi-diurnal tides with a spring tidal range of about 3.14m and the neap tidal range of 1.07m. The typical tidal constituents are shown in Table 1.

Table 1: Some tidal constituents for tides in Kenya inshore area (Nguli 2006)

Tidal Constituent	Period	Amplitude		
		Tudor Creek	Kilifi Creek	Kilindini Harbour
M_2	12.42	1.062	1.051	1.055
S_2	12.00	0.519	0.455	0.521
K_1	23.93	0.224	0.163	0.191
O_1	25.84	0.102	0.092	0.113

The coastal offshore waters experience swells of various magnitude in different periods of the year. During the northeast monsoon season 80% of the swells are from the north-east with a maximum significant height of 6m. The sea is usually calm during the inter-monsoon period (March-April) and wave height drops significantly to 2.5m and shifts clockwise to a southerly approach with large fluctuations in direction. During the southeast monsoon (May-October) waves are usually very large with a maximum significant height of 8m. These usually approach the coast predominantly from south-east and southwest direction. In the inter-monsoon period, calm conditions prevail and waves tend to approach the coast from a north-east direction.

2.5.3 Sea level change

Along the Kenya coast, there is no evidence of major acceleration in the rate of sea level rise, which is consistent with observations of Ragoonaden (2006). Maximum sea levels are usually observed in the period April-May and October. The lowest sea levels occur in February and in the period from July to August. These are attributable to inverse barometric effect. The interannual variation in sea level has been attributed to thermal expansion of the ocean due to global warming and steric effects that are attributed to salinity variations.

2.5.4 Ocean temperature

Ocean surface temperature in the Kenyan EEZ shows typical variations that can be attributed to the influence of the coastal current system and the monsoon seasons (Figure 7). The mean SST has increased from 27.2°C to 28.2°C since 1980. The temperature varies from 27 to 28°C during the northeast monsoon (Newell 1959). However, during the south east monsoon, the temperatures are generally relatively lower ranging between 24.5 and 25.8°C (Nguli 2006). The lowest temperatures occur during southeast monsoon months of July and August as a result of the influence of the EACC that brings relatively cool water from the south (Newell 1959, Nguli 2006). While in the open offshore waters, sea surface temperatures are relatively higher, in the shallow inshore areas, the temperatures exceed 30°C in the northeast monsoon season (Norconsult 1975, Nguli 2006).

The thermocline characterized by the largest vertical gradient occurs at a depth of 120m in August and March, and 80m in June and December. The vertical variation is due to the large seasonal variations in current velocities and the seasonal confluence of the EACC and the SC (Lucas *et al*. 1985, Swallow *et al*. 1991).

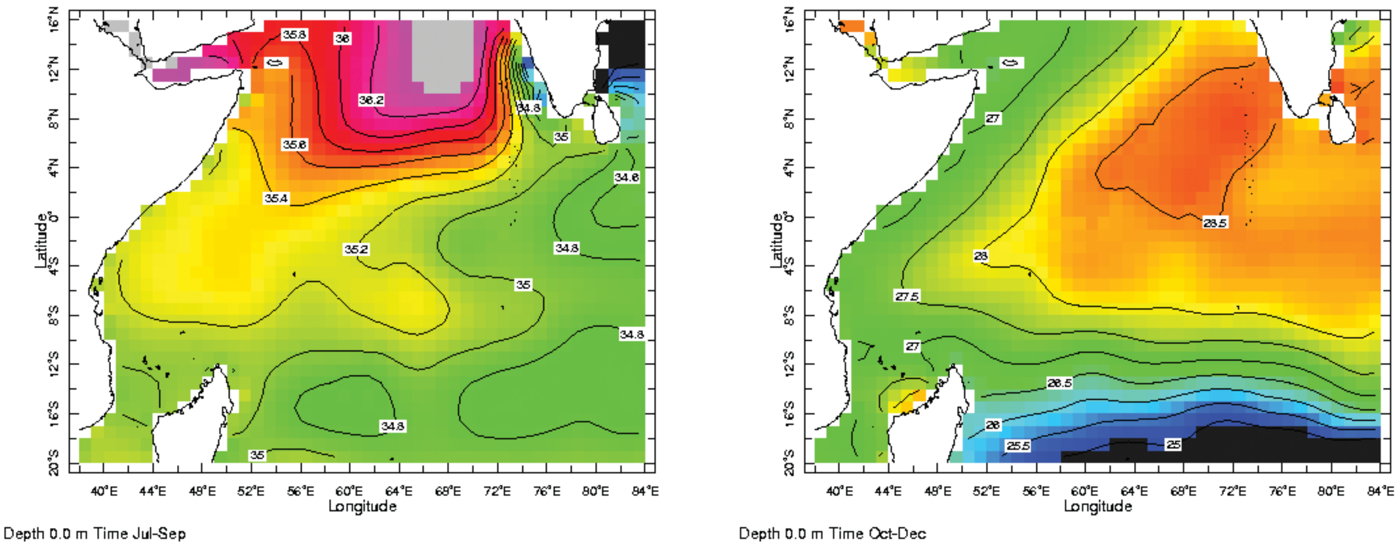


Figure 7: Patterns of SST and SSS in the western Indian Ocean (Nguli 2006)

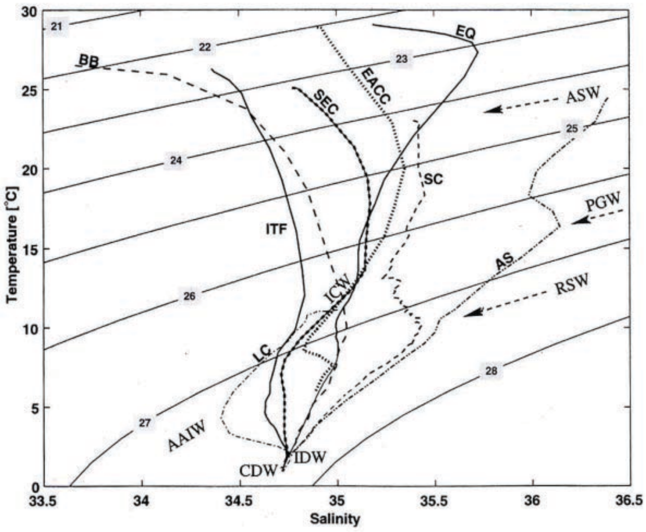


Figure 8: A typical water mass diagram for the WIO waters off the Kenya Coast (Schott and McCreary 2001)

2.5.5 Salinity patterns

Salinity patterns off the Kenyan coast are influenced by the outflow of low-salinity water from the Bay of Bengal (Newell 1959) and by the Indian Ocean Dipole (IOD) (Vinayachandran and Nanjundiah 2009). In addition, salinity in the inshore waters is influenced by the discharge of freshwater from Tana and Athi-Sabaki rivers, including a number of small river systems originating in the coastal ranges. Figure 8 shows the typical water masses in the offshore waters along the Kenya coast, as characterized by the salinity and temperature variations with depth. The high salinity water originates from the Arabian Sea and Red Sea. Low salinity occurs in the bays and creeks where the influence of river runoff is greatest. In estuaries such as Tana and Athi-Sabaki salinities are usually < 34‰. In the inner zones of estuaries, salinities are as usually less than 2‰. However, in tidal creek systems with limited freshwater input, hypersaline conditions (salinity >36‰) occur in the inner shallow areas due to high rates of evaporation (Kitheka 1997).

During the inter-monsoon periods (May-April), the offshore waters are usually characterized by relatively low surface salinity ranging between 34.74 and 35.08 PSU. This is attributed to rainfall as well as flow of relatively low salinity water from the Bay of Bengal and Indonesia (Newell 1959). In deep waters, salinity increases with depth to reach a maximum value of 35.5PSU near the thermocline (80-120m) (Nguli 2006) and then decreases with depth to a steady value of 34.9PSU.

The water masses that characterize the offshore waters of Kenya are the Bay of Bengal (BB), northern Arabian Sea (AS), Equatorial region of western basin (EQ), South Equatorial Current (SEC), East Africa Coastal Current (EACC), Indonesian Through flow (ITF), Leeuwin Current (LC), Somali Current (SC), Circumpolar Deep Water (CDW), Indian Deep Water (IDW), Antarctic Intermediate Water (AAIW), Indian Central Water (ICW), Red Sea Water (RSW), Persian Gulf Water (PGW), and Arabian Sea Water (ASW) (Quadfasel and Schoti 1982, Schott and McCreary 2001) (Figure 8).

2.5.6 Ocean-atmosphere interaction

The Indian Ocean has a unique circulation and transport of heat compared to the Pacific and the Atlantic. This is due to its geographic positioning where the Asian landmass blocks the ocean in the north so that currents cannot carry tropical heat to higher latitude (Sikka and Gadgil 1980, GOOS 2006).

The SW monsoon drives and influences the climate of the Kenyan coast. The expected warming of the Indian Ocean due to rising of global temperature is expected to drastically affect the ocean circulation, the Indian monsoon and thus the ocean-atmosphere fluxes over the region. In the vicinity of Kenya in the Indian Ocean, ocean-atmosphere interactions are dominated by the Somali jet, the Somali current, the Indian Ocean Dipole (IOD) and the upwelling systems (Figure 9) (Vecchi *et al*. 2004, Webster *et al*. 1999, Mafimbo and Reason 2010).

Most climate studies in the Kenya coast have focused on the inter-annual to seasonal variability of the processes that control it. Very little work has focused on intra-seasonal time-scales and mesoscale processes. There is a need to examine the characteristics of the atmospheric convergence and divergence over the upwelling regions and their influence on the climate of the Kenyan coast and to investigate how the Sea Surface Temperature (SST) and surface wind coupling affect the vertical profile of the atmospheric boundary layer cell.

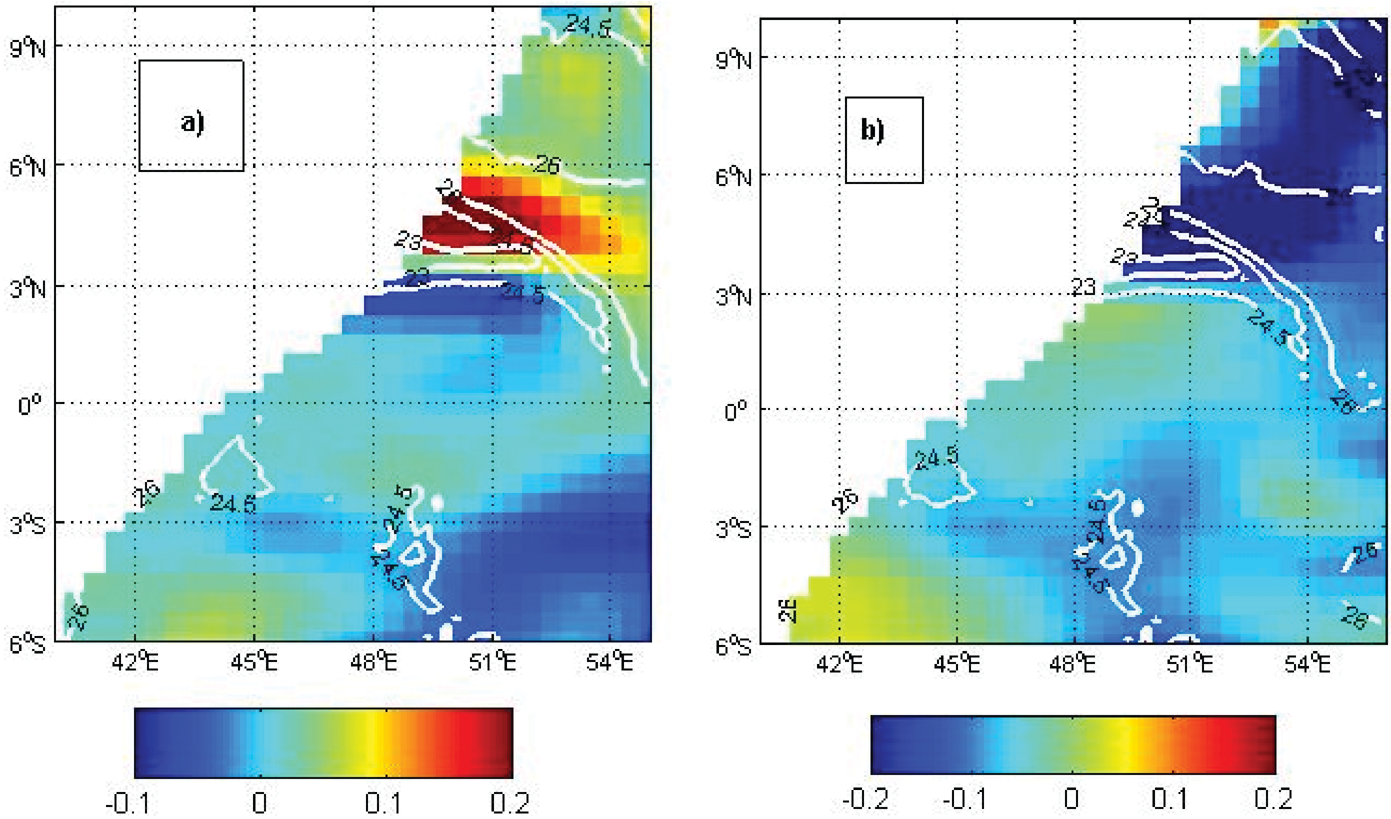


Figure 9: Maps of SST (contour in °C) and a) wind stress divergence ($Nm^{-2}[104km]^{-1}$), b) wind stress curl ($Nm^{-2}[104km]^{-1}$) over the upwelling tongue during the week ending 23 July 2005. The SSTs are in contour interval of 1°C (Adapted from Mafimbo and Reason 2010)

2.6 Chemical and Biological Oceanography

2.6.1 Nutrients

Kenya coast inshore waters receive nutrients via river systems that drain into it from various catchment areas that extend into the Kenya Highlands where agricultural activities are dominant. There is also outwelling of nutrients from mangrove areas. Thus mangrove fringed deltas, estuaries and tidal creeks that receive significant freshwater input such as Tana, Athi-Sabaki, Mwache, Tudor, Funzi and Shirazi are characterised by high nutrients levels as compared to the offshore waters (Bryceson 1982, Giesen and van de Kerkhof 1984, Newell 1959, Norconsult 1975, Mwashote and Jumba 2002, Kitheka *et al.* 2003). Along northern Kenya (towards the Somali border), there is also significant upwelling of the bottom nutrient rich waters of the same magnitude as the upwelling within the Somali Current system in the northern zone of the Somali coast. The low nutrients levels in offshore waters of Kenya explains the generally low productivity of the waters off Kenya coast (Iversen 1984).

2.6.2 Persistent organic pollutants

Assessment of the Kenyan coast for specific POPs has been done (Munga *et al.* 1994). The use of DDT is suspected in the upstream agricultural areas within Tana and Athi-Sabaki river basins (Saoke 2005). Some significant concentrations of pesticide residues in the River Sabaki and Ramisi River have been reported in previous studies (Wandiga *et al.* 2002, Wandiga 2005). Fish samples in the Tana, Athi-Sabaki rivers and estuaries have been found to have residue concentrations of pesticides (Munga 1985, Mugachia *et al.* 1992, Lalah *et al.* 2003). Also, contamination of sediments with POPs in Makupa Creek, Port Reitz and Port Tudor has been reported in previous studies (Williams *et al.* 1996, 1997). However, the persistence of POPs in the Kenyan environment has not been studied extensively. For instance, DDT has not been studied independently of other pesticides. Most published studies have only provided comparative analysis of DDT (as an organochlorine pesticide) with organophosphates and carbamates. Therefore more thorough research work is necessary in this area. There is also a need for the continued monitoring of POPs in the Kenyan coastal waters given that there are still some potential sources of these contaminants through use of pesticide in agricultural areas, and use of

DDT in the disinfection of the Kilindini harbor. The informal sector also contributes a lot in the production of dioxin and furans through the extraction of wires and metals from scrap cables, metals and old tyres.

The challenges experienced in as far POPs are concerned, include (i) inadequate human capacity in POPs research and analytical techniques, (ii) gas chromatograph equipment required for the analytical work is expensive to purchase, maintain and service, (iii) the consumables and reagents required to run samples are quite expensive making analytical work nearly impossible without continuous donor funding, and (iv) limited funding in the field of POPs has made POPs research lag behind in Kenya.

2.6.3 Primary production

Primary production in relation to climate

High productivity occurs in areas that are influenced by river discharges (Figures 10 and 11). These include Ungwana Bay that is influenced by Tana and Ath-Sabaki rivers, and Funzi-Shirazi Bay that is influenced by Ramisi and Umba rivers. High productivity is experienced during periods of high river discharge that are usually during rainy seasons. Kenya's oceanic waters have limited vertical mixing of nutrients due to the stable thermal stratification of the water column experienced in the equatorial region. High productivities have been reported at the thermocline depth where phytoplankton is present in high biomass. This is enhanced by their ability to capture and utilize low light intensity at this depth and utilize nutrients diffusing from the dense cold bottom water. This phenomenon is likely to impact the processes of primary productivity by increasing the net regions with low nutrients levels and further pushing the thermocline to depths with reduced light intensity (Osore *et al*. 2004).

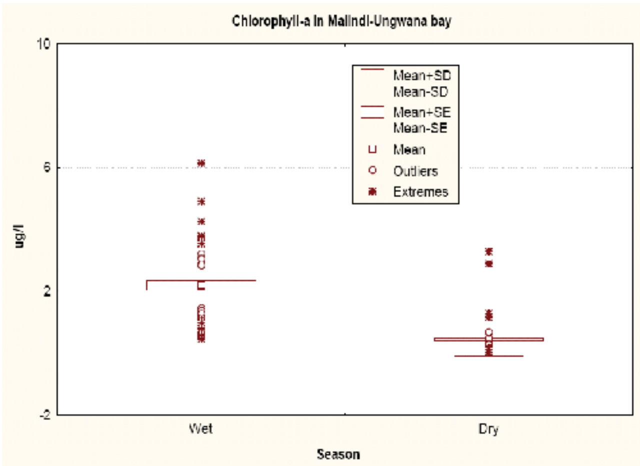
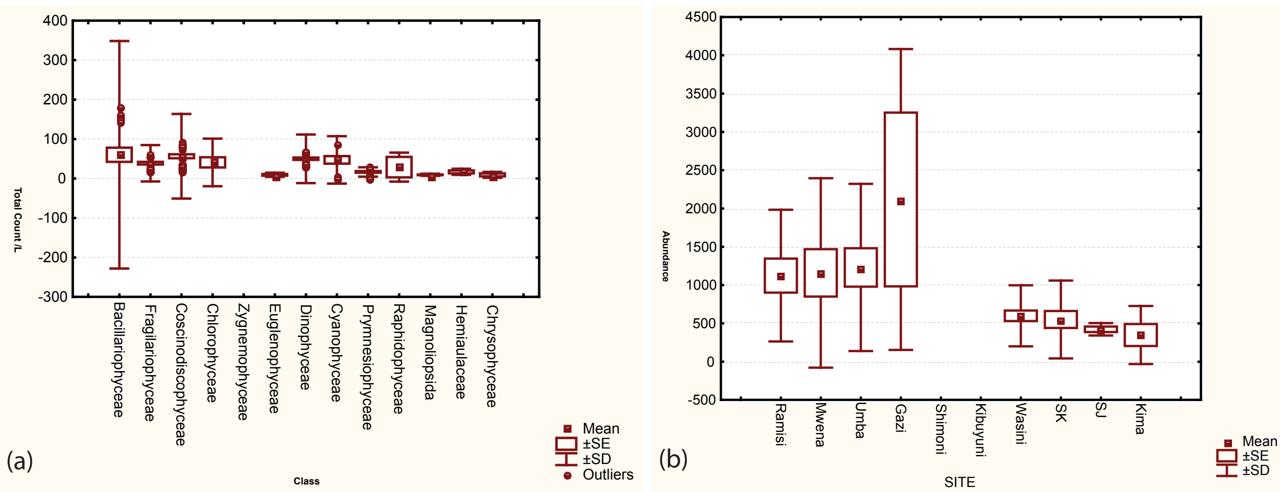


Figure 10: Seasonal variations in Chlorophyll a concentrations in Malindi-Ungwana Bay (Mwaluma 2002)



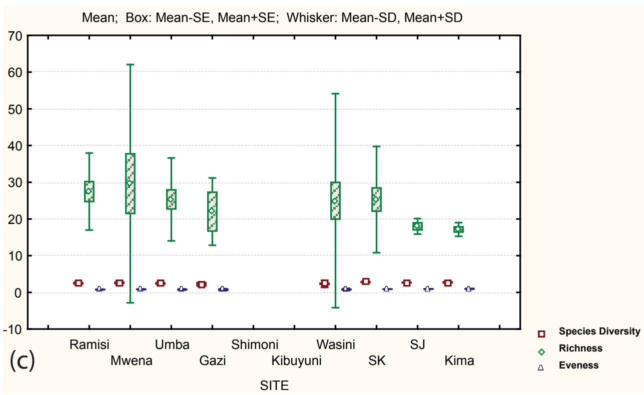


Figure 11: Distribution of (a) marine phytoplankton taxa (b) abundance and (c) species diversity, richness and evenness along the Kenya coast source (Okuku 2008)

Harmful algal blooms

A total of 24 species of potentially harmful microalgae are found along the Kenya coast (Hansen *et al*. 2001). Surveys undertaken off the southern Kenyan coast reported nine species in the 2007-2008 period and seven species in 2008-2009 period (Table 2). The occurrence of these Harmful Algal Blooms (HABs) in 2001 along the Kenya coast was associated with the strong upwelling along the Somali coast and subsequent southward flow due to unusually strong North-East (NE) trade wind. A bloom mostly comprising of *Gymnodinium* sp. was observed in the Kiunga National Marine Reserve in 2004 (IUCN 2004b). The bloom lasted for 10 days causing extensive marine life mortality due to hypoxic conditions that created dead zones.

Table 2: List of potentially harmful algal species encountered in Shimoni-Vanga area (South coast technical report)

Species	Group	Toxins	Diseases caused	Symptoms
Ostreopsis spp.	Dinoflagellates	1. Clupeotoxins 2. Palytoxins	Clupeotoxication	Vomiting and diarrhea
Procentrum micans	Dinoflagellates	1. Okadaic acid 2. Diniphysistoxins	Diarrhetic Shellfish poisoning (DSP)	Abdominal pain, diarrhoea, Nausea and cramps
Anabaena spp.	Cyanophytes	1. Saxitoxins 2. Neosaxitoxins	Paralytic shellfish poisoning (PSP)	Muscular weakness, respiratory distress and muscular paralysis
Pseudo-nitzchia spp.	Diatoms	1. Domoic acid	Amnesic Shellfish poisoning (ASP)	Nausea, vomiting, diarrhoea and neurological effect
Dinophysis spp.	Dinoflagellates	1. Okadaic acid 2. Diniphysistoxins	Diarrhetic Shellfish poisoning (DSP)	Abdominal pain, diarrhoea, nausea and cramps

2.6.4 Secondary production

Zooplankton taxa found along the Kenya coast are shown in Table 3. In addition to these taxa, Actinopoda, Brachyura larvae, Brachyuran megalopa and fish larvae have also been encountered in a number of studies (Osore *et al*. 2003, 2004). Studies carried out in Mida Creek identified at least 27 major taxa of zooplankton that were quite similar to those reported in other mangrove ecosystems in Kenya (Kimaro 1986, Okemwa and Ruwa 1990, Mwaluma 1993, Osore 1994). Copepoda is usually the dominant taxa represented by *Acartia*, *Paracalanus*, *Temora*, *Centropages*, *Labidocera* and *Calanopia* species.

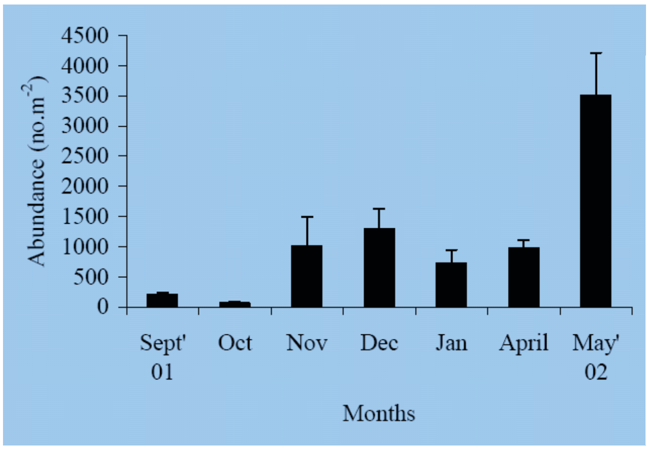


Figure 12: Mean abundances of Zooplankton in Ungwana Bay (Mwaluma 2002)

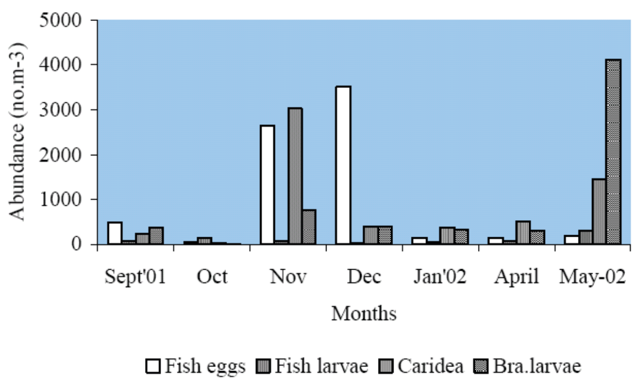


Figure 13: Seasonal abundance on important Zooplankton groups in Ungwana Bay (Mwaluma 2002)

Table 3: Zooplankton taxa along the Kenya coast

Phylum	Class	Genus	Reference
Annelida	Citellata	*Oligochaeta*	Okuku 2008
	Polychaeta	*Polychaeta*	
Arthropoda (Chelicerata)	Arachnida	*Heteropoda* sp., *Microthrombidium* sp.	
	Brachiopoda	*Cladocera* sp.	
	Pycnogonida		
	Diplopoda		Osore *et al*. 2004
Arthropoda (Uniramia)	Insecta	*Ctenophora* sp., *Halobates* sp., *Phyllosoma* sp., Water mite.	Okuku 2008
Arthropoda (Crustacea)	Malacostraca	*Amphipoda* spp., *Caridea* spp., *Cumacea* spp., *Euphasid* spp., *Hyperia* spp., *Isopoda* spp., *Lucifer* spp., *Mysida* spp., Sergestidae spp., Tanaidacea spp., Thalassinidea spp.	
	Maxillopoda	*Acartia* sp., *Calanopia* sp., *Candacia* sp., *Centropagges* sp., *Cirriped* sp., *Copillia* sp., *Coryceaus* sp., *Eucalanus* sp., *Euchaeta* sp., *Harpacticoida* sp., *Labidocera* sp., *Lucicuta* sp., *Macrostella* sp., *Monstrlloid* sp., Nauplii (barnacle), *Neocalanus* sp., *Oithonaa* sp., *Oncaea* sp., *Paracalanus* sp., Parasitic copepod, *Pontellina* sp., *Pontelopsis* sp., *Pseudodiaptomus* sp., *Rhincalanus* sp., *Sapphirina* sp., *Remora* sp., *Tartans* sp., *Undiluna* sp.	
	Ostracoda		
Bryozoa			
Chaetognatha			
Chordata	Thalicea	Thalia dermocratica, Doliolum sp., Doliolid sp., Salpa sp.	
	Ascidiacea	Ascidian sp.	
	Ciliates	Tintinnid sp.	
Cnidaria	Hydrozoa		
Echinodermata	Ophiuroidea	*Ophiopluteus* sp.	
Ectoprocta	Gymnolaemata	Planula larvae	
Mollusca	Bivalvia		
	Cephalopoda		
	Gastropoda	Cavoliniidae sp, *Creseis* sp.	
Nematoda			
Platyhelminthes			
Priapulida	Priapulidae	Priapulida	
Protozoa	Acantharia		
Rotifera			
Sarcomastigophora	Foraminifera	Globigerina sp.	Osore *et al*. 2004
Urochordata	Appendicularia		

Rainfall is the most important factor influencing zooplankton abundance and community structure along the Kenya coast. The peak abundance is observed during the rainy season in the period between November-December and March-May (Mwaluma 2002). The peak zooplankton densities are observed around May (326 animals/m^3) during the long rains, due to high nutrient input (Osore 1992). Fish eggs are also abundant in rainy seasons (Figure 12). Zooplankton abundance during the rainy season is attributed to high nutrient input associated with river runoff. The trends in zooplankton abundance follow that of phytoplankton as shown in

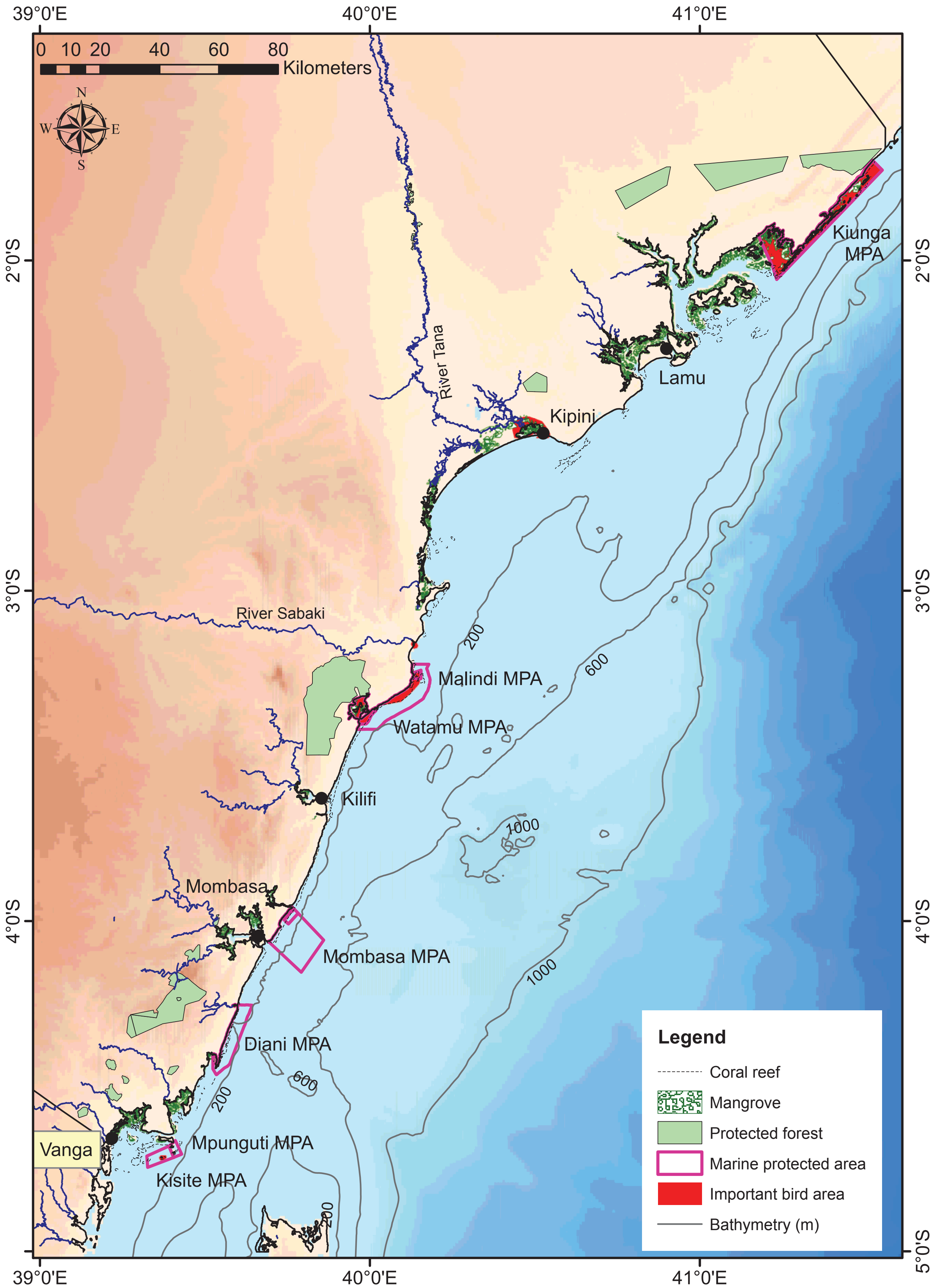


Figure 14: Major coastal and marine ecosystems in Kenya (GOK 2008)

Figure 13. Phytoplankton and zooplankton are normally consumed as food for the early life history stages of Caridea, fish and crabs. Consequently, high abundances of these groups occur during the same period (Osore *et al*. 1997). There are also inter-tidal influences with Copepoda species showing the highest abundance during spring tide while others show the highest peak during neap tide (Okemwa and Ruwa 1990). There are also seasonal variations due to temperature changes (Figure 13).

I) ISSUES

- Kenyan coastal waters are increasingly being impacted by land-based pollutants through wastewater discharge. This creates conditions that are ideal for the occurrence of harmful algal blooms (HABs).
- Currently, the ballast water handling facility at the Kenya Port Authority is not operational. This poses a major risk of the introduction of new plankton communities (including HABs) which could flourish at the expense of the native species.
- With the current expansion of Kilindini Port and the development of a new port at Lamu, there are increased risks of oil pollution with the consequent impacts on productivity of the systems.
- Increase in development activities in the river basins have intensified habitat destruction and soil erosion resulting in high sediment load into the coastal water. This has the effect of reducing the depth of the photic zone thus limiting productivity of the marine ecosystems.
- The impacts of global warming are already being felt globally. Kenya lies along the equator and more stable water stratification is expected due to global warming. This could result in reduced advection of nutrients from the deeper water to the upper photic zone. Ocean acidification will also have adverse effects on plankton communities more particularly calcifying Coccolithophorids, planktonic Foraminifera and Pteropod species.

II) GAPS

- The offshore waters of Kenya are least studied, and there is an urgent need for further oceanographic research to unravel key features of productivity (Hood *et al*. 2009). Past monitoring studies have relied on chlorophyll-a concentration as a proxy for estimating primary production. Due to limitations of sampling techniques, most monitoring studies have been excluding picoplankton (<2μm), leading to underestimation of the overall phytoplankton biomass. There is a need to employ techniques such as satellite imagery, pigment fingerprinting, stable isotope analyses and molecular tools in addition to field experiments to enable complete understanding of the productivity of Kenya oceanic waters and trophic relations.

2.7 Coastal zone and continental shelf

2.7.1 Description and extent of coastal and marine habitats

The coastal ecosystems in Kenya can be said to comprise the western extremity of the tropical Indo-Pacific bio-geographic region, and have most recently been classified as part of the Coral Coast of the East African Marine Ecoregion (Samoilys 1988). The region is characterized by diverse coastal and marine ecosystems including coral reefs, seagrass beds, mangroves, sandy beaches, sand dunes and terrestrial coastal forests (Figure 14). Table 4 presents the key ecosystems found in Kenya and their extent.

Table 4: Critical coastal and marine habitats in Kenya (GOK 2008)

Ecosystem	Area (ha)	Number of species	Important locations
Mangroves	54,000	9	Lamu, Tina Delta, Gazi, Tudor, Port-Reitz, Kilifi, Mida, Funzi-Shirazi
Coral reefs	63,000	237	Diani-Chale, Kisite-Mpunguti
Seagrass beds	3,400	12	Diani-Chale, Kiunga, Malindi, Mombasa
Coastal forests	139,000	-	Arabuko Sokoke, Diani, Shimba Hills

2.7.2 Productivity of coastal and marine habitats

Mangrove forests

In Kenya, mangrove forests are estimated to cover about 54,000ha (Doute *et al*. 1981). About 70% of these forests occur in the Lamu County. Smaller mangrove areas occur in the mouths of semi-perennial and seasonal coastal rivers in Vanga, Funzi, and Gazi Bay, as well as in creeks such as Tudor, Port-Reitz, Kilifi and Mida (Table 4). Nine mangrove species are found, with *Rhizophora mucronata* and *Ceriops tagal* being the dominant species represented in almost all mangrove formations. The rare species include *Heritiera littoralis* and *Xylocarpus moluccensis* (Macnae 1968, Kokwaro 1985). Mangroves in Kenya have been heavily impacted by human activities particularly through the removal of wood products, land conversion pressure, and pollution (Abuodha and Kairo 2001). Recent estimates indicate a 20% decline in mangrove area over the last two decades (FAO 2005).

Seagrass beds

In Kenya seagrass beds cover a surface area of about 3,400ha, with the most important sites being Kiunga, Malindi, Mombasa, and Diani-Chale Island (Table 4). There are 12 species of seagrasses in Kenya, the dominant one being *Thallasondendron ciliatum* which forms monospecific stands (UNEP 1998). Seagrass beds provide habitats for commercial fisheries as well as serving as important foraging grounds for endangered marine species such as dugongs and turtles. Seagrass degradation in Kenya is usually as a result of physical dragging of fishing nets (Ochieng and Erftemeijer 2002), pollution, herbivory by urchins (Eklo *et al*. 2008) or by discharge of sediment laden low salinity water derived from rivers (Short and Neckles 1999, Kazungu *et al*. 2001, Bandeira and Gell 2003).

Coral reefs

Kenya's coral reefs cover a surface area of about 63,000ha, and contain 220 coral species. Dominant coral species in Kenya include *Porites lutea*, *Galaxea astreata*, and a broad diversity of species in the genera *Acropora*, *Pocillopora*, *Favia* and *Favites* (Hamilton and Brakel 1984). The best reef development is found in the fringing reefs in the southern part of Kenya at Diani-Chale and Kisite-Mpunguti MPA (Table 4). Reduced reef development in the northern part of the Kenya coast is attributed to the large areas of loose sediment and significant fresh water inputs from Tana and Athi-Sabaki rivers (Spalding *et al*. 1997). Fringing reefs are also found off Lamu Archipelago and along many of the barrier islands to the north. Coral reefs provide a habitat for many of the sensitive marine species, such as turtles, dugong, and whale sharks. Coral reefs' high biodiversity, high productivity and ability to protect the coastline from ocean waves make them highly valuable ecosystems (Carreiro-Silva and McClanaham 2001). Coral reefs support the artisanal fishery dominated by local and migrant fishers. Currently it is estimated that over 10,000 fishermen are directly engaged in artisanal fishing in the Kenyan coast (Ochiewo 2004). The landing from artisanal fisheries ranges from 5,000 - 8,000 tonnes per year which is about 95% of the total marine catch.

Analysis of human impacts on coastal and marine ecosystems

The WIO-LaB Transboundary Diagnostic Analysis (TDA) focussed on land–based activities and sources established that land use change has had significant impacts on the coastal and marine environment (UNEP/ Nairobi Convention 2010). Poor land use practices in the Athi-Sabaki River Basin for instance, has resulted in the increased discharge of huge volume of sediments in Malindi Bay with far reaching ecological and socio-economic consequences. Massive sedimentation interferes with growth of mangroves and also smothers coral reefs and sea-grass beds (GOK 2008).

The degradation of coastal forests (through clearing of buffer vegetation in environmentally sensitive areas close to shorelines) impacts on the marine environment, resulting in increased erosion and sedimentation. The problem of shoreline change is most prevalent in Malindi-Ungwana bay (Kairu and Nyandwi 2000).

The expansion of economic activities such as the dredging of the Lamu channel to provide additional port and harbour facilities has interfered with the hydrodynamic regimes in the creek leading to the death of mangroves in some areas. Conversion of mangrove areas for solar salt works, urban development, agriculture and aquaculture has also contributed to mangrove degradation in Kenya. For example, more than 5000ha of mangroves at Ungwana bay have been cleared to pave way for solar salt works and aquaculture (Abuodha and Kairo 2001).

Some estuaries have also been impacted due to poor agricultural practices, deforestation and increased soil erosion within the river basins. Consequently the Tana and Sabaki estuaries are characterised by highly turbid water that limits primary productivity. Increased sediment loads have also resulted in accretion of beaches in Malindi and Ungwana bays (GOK 2008).

2.8 Microfauna and meiofauna

Status

Various studies have been carried out on the seasonal variation of marine bacteria, algal population and species composition, occurrence of Trichodesmodium, the diversity of cyanobacteria and other epiphytes associated seagrasses (Kromkamp *et al*. 1997, Uku *et al*. 2007). Studies on Zooxanthellae, the coral bleaching of 1998 and coral mortality have also been carried out in recent years (McClanahan *et al*. 2004). Other studies include those on the extraction of secondary metabolites of pharmaceutical importance from cyanobacteria and 16S rDNA classification of epiphytic bacteria associated with the cyanobateria (Dzeha 2004).

The studies on meiofauna in Kenya have mainly dwelt on community structure, ecology and taxonomy (Ansari 1984, Verschelde and Vincx 1993, Okondo 1995, Muthumbi and Vincx 1998, Bezerra *et al*. 2007, De Troch *et al*. 2001). Studies on the interaction between epifauna and meiofauna in mangrove sediments have also been undertaken in Kenya (Schrijvers *et al*. 1995, 1997).

Dead Zones

Along the Kenya coastal waters, occurrence of dead zones due to eutrophication is limited due to high tidal water exchange rates and wave action that mixes the water columns effectively and prevents build up of nutrients in sheltered inshore waters. In this regard, typical dead zones that are attributable to eutrophication are rare. There is no credible scientific proof of the occurrence of eutrophication along the Kenya Coast. However, there have been two significant episodes where there has been massive mortality of marine organisms such as corals or fishes, but these cannot be wholly be attributed to the occurrence of dead zones and eutrophication. One such event first occurred in 1997-1998 during the El Nino event when extensive bleaching of the corals occurred due to an increase in sea water temperatures above threshold levels lead to the expulsion of the zooxanthellae from corals. The second case was in February 2002 when massive fish kills occurred along the Kenyan coast due to the occurrence of harmful algal blooms (with *Gymnodinium*) associated with upwelling along the Somali coast (IUCN 2004b). In Makupa Creek, oil spills that occurred in 1988 caused massive death of mangroves in the creek. For a number of years, the Makupa creek was characterized by low infauna diversity and minimal mangrove regeneration. However, the mangroves have recently recovered although the sediment remains contaminated.

I) ISSUES AND GAPS

- Limited studies in the fields of meiofauna and microfauna especially in terms of areas and systems covered along the coastline.
- Lack of baseline data for monitoring purpose and studies on the use of meiofauna and seagrass in the monitoring of ecosystem recovery.
- Some important resources, particularly bioactive compounds have not been studied well or exploited.
- Lack of studies on viruses, fungi and bacteria that cause coral mortality which in turn affects the zooxanthellae.
- Limited regional collaboration in assessment of transboundary issues associated with harmful algal blooms, pollution and diseases.

Recommendations

- Carry out a comprehensive inventory of the meiofauna of the Kenya coast.
- Assess marine resources of commercial and biological importance.

- Cary out multidisciplinary and regional research studies to address common transboundary issues.
- Put in place wastewater treatment systems in urban areas along the coast.
- Promote natural ecological systems such as mangrove wetlands for sewage filtration and treatment.
- Build capacity and provide facilities and other resources for research.

2.9 Macrofauna

2.9.1 Invertebrates

Several studies have been carried out on the marine invertebrates in Kenya (Stephenson and Rees 1968, Marsden 1975, Reay and Haig 1990, Gherardi and Vannini 1993, Cannicci *et al*. 1998, Gillikin *et al*. 2004, Hartnoll *et al*. 2004, Losse 1997, Fulanda and Motong'wa 2001, Kulmiye 2002, Okechi and Polovina 1995, Mwaluma 2002, 2003, Oduor-Odote *et al*. 2005, Hartnol *et al* . 2004). Along the Kenya coast, invertebrates have been exploited for various purposes. The groups targeted for exploitation include the following:

- Crustaceans: Penaeid prawn species *Penaeus indicus*, *Metapenaeus monoceros*, *Penaeus semisulcatus*, *Penaeus monodon*, and *Penaeus japonicus*.
- Spiny lobsters: *Panulirus ornatus*, *Panulirus longipes*, *Panulirus versicolor*, *Panulirus homarus, Panulirus dasypus*, *Panulirus penicillatus*.
- The deep water prawns *Heterocarpus woodmasoni*, lobsters *Puerulus angulatus, Thenus orientalis* and *Metanephrops andamanicus*.
- Portunid crab species in mangroves (*Scylla serrata*) and the swimming portunid crabs (*Charybdi*s spp.). Others include *Parasesarma catenata* (Brachyura: Sesarmidae), *Epixanthus dentatus* (Decapoda: Oziidae), *Thalamita crenata* (Latreille) and Hermit crabs e.g. *Clibanarius laevimanus*.
- Sea urchins including: *Stomopneustes varioliaris* (Lamark), *Echinometra mathaei*, *Echinothrix diadema* (Linnaeus), *Diadema setosum* (Leske), *D. savignyi* Michelin and the sea cucumber *Holothuria arenacava*. (cf. Brodie *et al*. 2005)
- Oyster *Crassostrea cucullata* and oyster pearl *Pinctata imbricata*, barnacle *Balanus amphitrite* and gastropod *Cerithidea decollata*.
- Octopus (*Octopus* spp.), squids and cuttlefish.
- Snails *Nerita plicata*, *N. undata* and *N. textilis* (Prosobranchia: Neritacea) and *Drupella cornus*.
- Echinoderms: *Actinopyga mauritiana*, *Actinopyga miliaris*, *Actinopyga echinites*, *Actinopyga lecanora, Bohadschia marmorata*, *Bohadschia argus*, *Bohadschia vitiensis*, *Holothuria scabra*, *Holothuria nobilis*, *Holothuria atra*, *Holothuria fuscogilva*, *Holothuria edulis*, *Holothuria leucospilota*, *Holothuria fuscopunctata*, *Thelenota ananas*, *Thelenota anax*, *Stichopus variegates*, *Stichopus chloronotus.*

I) ISSUES

- Overexploitation of some groups of invertebrates such as sea cucumber.
- Limited research capacity (human, financial, facilities).
- Destruction of habitats affecting invertebrate populations.
- Destructive fishing practices (e.g. trawling, dynamite fishing).
- Pollution of the coastal waters.
- Heavy sedimentation associated with river discharges.
- Global warming and climate change.

II) GAPS

- Limited studies on the biogeography, ecology and systematics of Cnidarians, Echinoderms, Mollusks and Crustacea in the critical habitats such as seagrass beds, coral reefs, estuaries, mangroves, lagoons and rocky shores.
- Limited knowledge on the effect of abiotic factors such as temperature, salinity, tides, currents, seasons and water depth on the larval development, speciation and reproduction of Cnidaria, Echinoderms and coelenterates.
- Limited knowledge on the predator-prey interactions among all the invertebrates.
- Limited knowledge on toxicity biomarker responses in all the invertebrates, other than the echinoderms.
- Limited knowledge on the impacts of anthropogenic influences, natural threats such as El Niño and ocean dynamics on marine invertebrate biodiversity in all the critical habitats.

- Lack of studies on the genetics of invertebrates.
- Limited understanding of the relationships between brackish waters and fresh waters for invertebrates.
- Lack of studies on the bio-erosion of coral reefs and its effect on invertebrates.
- Limited knowledge on the effects of various natural and anthropogenic factors on invertebrate biodiversity including over fishing, destruction of habitats, fishing methods, pollution, El Nino, global warming and climate change.

Recommendations

- Priority study sites be linked to WWF-EAME conservation areas.
- Provide funding and research facilities for invertebrate studies.
- Carry out training for marine invertebrate taxonomists.
- Promote overseas taxonomist exchange programmes.
- Create awareness on the impacts of global warming on marine invertebrates.
- Create awareness among politicians and managers on the value of marine biodiversity.

2.9.2 Fish and fish resources

Various research studies related to marine fisheries have been conducted along the Kenya coast, mostly in inshore waters (McClanahan and Arthur 2001, Arthur and McClanahan 1995a, 1995b, McClanahan *et al.* 2005b, 2008, Kiszka *et al.* 2008, Obura *et al.* 2002, Kaunda-Arara *et al.* 2000, Fulanda 2003, McClanahan and Mangi 2001, DeSouza 1981, Kulmiye 2002, Ntiba and Jaccarini 1988, Nyunja *et al.* 2002, Kaunda-Arara and Rose 2004, Ndegwa *et al.* 2008, Kaunda-Arara *et al.* 2003). Fish surveys along the coast have been carried out by MENIKA II and MANIHINE expeditions in 1964 and 1965, respectively. Other surveys include those of Prof. Mesyasterv carried out in the period 1975-1976, RV Ujuzi 1979-1981 and Nansen 1980-83 (Oduor 1984).

Marine fisheries in Kenya mainly involve small-scale artisanal fishermen currently estimated to be 12,077 (GOK 2004, 2008). There are 141 fish landing sites and 2,687 fishing crafts operating in the small-scale fishery. The annual marine fishery production is about 7,000 tonnes (GOK 2008). Fish landing shows significant inter-annual variabilities (Figure 15). The biomass estimate in 1980 was 18,000- 32,000 tonnes while the offshore potential yield has been estimated to be 10,000 tonnes (Iversen 1984). The marine fish production potential has been estimated by the Fisheries Department to be 150,000 tonnes per year (GOK 2004). Of the 736 marine fish species reported for Kenya, 127 species are commercially exploited, 193 are ornamental, 26 are threatened and only about 15 species have been studied.

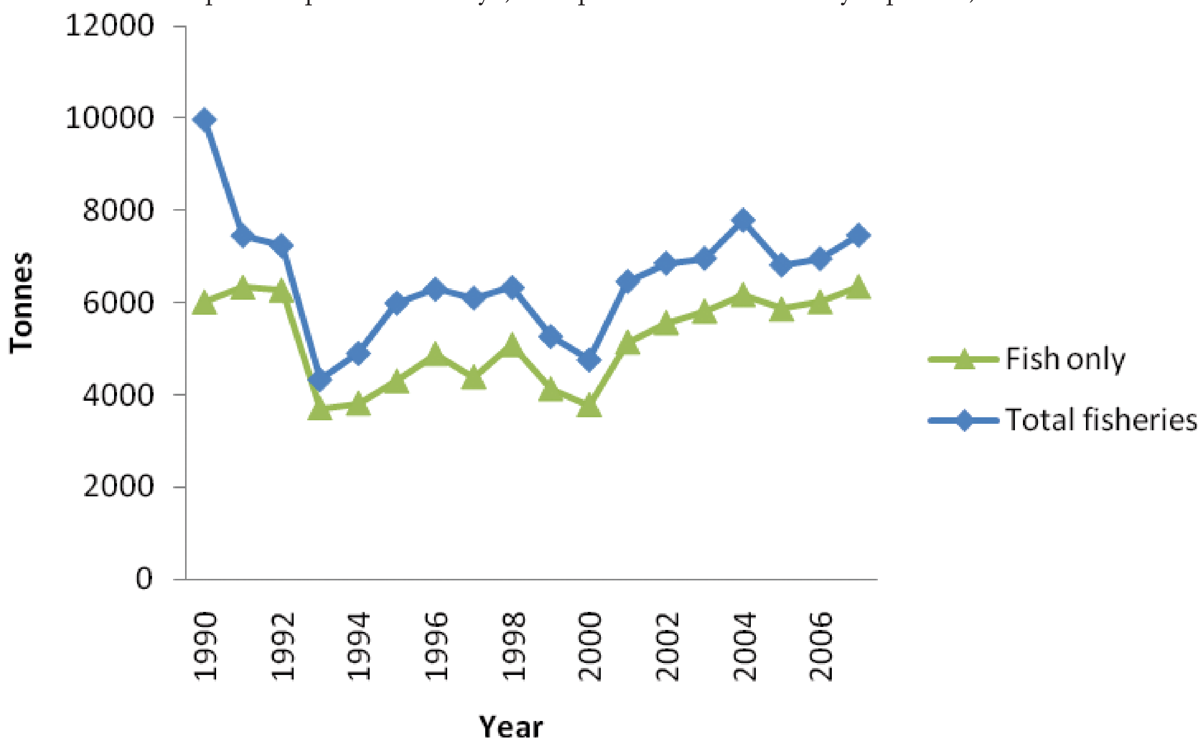


Figure 15: Annual Marine Fishery Production from 1990-2007 (GOK 2008)

I) ISSUES

- Decline in harvests of marine and coastal living resources
- Degradation of coastal habitats leading to loss of biodiversity and reduced productivity.
- Overall water quality decline leading to reduced productivity.
- Contamination of coastal waters, beaches and living resources.

Other issues/concerns include:

- Concentration of fishers in small areas leading to over-harvesting particular resources
- Use of illegal fishing practices such as beach seine and spear guns.
- Prawn trawling leading to destruction of habitat.
- High by-catch levels and decline in abundance of by-catch species.
- Over- fishing by foreign fleets and artisanal fishers.
- Lack of information (biological, stocks migration etc.) on pelagic and demersal species.
- Lack of species specific management strategies
- Use of poorly researched modern fishing techniques (e.g. ring nets).
- Insecurity and piracy along the Somali coast extending to the Kenya coast.
- Migratory fishermen from neighbouring countries, particularly Tanzania.

II) GAPS

- Limited data and information on the pelagic fisheries for assessments of status or fisheries.
- Limited data and information on medium pelagic fishes (i.e. fishing effort and targeted or bycatches).
- Limited studies on the biology, migration patterns, population, genetic structure, age, etc of small tuna and tuna-like species.
- Limited knowledge on the impact of fishing on large pelagic fishes.
- Limited data and information on the biology, genetics, migrations, feeding biology and vertical movements of pelagic fishes.
- Limited data and information on the threatened and vulnerable groups (e.g. sharks).
- Lack of surveys using instrumented long-lines to determine the habitat and behavior of medium to large pelagic fishes.
- Limited data and information on the environmental preferences for pelagic species.
- Limited capacity for the development of anchored Fish Aggregation Devices (FAD) fisheries for medium to large pelagic fishes (Crabbee and McClanaham 2006).
- Limited data and information on age and growth, life history and species biology of commercially important species.
- Limited data and information on catch trends, Catch per Unit Effort (CPUE) especially for the common demersal species.
- Lack of stock assessment.
- Limited data and information on the genetic stock structure.
- Limited data and information on the ecosystem trophic dynamics.
- Limited data and information on the transboundary marine fish resources.
- Limited data and information on the impacts of destructive fishing gears e.g. spear gun, beach seine.
- Limited data and information on gear selectivity, ecological and socio-economic impacts of the ring net fishery.

Recommendations

- Assess the state of stocks and advice on sustainable yields and recommended total allowable catches.
- Carry out joint surveys, Tuna Tagging Programme and other relevant projects of the Indian Ocean Tuna Commission (IOTC), rather than develop stand-alone activities.
- Link information on pelagic fisheries to environmental information.
- Carry out studies on transboundary movement of species shared between countries.
- Carry out genetic studies on stock differentiation.
- Establish national and regional management plans for key fisheries (including transboundary stocks).
- Promote fishing strategies that reduce by-catch.
- Increase efforts in the conservation of threatened species.

- Set up well-equipped laboratories with necessary facilities for analysis e.g. genetic analysis.
- Adopt an ecosystem approach to fisheries management.
- Involve communities in fisheries management.

2.9.3 Mammals

Marine mammals in Kenya include cetaceans (whales and dolphins) and sirenians (dugongs). In an aerial survey, sperm whale (*Kogia* spp), humpback whale (*Megaptera novaeangliae*), Bryde's whale (*Balaenoptera edeni*), Minke whale (*B. acutorostrata*), Killer whale (*Orcinus orca*) and melon-headed whale were sighted (Wamukoya *et al.* 1995). In addition, 447 dolphins were counted. Dolphin species included the bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus* sp), humpback dolphin (*Sousa chinensis*), spinner dolphin and spotted dolphin (*Stenella attenuate*). Additionally Fraser's dolphin (*Grampus griseus*), Risso's dolphin (*Lagenodelphis hosei*) and the striped dolphin (*Stenella coeruleoalba*) are also found. The indo-pacific bottlenose and humpback dolphins is the most common dolphin species in Kenya while the humpback whale is the most common among the whale species (Kiszka *et al*. 2008). Information on their status is however limited.

Dugongs (*Dugong dugon*) have been sighted or found stranded in a number of areas including Mombasa and Malindi marine parks, Kipini and the Lamu archipelago in the north coast. In the south coast, sightings have been reported in Gazi, Msambweni and Kisite marine parks (Marsh *et al*. 2002). Dugong populations in Kenya have declined rapidly from a herd of 500 individuals reported at the south coast in 1967 to 8 in 1975 (Ligon 1976), 10 in 1994 and only 6 in 1996 (Wamukoya *et al*. 1996, 1997, WWF EAME 2004). Dugongs are still present in low numbers confirmed by an incidental capture of a dugong calf by fishermen in Kiunga in 2009.

I) ISSUES

- The main threats to marine mammals include accidental capture in artisanal gillnets, trawlers and other set nets, industrial pollution, degradation of habitats, among others (Kiszka *et al*. 2008). Tourism activities and boat traffic also threaten marine mammals through noise pollution and boat strikes. Marine mammals can undertake long-distance migrations of up to several hundred kilometres in a few days. Given this capacity to move across jurisdictional boundaries, the transboundary issues of concern include capture by artisanal fishers and capture as by-catch in pelagic or high seas fisheries. Pollution and habitat degradation are also becoming important threats.

II) GAPS

- Limited data and information on marine mammal population characteristics (status, distribution, movements, and genetics) and status of their habitats.
- Insufficient data and information on the magnitude of incidental fisheries by-catch of marine mammals.
- Recommendations
- Conduct population assessments of mammals using a variety of techniques including genetics, photo identification and GIS analysis.
- Build institutional and human resource capacity for research and monitoring including training of managers and scientists on survey methodologies.
- Promote extensive involvement of communities to reduce impacts of human activities on marine mammals.

2.9.4 Birds

There are five key bird habitats along the coast, namely the Sabaki estuary, Mida Creek, Chale Island, Malindi-Watamu area, Kisite Island, Kiunga Marine National Reserve and the Tana Delta (Bennun and Njoroge 1999) (Figure 16). These are designated as Kenya's network of Important Bird Areas (IBAs) on the basis of designation criteria prescribed by BirdLife International (BirdLife International 2009a). The five IBAs vary in size and micro-habitat type but all interact directly with the marine system (Table 5). In general, the waters of the offshore islands provide much of the pelagic fish required by the seabirds while the seashore and estuarine habitats support many waders due to continuous supply of allochthonous and autochthonous benthic invertebrates (John and Pedersen 2006). Some birds nest and breed on these islands. Kisite Island hosts the largest nesting colony in East Africa for the Roseate Tern, *Sterna dougallii*. This species also breeds in Kiunga

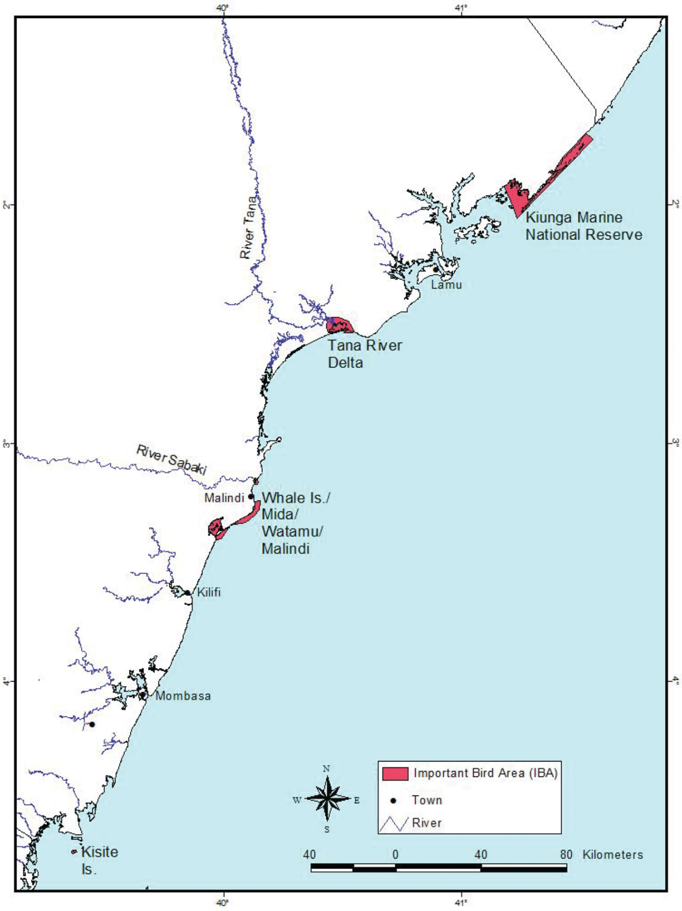


Figure 16: Important Bird Areas (IBA) in the Kenya coast (KMFRI GIS Coastal Resource Database 2011)

Marine reserve. Sooty Terns, *Sterna fuscata*, also nest on Kisite Island. Other birds which nest in Kiunga are Sooty Gull, *Ichthyaetus hemprichii*, White-cheeked Tern, *Sterna repressa*, Bridled Tern, *Onychoprion anaethetus* and Brown Noody, *Anous stolidus*. There are also breeding colonies of Roseate Tern and Bridled Tern on Whale Island while more than 10 species of wading shorebirds nest in the *Terminalia brevipes* thickets in the Tana Delta.

Over the past decade, populations of shorebirds and seabirds, particularly terns and gulls, have undergone a general decline along the Kenyan coast (Figure 17) (National Museums of Kenya 2009). These declines may be attributed to such varied factors as climate change, habitat destruction, pollution, destruction of nesting and breeding sites, nest predation by invasive animals, adverse fishing methods and lack of public awareness on habitat requirements of the birds (Musila *et al.* 2005).

Egg collection is prevalent in all of Kenya's marine Important Bird Areas. In Kisite Island, Whale Island and Kiunga Marine Reserve, many years of egg collection by fishermen has predisposed many birds in the *Sterna* genus to breeding failure (Bennun and Njoroge 1999). In addition, cattle roaming around the shoreline to graze trample on eggs of ground-nesting *Vanellus armatus* in sub-tidal areas of Sabaki Estuary (Otieno *et al.* 2008).

Table 5: Marine IBAs along the Kenyan coast showing important criteria of BirdLife International. Note: C = Regular congregation of more than 1% of biogeographic population of the species; RT = Regionally-threatened; GT = Globally-threatened (Bennun and Njoroge 1999)

IBA Site	Main Site Features	Impotant bird species and critera	Bird Breeding / colonial nesting
Kisite Island	Coral rock and low scrub	1(C)	• Seabirds
Mida Creek, Chale Island, Malindi and Watamu Marine Parks	Inter-tidal rock; coral reefs; sea-grass beds; sandy beaches; mangrove forests	5 (C)	• Seabirds • Shorebirds
		1 (RT)	
Sabaki River Estuary	Estuarine sand-banks; mud-banks; fresh and brackish water; sand dunes; freshwater pools; sandy beaches	4 (C)	• Shorebirds
		1 (GT)	
		2 (RT)	
Kiunga Marine National Reserve	Mangroves, coral islets and platforms; sandy beaches	2 (C)	• Seabirds
Tana Delta	Fresh and brackish lakes; streams; freshwater and saline grasslands; beaches and mud-flats; dune ridges	1 (GT)	• Seabirds • Shorebirds

While the influx of tourism activities is a constant source of disturbance to foraging marine birds (Bennun and Njoroge, 1999), habitat is lost mainly through the proliferation of coastal development activity in the private and public infrastructure sectors as well as mining and prospecting activities such as salt and other minerals.

Some seabirds and coastal shorebirds suffer from predation of eggs and chicks by the alien Black Rat *Rattus rattus* (Pye *et al.* 1999). In response, some species such as Sooty Tern *Sterna fuscata*, try to avoid breeding on islands with predatory animals (BirdLife International 2009b). The Indian House Crow, *Corvus splendens*, is also suspected to contribute to the predation of Roseate Tern, *Sterna dougallii*, eggs although this is not well documented in East Africa (Caut *et al.* 2007).

To a significant extent, piscivorous birds suffer reduced food supply resulting from overfishing by artisanal fishermen (GOK 2008). Trawl-fishing in Ungwana Bay has reduced fish food available to pelagic fishing seabirds, and created bird-vessel dependency which leads indirectly to unsustainable feeding relationships.

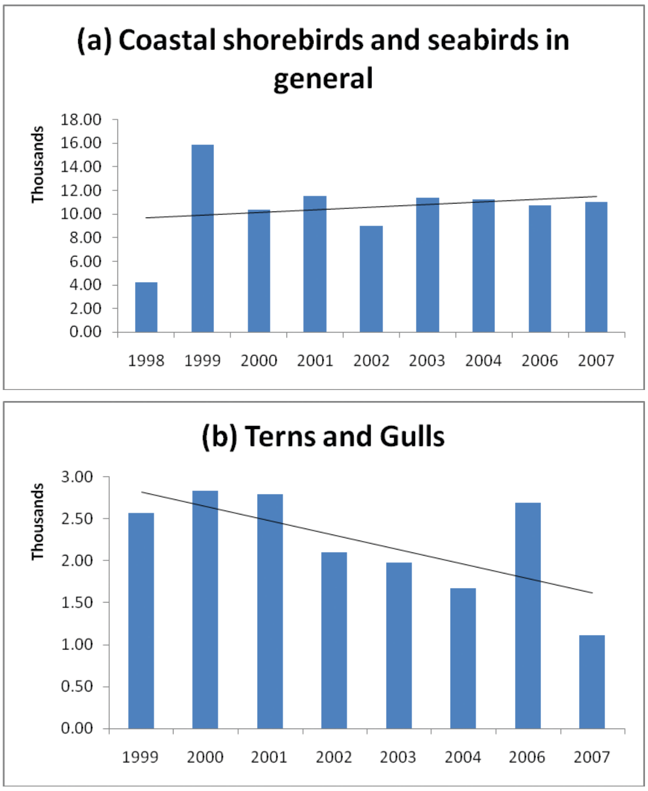


Figure 17: Population trends of (a) seabirds and shorebirds in general and (b) Terns and Gulls (the main seabirds) along the Kenyan coast:-(National Museums of Kenya 2009)

I) ISSUES

- Considerably low levels of awareness amongst many stakeholders and the general public about ecological requirements for marine birds and the impact of human activities on their habitat.
- There is lack of regional scope in ornithology research limiting transboundary collaboration.

There is also need to facilitate wider availability of existing and future research data through a formal regional data sharing policy among relevant institutions, and establishment of a framework for multi-taxon marine monitoring process. Since seabirds and many coastal shorebird species move through widely overlapping ranges in the WIO region and beyond, collaborative strategies would help bridge the gaps in knowledge required to plan for the conservation action. Finally, the use of Marine Protected Areas as a concept and tool for conserving the marine resources of Eastern Africa (IUCN 2003), should be expanded and strengthened among the member states, particularly around Key Biodiversity Areas.

2.9.5 Exotic and invasive species

Thirty six exotic species are listed as occurring in Kenya in the IUCN Global Invasive Species Database (ISSG 2009). Only the bacteria that causes cholera, *Vibrio cholerae*, found in both marine and freshwater habitats, is reported as invasive. Other exotic marine species in the database listed as occurring in Kenya include the red algae *Acanthops spicifera* and *Gracilaria salicornia* and the coral *Tubastraea coccinea* (Synonyms: *Coenopsammia* spp/ *Dendrophylia* spp). The invasive status is however unknown.

Risks of exotic invasions are especially high if the ecosystems of origin and introduction are climatically similar and more prevalent in disturbed, polluted and overfished areas (Drake *et al.* 2007). Outbreaks of *Vibrio cholerae* and the crown-of thorns starfish *Acanthaster planci* which predate on corals proliferate after phytoplankton blooms triggered by increased temperature and enhanced nutrient enrichment (ISSG 2009). Localized starfish outbreaks are a serious threat in terms of the health of coral reefs, and may have significant negative impacts on coral communities particularly in peri-urban areas associated with high human impacts (Amiyo *et al.* 2007).

Removal of the natural predators of *A. planci* through overfishing of its natural predators contributes to its outbreaks.

I) ISSUES

- Loss of biodiversity due to preying on native species, competition for space with native species, hybridisation causing genetic dilution, changes in ecosystem function and decreased water quality.
- Economic and cultural impacts due to interference with fisheries stocks, costs of clean up or control, damage to infrastructure and loss of livelihood from mass mortalities.
- Human health and wellbeing impacts resulting in decreased recreational opportunities, increased incidences of parasitic and bacterial infections (IUCN 2000b).

II) GAPS

- Limited national capacity in taxonomy to identify potentially invasive species.
- Lack of scientific information on the environmental and socio-economic consequences.

Recommendations

- Collaboration with Universities to build capacity in terms of taxonomic skills.
- Implementation of regular monitoring surveys so as to develop contingency planning strategies for early detection, risk assessment and rapid response to invasive species.
- Strengthen national, regional and international cooperation towards tackling marine invasive species through existing legal and institutional frameworks.
- Promote education and awareness programmes, particularly targeting resource managers and port personnel on the dangers of ballast water in introducing invasive species.

2.10 Long-term predicted climate changes

Indicators of climate change along the Kenyan coast include rising temperatures, significant shifts in rainfall patterns, increased frequent of extreme events such as floods and droughts, melting of ice caps on high mountains such as Mt. Kenya and Mt. Kilimanjaro, and sea level rise (GOK 2009). Analysis of trends in air temperature indicates that both minimum and maximum temperatures have increased in the last 50 years. In the inland areas the minimum temperatures show a steeper increase than maximum temperatures (Figure 18). These trends reverse for stations at the coast (Figure 19). In both cases, there is a decrease in the temperature range, although there is a general increase in temperature (GOK 2009).

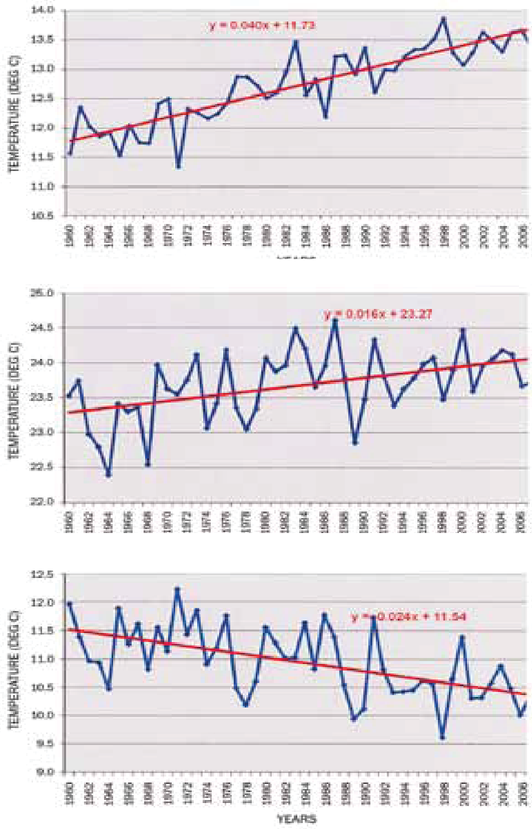


Figure 18: Temperature trends for Nairobi, Kenya: Trends in annual minimum temperature (top); annual maximum temperature (middle); temperature range (bottom)(KMD 2009)

Rainfall patterns in the coastal region of Kenya have shown distinct changes in the recent past. Changes have been depicted in patterns of onset, distribution and the total amounts of rainfall received in a given rainfall season. The frequency of extreme events has increased in the recent past. Flood events in the recent past occurred in 1997-1998, 2003 and 2006 and droughts occurred in 1999-2001, 2005 and 2008-2009 (KMD 2009). Climate change will alter ecosystem structures and functions, as well as human lifestyles (KMD 2009).

I) ISSUES

There is a need for studies to generate knowledge on the net sources and sinks of carbon in Kenya, as a contribution towards quantifying global carbon sources and sinks. There is also a need to carry out studies on carbon sequestration by marine ecosystems such as mangroves, seagrass beds and coral reefs.

Feedback mechanisms between the carbon cycle and the climate system are critical for projecting changes in climate. For example, if the warming leads to enhanced rates of decay of organic matter in soils, or a reduction in oceanic carbon uptake, then the concentration of CO_2 in the atmosphere will rise more rapidly than it would in the absence of such

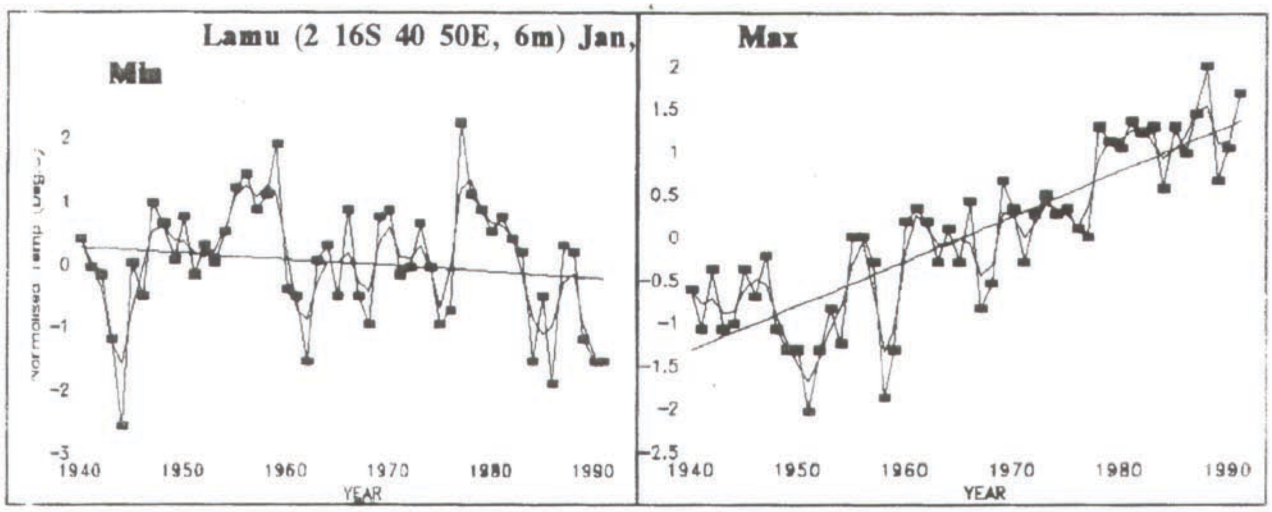


Figure 19: Decreasing trend of min. temperatures (left) and steeper increase of max. (right) at Lamu (KMD 2009)

(positive) feedbacks, and the rate of warming will be greater as well. There is therefore a need to study these feedback mechanisms.

3. HUMAN ENVIRONMENT

3.1 Coastal population – current status and trends

The most detailed information on demographic characteristics of the coast of Kenya can be obtained from the national population and housing census of 1999. The coastal region has about 2.5 million people with a population density of 77 per km^2. Data from the World Resources Institute (WRI) puts the coastal population at 8% of the total national population in Kenya. The population increase in the period between 1989 and 1999 was 54%. Most of the population is concentrated in areas which are located along the coastline. The urban centres have higher population densities, attributed to rural-urban migrations driven by better economic opportunities and social amenities in urban areas such as Mombasa, Malindi and Kilifi. Mombasa County accounts for 27% of the total coastal population. Some selected demographic information is presented in Table 6 (GOK 2007).

Table 6: Demographic characteristics of the seven districts in coast province in 2005 (GOK 2005)

Demographic Profiles	Mombasa	Malindi	Lamu	Kwale	Kilifi	T/Taveta	T/River	Total
Population Size	650,018	281,552	72,686	496,133	544,303	246,671	180,901	2,487,264
Males	363,552	139,340	37,553	240,764	258,505	123,329	90,613	1,253,656
Females	301,466	142,212	35,133	255,369	285,798	123,342	90,288	1,233,608
Total number of youth (15-25)	186,386	71,489	15,512	119,017	118,304	54,998	45,498	611,204
Population Growth Rate	3.60%	3.90%	-	-	3.05%	1.70%	3.40%	3.5%
Population Density (persons per km^2)	2,896	36	12	60	114	14	5	30
No. of Households	183,540	52,164	15,006	92,594	90,311	57,635	36,177	527,427
Urban Population	665,018	118,428	17,130	59,786	257,736	101,200	15,947	1,235,245

Coastal urban centres where there is a high concentration of people are mostly located in the vicinity of estuaries, mangrove swamps and coral lagoons. A good example is the case of Mombasa which is surrounded by Port-Reitz and Tudor Creeks. Concentration of populations in these centres places significant pressure on the coastal environment and its resources due to over exploitation of natural resources, generation and discharge of waste in to the marine environment. Most of the pollution hotspots are located near urban centres (GOK 2003).

The inhabitants of the coast of Kenya are culturally diverse with the largest ethnic group being the Mijikenda which is made of nine sub-tribes. Other coastal ethnic groups found in the coastal region of Kenya include Taita, Sagala, Pokomo, Bajuni, Orma, and Swahili. A significant segment of tribal communities found in inland Kenya have also migrated to the coast in the recent past. These includes Kamba, Kikuyu, Luhya and Luo (UNEP 1998).

I) ISSUES

- Rapid population growth is putting a lot of pressure on the coastal ecosystems. The rapid population growth and expansion has led to over-exploitation of nearshore fisheries, degradation of mangrove areas, shoreline changes and conflicts in the use of natural resources.
- High population concentration along the coast is leading to increased generation of waste. Disposal of domestic sewage and industrial waste has become a major challenge for most of the main urban centres such as Mombasa, Kilifi, Lamu and Malindi. There are increased incidents of contamination of ground and surface water resources and associated public health risks.

3.2 Sites of religious or cultural significance

Many of the historical, cultural and archaeological sites in the coastal region of Kenya are closely linked to the past long distance trade, navigation and development of the Swahili culture in East Africa. Some of the earliest trading settlements such as Mombasa, Lamu and Malindi have grown and became important towns. A number of these towns also have been designated as Conservation Areas by National Museums of Kenya – for instance Mombasa Old Town Conservation (MOTCO) area in Mombasa and Lamu Old Town Conservation (LOTCO) area in Lamu. In addition, historical and archaeological sites have been declared as National Monuments under the National Museums and Heritage Act (2006). Both Mombasa and Lamu old towns and other historical sites serve as important attractions for the tourism industry.

The coast of Kenya has unique lowland tropical forests that are known as Kayas. The Kaya forests are distributed in a few remaining patches along the coast which have a high cultural significance to the local Mijikenda community who have traditionally used them for religious and spiritual rituals (Blackett 1994). The sacred values associated with these forests have contributed to their conservation and growth of forest tourism in the coast region. However, cultural belief associated with the Kayas is progressively being eroded. This is threatening the conservation of these important indigenous forests. Thus the gains realised in the use of traditional knowledge in natural resource management will be lost. Cultural erosion has also been attributed to modernization as well as recent growth in tourism. Social problems such as high school drop-out rate, drug peddling and prostitution have been blamed on the tourism industry (Sindiga 1999).

3.3 Human Health

Some of the major factors that influence the state of human health and disease prevalence along the coast of Kenya include high levels of poverty, low level of education, high cost of health care, low doctor/patient ratio, poor state of health infrastructure and the poor state of environment (GOK 2005). Poverty levels are generally high thus limiting access to modern health care facilities (GOK 2002). The doctor-patient ratio is still low as compared to other parts of the country. Kilifi County has the worst doctor-patient ratio in the entire country at 1:100,000, with high levels of superstition (GOK 2002). Table 7 provides some important data on the available health care services and facilities.

Table 7: Indicators of health services for the seven districts in coast province (GOK 2002)

Health Indicator	Mombasa	Malindi	Lamu	Kwale	Kilifi	Taita Taveta	Tana River
Doctor/patient Ratio (GOK)	1:3,000	1:19,502	1:36,343	1:82,690	1:100,000	1:41,000	1:95,500
No. of health facilities	211	83	5	57	73	44	57
No. of hospitals	9	3	1	1	2	3	2
No. of nursing homes and health centres	19	2	1	5	5	7	5
No. of dispensaries	183	24	4	51	21	22	36
Average walking distance to Health centre (km)	0.5	1.5	5	30	5	10	50

Health care in public hospital is not free of change following the introduction of cost-sharing. There is however a provision for waiver of charges for patients who cannot afford to pay for the cost of getting services at the public health facilities. In addition to Public Health facilities, there are also several Private health facilities that are also available at a fee. A large segment of the population in most of the coastal counties cannot however afford to pay for modern health care (GOK 2002). This has forced a large proportion of the population to depend on traditional healers for their health care needs (UNEP 1998). Literacy levels among women are significantly lower than that of men in all counties in the coastal region of Kenya (Hoorweg *et al*. 2000).

Access to potable water

In the coastal region of Kenya only 11% of the population have access to well water, 10.7% to river water, 9.2%

to pond water, 6.4% to boreholes and 5.8% to dam water (GOK 2009). Water supply in most counties is poor and inefficient. This is due to poor planning, mismanagement and lack of technical expertise. Demand for freshwater has far exceeded supply. Access to piped water is 80% in Mombasa, 50% in Kilifi, 52% in Malindi and 57% in Taita Taveta (World Bank 1996). To address water shortages, the Coast Water Board (CWB) is investing in new water supply systems and development of complementary water sources such as communal boreholes, roof catchments, dams and wells.

3.4 Infrastructure

Important infrastructure in the coastal region of Kenya includes roads, airports, railways, ports and harbours, energy, water supply and sanitation. The road network is influenced by the existence of important industrial and commercial centres hence the only substantially good road networks are in Kwale, Mombasa and Kilifi District. There is an international airport in Mombasa that serves both international and domestic flights. In addition, there are smaller airports in Malindi, Lamu and Ukunda mainly serving tourists (GOK 2007).

There is a railway line that links Mombasa with the inland branching at Voi to serve Taita Taveta County bordering Tanzania. In Mombasa County the railway distribution is concentrated in the industrial area, railway deports and port warehouses. The quality of rail services is poor having deteriorated in the recent years.

Mombasa has one of the largest sea ports in Eastern Africa. The Port of Mombasa serves a number of east and central African countries, such as the Democratic Republic of Congo, Rwanda, Burudi, Uganda and Southern Sudan. The port accounts for 15% of the coastal economy. There are a number of small ports located at Tudor Creek of Mombasa, Shimoni, Kilifi, Kipini, Shimoni and Lamu. Presently, there are plans to construct a second large port at Lamu (GOK 2007).

There are various sources of energy along the Kenya coast. These are petroleum fuels, oil fuels, electricity, wood fuel, charcoal, solar, wind, ethanol, coal and biogas. Petroleum fuels and hydro-electricity are currently the major sources of energy for industrial and commercial establishments. Electricity supply has generally kept pace with growth in demand. The distribution of power has been concentrated in the urban centres where the demand has been relatively high compared to rural areas (GOK 2008). However, the government has introduced a rural electrification programme that is targeting rural areas.

4. COASTAL LIVELIHOODS

A comprehensive coastal livelihoods assessment has been carried out. Chapter summaries are presented below, and the full Coastal Livelihoods Assessment may be found in Annex XII for further information.

4.1 Small-Scale Fisheries

The small-scale fishery in Kenya is an important source of livelihood as it employs 12,000 people and supplies 95% of the country's total marine catch, generating an estimated US$ 3.2 million per year. The sub-sector also accounts for between 2% and 6% of total fish production in the country. An estimated 60,000 coastal residents depend on this sub-sector for their livelihood. The level of dependence is high in areas with low development, low salaried employment and high poverty rates. Hence while the entire fisheries sector only contributes 0.5% to national GDP, it is nevertheless a vital component to economic activity in the coastal region of Kenya.

Population growth, along with high levels of poverty in the coastal region, has contributed to increases in the number small-scale fishers, with a 34% increase in the period between 2004 and 2008. This has, in turn, placed great strain on fish stocks along the coast, resulting in the over-exploitation of fisheries resources. This has subsequently resulted in an overall decline in small-scale landings, which is evident in the 50% decrease in demersal coral reef fish yields through the 1990s. Rabbit fish and other scavengers which make up nearly 40% of the small-scale fishers' landings have declined by 40% in the 1990s, while the catch of tuna has been declining since 2004. Destructive fishing techniques such as trawling as well as the use of seine nets and spear guns have facilitated these declines.

Investments in fish processing by the private sector have opened up opportunities for small-scale fishers to venture into non-traditional fishing grounds and strengthen value chain links. The Oceans and Fisheries policy (2008) along with its new co-management programs have also empowered coastal fishers, promoted sustainable fishing practices and improved compliance in licensing requirements. Increased competition from recreational fishers and prawn trawlers, as well as a lack of capacity at the local level, does however, highlight the challenges still confronting the sector (Allidina 2005).

4.2 Tourism

Tourism is an important source of livelihood in the coastal region of Kenya, despite the fact that only between 2% and 5% of tourism receipts actually trickle down to local communities. The major tourist attractions are beautiful sand beaches, the sun, wildlife, historical sites and local culture. The sector has been strong in recent years, with arrivals increasing from 814,000 in 1990 to over 2 million in 2007 and revenue increasing from US$864 million (Kshs56.2 billion) to US$ 1 billion (Kshs 65.4 billion) between 2006 and 2007, representing an 11.6% growth rate. It is estimated that 60% of the revenues generated by the tourist sector in Kenya are due to Coastal tourism.

4.3 Mariculture

There are several mariculture activities currently in the experimental stage along the south coast of Kenya. This includes eight finfish farms, six crab farms and four prawn farms, all of which are currently producing for domestic consumption. This development is a reflection of the enthusiasm of coastal communities to develop mariculture activities. Many mariculture operations, particularly crab and finfish, are also being developed as community-based initiatives, again a testament to the willingness of coastal communities to become involved in the sector. Thus, despite inadequate coordination and planning in the sector, mariculture is a developing field in the Kenyan economy.

Challenges such as theft, conflict with other coastal users and poor training are constricting the farming of crab, while a lack of financial support, poor pond quality and the seasonal availability of fingerlings continues to hinder the successful farming of finfish. Issues of land tenure are also constraining the development of community-based initiatives in prawn farming, and suitable conflict-free culture space is limited for the development of seaweed farming. Environmental issues have also been reported, with the destruction of mangrove habitats being witnessed in prawn farming, while crablets are being harvested from the wild with little regard for resource status.

4.4 Agriculture and Forestry

Agriculture and forestry is clearly the most dominant sector in the Kenyan economy. The sector employs 70% of the total work force, supplies 70% of raw materials for domestic agro-industry and makes up 80% of total export earnings. The sector contributes 45% of government revenue. Agricultural activity in the coastal zone is also significant, producing food and non-food products for both subsistence and commerce, with cashews, bixa, sisal, as well as fruits and vegetables, all being produced for export.

4.5 Energy

Kenya has a downstream oil industry, along with East Africa's only refinery producing 1.6 million tonnes annually in Mombasa. The refinery is owned and operated by Kenya Petroleum Refineries Limited, in which the Government of Kenya owns a 50% of the shares. The oil refinery supplies petroleum products to Uganda, Rwanda, Burundi, Eastern DRC and Southern Sudan, in addition to the local domestic market.

The National Oil Company (NOC) has demarcated 17 blocks for petroleum rights negotiations, while all offshore exploration is currently being undertaken by the private-sector. To date, bio-fuel development remains in its early stages and there is no firm evidence of offshore exploitable petroleum or gas reserves.

A number of constraints have been identified in the sector as detailed in the SWOT analysis.

4.6 Ports and Coastal Transport

Kenya has only one main port located in Mombasa. A number of smaller ports exist in Lamu, Malindi, Kilifi and Shimoni. All the ports are administered by the Kenya Port Authority (KPA) under the Ministry of Transport. The port in Mombasa, which is the country's only international port, has recently undergone numerous reforms. A new Vessel Tracking Management System (VTMS), Global Maritime Distress Signalling System (GMDSS), as well as new safety regulations and a shift to 24-hour services, have all increased efficiency at the port. This has led to a 2.8% increase in throughput and 10.8% increase in cargo transits.

4.7 Coastal Mining

The mining sector accounts for only 0.5% of total GDP, with mineral exports making up between 2% and 3% of total exports. The sector employs an estimated 50,000 people. Along the coast there are important deposits of heavy metal titaniferous sands, coal, limestone, and lead, among others. However, mining activity in the coastal zone is currently focused on cement production through exploitation of abundant limestone, shale, and sand. The three largest limestone quarries are located in Mombasa, while informal mining is prevalent in the Kilifi and Kwale districts.

4.8 Conclusion

Each sector covered in this report has had, and will continue to have, a distinct impact on the socio-economic status of the coastal communities in Kenya. There are many constraints that remain constant across sectors, such as a lack of effective planning and management and the over-exploitation of natural resources, both of which have had widespread impacts.

Planning, management and training are clearly constraining developments in the seven sectors. For example, inadequate planning and training in specific types of fishing has been identified as a weakness in the small-scale fishery. Similarly, poor training has been identified as a constraint in the development of the mariculture sector, while uncoordinated management and a lack of training at the community level have affected the conservation of mangrove forests in the agriculture and forestry sector. The same challenge can be seen in the ports and coastal transport sector, where a lack of training institutions and skills deficiencies have been documented as a threat to further development. Progress has, however, been seen in addressing these weaknesses. For example, the Fisheries Department has been reorganized in order to develop a more effective and efficient institutional framework capable of overseeing the sector, whereas NGOs and donors are currently providing technical support and training to communities in the mariculture sector. Likewise, the government is currently promoting participatory resource management in the agriculture and forestry sector, which is positive from a planning and management perspective moving forward.

Environmental degradation and over-exploitation of natural resources are also challenges to Kenya's coastal communities. In the small-scale fishery, the use of destructive fishing techniques, poverty and population growth all continue to strain resources on the coast. In mariculture, the destruction of mangroves to make way for prawn farming, as well as the potentially harmful use of wild caught crablets, highlights the unsustainable practices currently taking place in the sector. Similar practices have been documented in agriculture and forestry, where poverty and over-exploitation are both seen as key variables facilitating the depletion of coastal and mangrove forests. However, methods of mitigating this exploitation, such as the development of substitutes and subsequently the creation of alternative income streams, are currently being implemented. This is most prevalent in agriculture and forestry, wherein, the World Bank is financing projects that seek to create employment in alternative sectors such as renewable energy, beekeeping and ecotourism. Mariculture itself is also a sector that could potentially attract labour away from sectors that would otherwise contribute to the over-exploitation of resources. The important point, in all cases, is that there is a direct link between poverty and natural resource exploitation, thus, creating alternative forms of employment should be a priority in the sectors where environmental strain is predominant.

Potential opportunities across sectors, particularly within the private-sector, could also be utilized as a means to spur alternative forms of employment across sectors. This is most prevalent in ports and coastal transport, where private-sector investments at the ports in Mombasa and Lamu have been very positive in improving efficiency. Such investment is also expected to be key in the development of both the Lamu corridor and the Northern corridor, which are expected to have potential spillovers in the respective coastal communities located nearby. In agriculture and forestry, there is an opportunity to utilize marginal lands for livestock production, while private-sector investment in processing could potentially open up new markets for the small-scale fishery. Likewise, the prevalence of numerous candidate species highlights the opportunities in mariculture, which again could potentially create employment and subsequently shift labour away from more exploitive occupations. The government has also shown a commitment to oil exploration, which, if fruitful, also has the potential to create employment, particularly in the downstream sector.

Overall, there are clearly many strengths and opportunities that can be utilized to spur sustainable growth and development in Kenya's coastal region. Many of these opportunities also have the potential to generate alternative forms of employment, which, as alluded to above, could potentially lessen the strain being placed on coastal ecosystems. Creating alternative streams of income could, in turn, be conducive to sector spillovers, which could counter the cyclical relationship documented between poverty and natural resource exploitation. It is also positive to note that the Kenyan government has not only recognized the causal links between poverty and resources, but it has begun generating policies that intend to deal with the problem. The emphasis being placed on training, management, alternative employment and the sustainable use of resources all highlight the positive commitment the government is making in relation to the coastal region. Thus, while challenges still remain abundant, opportunities and a commitment to act are clearly present.

5. POLICY AND GOVERNANCE

A comprehensive report was prepared on Policy and Governance, which is Annex V to this MEDA. A summary is presented below.

The Fisheries Management Bill (GOK 2009) requires a full review since it has been weakened by various overlaps in mandates of institutions that directly or indirectly interlink with fisheries resources and its environment. There is further need to review the Fisheries Act to domesticate the regional and international conventions, and agreements into Kenyan law.

The Tourism Policy (GOK/MOTW 2006) and the Tourism Bill (GOK/MOT 2010) have created more corporate bodies in the Ministry of Tourism which still promotes administrative overlaps in their mandates and can cause conflicts. The conflicts may be aggravated further by other institutions with linkages to these tourism institutions. It is recommended that the Tourism Policy, existing Acts and the Tourism Bill provide for domestication of relevant regional and international treaties and convention to which Kenya is party. Further it is recommended that the tourism Policy and Law should embrace ecosystem based management since Kenya's tourism is essentially anchored on nature and environmental resources.

The maritime zones of Kenya have not yet been designated with Somalia. Addressing transboundary issues has further been complicated by civil conflicts in Somalia.

Although in the Seventh National Development Plan of 1994-1996, government policy recognized the economic contribution of mineral wealth to the economy and at the same time the need to preserve a clean environment for sustainable mineral utilization and management, this was not embraced in the Mining and Minerals Act and the Petroleum (Exploration and Production) Act. There is need to review the Acts to embrace ecological considerations.

Growth of commerce in the East African region has necessitated expansion of port and maritime transport facilities not only to serve the country but also neighbouring landlocked states in the region. Policies and Acts created for institutions to manage maritime transport and ports should contain environmental considerations.

To support agricultural production in line with addressing the MDG7 and the National Food Policy which advocates for good land use for self sufficiency in food production, an integrated ecosystem based management supported by the Integrated Coastal Zone Management, Wetlands Policy, Land Policy and Forest Policy and their corresponding Acts has to be enforced. This is essential noting also the fragile nature of the coastal areas being variably arid to semi arid in nature and that poor management can lead to collapse in agricultural production. Policies and Acts to support appropriate technological advances in sustainable agricultural production and environment management in the prevailing environmental conditions and climate variability are required and appropriate monitoring, control and surveillance must be enforced.

6. PLANNING AND MANAGEMENT

6.1 National disaster management plans

Kenya has established the National Warning Centre (NWC) based at the Kenya Meteorological Department (KMD). In addition there is the Information Centre at the National Disaster Operation Centre (NDOC) as required by the Indian Ocean Tsunami Warning System (IOTWS). The centres receive warning information from the Pacific Tsunami Warning Center (PTWC) and the Japan Meteorological Agency (JMA) which acts as interim warning centers for the Indian Ocean until the IOTWS is fully operational (Kenya Meteorological Department 2008).

A number of Tide gauges have been installed at Lamu, Malindi, Kilifi and Shimoni and KMD is planning to install a DART buoy in the offshore waters within the EEZ for monitoring potential tsunamis and other marine hazards. Efforts are also being made to improve capacity for modelling inundation within the lowlying zones of the coast of Kenya. The collaborating institutions include Kenya Marine and Fisheries Research Institute (KMFRI), Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), and all maritime Organizations through the Kenya National Hydrographic Committee (Kenya Meteorological Department 2008).

Kenya is presently finalizing the contingency plan for petroleum oil spill management. This is for persistent oils in particular crude oils and fuel oils. Plans are in the initial stage to develop a contingency plan for management of hazardous chemicals in line with IMO conventions.

6.2 Environmental sensitivity mapping

Kenya has an Environmental Sensitivity Atlas (KENSEA) that contains information on the sensitivity and vulnerability of marine environment to oil spills (Tychsen 2006). A study was also done on the vulnerability of the Kenyan coast to Tsunami phenomena (Kensea 2007). The Western Indian Ocean Marine Highway Development and Coastal Contamination Prevention project is also in the process of determining the environmental sensitive areas with regard to maritime transport.

6.3 Coastal management/development plans

Mitigation of Sea Level Rise

Most settlements, commercial developments and tourist beach hotels are found within a few hundred metres of the sea. This makes such developments vulnerable to sea-level rise (UNEP/FAO/PAP/CDA 2000). There are also several low-lying islands that are vulnerable to sea level rise. Kenya has developed a strategy to mitigate the impacts of sea level rise through development of adaptation measures, erection of defence structures, and relocation of vulnerable populations.

Spatial Development plans

The Physical Planning Act (CAP 286) of 1996 of the laws of Kenya requires the preparation of physical development (regional and local) and / or land use plans. The purpose of spatial development planning is to guide the overall development along the coast. Such plans have been prepared by the Physical Planning Department in collaboration with other line ministries. Spatial development plans that have been prepared along the Kenya coast include Lamu Regional Physical Development Plan, Kwale/Mombasa Mainland Regional Physical Development Plan, Kinango Constituency Local Physical Development Plan, Nyali/Shanzu zoning plan and Changamwe Zoning plan. The Physical Planning Department of Mombasa in collaboration with the Ministry of Tourism is also planning for the development of resort and tourist cities in Kilifi and Kwale Counties. However a large section of the Kenya coast has no spatial development plans, thus leading into haphazard and unsustainable development.

Partial Development Plans have been prepared for settlement schemes at Mwakirunge I, Mwakirunge II, Maganda and Vyemani. The National Land Policy, which is yet to be enacted by Parliament and the National

Land Use Policy, currently in preparation, would guide the land use systems in Kenya. It is important to note that land is a sensitive issue in the Kenyan coastal region since a huge segment of the coastal population lives in squatter settlements and has no rights to land.

Integrated Development Planning

The Integrated Coastal Zone Management (ICZM) policy has been developed by NEMA (NEMA 2010a). The policy provides a legal basis for integrated planning at the coast. The policy also reinforces legal and institutional instruments for coordinating sustainable development of Kenya's coast. A National Plan of Action (NPA) for implementing the ICZM Policy is under preparation (NEMA 2007, 2010b). The objective of the NPA is to action the implementation of the ICZM policy.

Environmental Management Plans

Environmental Management and Coordination Act (EMCA) of 1999 is the framework environment law in Kenya that is intended to promote sustainable development. EMCA has several specific regulations such as Environmental Impact Assessment and Audit Regulations of 2003 which guides the conduct of EIA processes in the country. The Environmental Impact Assessment identifies the adverse effects of development and suggests mitigation measures to be undertaken through the implementation of an Environmental Management Plan (EMP). A large number of coastal development projects have in the recent past been subjected to an EIA Process.

Coastal Management Plans

EMCA envisages that coastal management plans are developed and reviewed periodically. This is intended to provide synergy with the existing Coastal Management Plans based on the concept of zoning where space is designated for different uses such industry, agriculture and settlement, commercial, conservation or preservation. Individual zones have specific Management Plans, implemented solely for sustainable development purposes. Thus, several areas have been declared as protected areas for preservation and conservation, e.g. the terrestrial and marine Parks and Reserves. There are also well designated industrial and commercial areas in most towns where environmental health considerations are paramount in the protection of the health and safety of the workers (Occupational Health and Safety Act 2007). Other designated zones include settlement areas (Public health Act Cap 242).

There are also plans for management of forest areas in collaboration with forest-neighbouring communities (Draft Forestry Policy 2009) and plans for the management of Kenya's natural heritage (The Antiquities and Monuments Act 1983). There are also zones where, for purposes of preservation, extractive activities are prohibited, for example the kaya forests and marine shrines of the Mijikenda. Vulnerability assessments have also been used as tools for identifying and mapping areas that need management attention against occurrences of floods, erosion and oil spills. On the Kenya coast, management plans for wastewater are found only in urban areas. However, it is important to note that most towns do not have such plans.

Marine protected areas

Kenya has some of the oldest marine protected areas in the WIO Region (Muthiga *et al*. 2008). There are four marine parks and five marine national reserves (Figure 20). The total area of the parks is estimated at 54 km2, while that of reserves is 898 km2 representing approximately 8.7% of the Kenyan territorial waters (Nyawira 2003). Fishing and tourism are the main coastal livelihood sectors in these areas but the main intention is the protection of critical habitats. In addition, there are a number of community protected areas located in Wasini, Kuruwitu, Bureni, Trade-Winds, Kibuyuni and Kiweni. These are mainly intended to encourage responsible fishing (Oluoch *et al*. 2008).

Violations in both the parks and community protected areas consists of use of illegal gears and poaching (Muthiga *et al*. 2009). In some places fishermen have been engaged in participatory monitoring through formal training and indigenous conservation knowledge (Obura *et al*. 2002).

Conflicts have been observed whereby local fishing communities harbour negative attitudes towards establishing new government managed MPAs, creating an impediment to government commitment to increase MPA coverage (Muthiga *et al*. 2008). Local resource users are still concerned about denied access, and control over the

Figure 20: Marine and terrestrial parks and reserves on the Kenyan coast.

resources in marine parks and reserves (Nyawira 2003). Conflicts within community managed areas exist between the various interest groups.

There has been a low level of public involvement in most MPAs since they were initiated without adequate consultation and participation of the local community (Muthiga *et al.* 2003). Awareness raising programs exist but participation is not adequate (Nyawira 2003). Increasing the area under protection may be challenging as a large proportion of fishers still perceive MPAs to be an impediment to themselves and their communities.

I) ISSUES AND GAPS

- Guidelines should be developed for implementation of the locally marine managed areas to reduce conflicts amongst the stakeholders. In addition there should be clear demarcations for community managed areas.
- Monitoring of protected areas must have defined social and ecosystem goals that can be measured using specific indicators to quantify MPAs' contribution to community livelihoods.
- Integrated planning will ensure that tourism, management of fisheries in reserves and control of land-based activities harmonise with MPA management plans.
- The WWF-Eastern African Marine Ecoregion (EAME) strategy for conservation of biodiversity represents a great opportunity for addressing areas of special concern. The strategy has set actions to support marine conservation through priority seascape areas and expansion of the MPA networks using an ecosystem approach.
- According to Resolution 2.20 on Conservation of Marine Biodiversity (IUCN 2000a) and the World Summit on Sustainable Development (WSSD) 2002, countries are expected to establish marine protected areas beyond national jurisdiction within the international law and based on scientific information (IUCN 2003). However inadequate studies on off-shore systems in Kenya beyond the reef present great challenge to implementing this resolution.

6.4 Monitoring, Control, Surveillance

The Monitoring , Control and Surveillance (MCS) operational aspects in Kenya are addressed through the National Oceans and Fisheries Policy of 2008 (GOK 2009), Fisheries Management Bill 2009 (GOK 2009) and the Fisheries Strategic Plan 2008 – 2012 (GOK 2009), stating that the Ministry in charge of fisheries will strengthen MCS units, build their capacity through the provision of modern equipment and skill development in order to ensure effective patrols. Other instruments deemed important include 1982 UN Convention (UNCLOS)(UN 1982), FAO Compliance Agreement (Hedley 2008), 1995 UN Fish Stocks Agreement (UN 1995), and the FAO Code of Conduct. It should be noted that MCS is a very expensive programme venture and Public private partnership may be the best option to manage the offshore stocks under observer programs.

In Kenya, capacity for at-sea inspectors, observers and coast guards is inadequate for instituting an effective MCS system. There are no offshore fishing patrols except those carried out by the Kenyan Navy during its routine surveillance. Due to limited resources inshore fisheries patrols are also limited (GOK 2008). More patrols need to be implemented through synergies between various key government departments such as Kenya Navy, Kenya Police, Kenya Revenue Authority, and Kenya Wildlife Service. Presently, Kenya relies on its Navy for patrols in the territorial waters through a Memorandum of Understanding (MOU) signed with the Ministry in charge of fisheries development.

Kenya is devising an MCS strategy for implementation in high seas, territorial and inshore waters in cooperation with IOTC and Kenya Coastal Development Project (KCDP). It is important to note that Kenya has no total allowable catch or quota system. All fisheries are subject to licenses, irrespective of their economic value, except for subsistence fishing activities. A satellite-based VMS is under implementation at national level to provide for a better monitoring of fleet operations in a cost-efficient way. The VMS will be mandatory for all tuna fishing vessels prior to licensing.

Regional collaboration and joint monitoring of all tuna vessels in the WIO area is high on the agenda of IOTC including fisheries observer programme. Information sharing mechanisms are currently in place through IOTC and the regional projects like SWIOFP.

7. COST-BENEFIT ANALYSIS

7.1 Fisheries Sector

In Kenyan waters, five fisheries sectors are recognised, namely artisanal, sport fishing, shallow water shrimp trawling, long liners and purse seiners. Fishers use artisanal fishing methods and gears to capture a variety of species which include fin fishes (pelagic such as king fish, barracuda, mullets, queen fish and dermersals e.g. rabbit fish, snapper, rock cod, scavenger etc), crustaceans (prawns, lobsters, crabs, etc), and Cephalopods (squids, octopus, etc). Other marine fisheries activities are aquaculture and a limited fishery for the aquarium trade. The latter however contributes a great deal to the export of aquarium fish.

7.1.1 Artisanal Fisheries

In the year 2007, the marine artisanal fish production was 7,467 tonnes with an ex-vessel value of Ksh.610, 865,000. This was a slight increase both in quantity and value compared to the previous year. Total artisanal marine fish production represented approximately 5.5% of the country's total annual production in 2007. As in previous years, most of the catches in 2007 were landed in the south and north counties of Lamu and Kwale. Kwale County contributed 2,236 metric tons (30%) of the total artisanal production followed by Lamu with 1,977 tonnes (26%), Malindi 1,292 tonnes (17%), Mombasa 934 tonnes (13%), Kilifi 826 tonnes (11%) and finally by Tana River district which contributed only 203 tonnes (3%).

Despite the fact that there has been a fluctuating trend in the fish landings from artisanal fishery the value of the fish catch has maintained an increasing trend over the years, possibly due to inflationary pressure. In 2007, the demersal fish species category dominated the marine artisanal fish landings by contributing 47.0% of the landings while the pelagic fish category contributed 27.4%, the sharks, rays and sardines category made up 10.7% of the landings, crustaceans 8.3% and mollusks 6.6%. The Artisanal fishing subsector has created direct employment to 10,276 fishers of which 9,601 were boat fishers and 675 foot fishers.

During the 2007, a total of 8,736 metric tonnes of assorted fish species valued at US$11,511,969 (Ksh.736, 766,000) were landed. This production reflected an increase of 17.0 % from last year's production. These were landed from 141 landing sites distributed all along the whole stretch of the Kenyan Coastline. Fish landings from the artisanal fishery have experienced a boom over the years despite the fact that value-wise costs have been increasing, mainly due to inflationary pressure. Pelagic fisheries for the past three years (i.e. 2006-2008) generated an approximate value of US$ 2,369,934 per annum (Table 8).

In 2008, the demersal fish species category dominated the marine artisanal fish landings by contributing 46.8% of the landings while the pelagic fish category contributed 29.4 %, the sharks, rays and sardines category made up 10.2% of the landings, crustaceans 6.6% and molluscs 6.8% (Table 9). The aggregated fish production from the marine and coastal fisheries has remained fairly constant. There has been fluctuation in production quantities when analyzed at district level but generally the trend and order of contribution has remained very similar. In this case Kwale continued to be the leading county, followed by Lamu, Malindi, Mombasa, Kilifi and Tana Delta.

As shown in Table 9, over the past three years (i.e. 2006-2008) the demersal fisheries have generated catch valued at US$ 1,408,113 per year. The 2007 frame survey indicated that artisanal fishing activities were undertaken by 12,077 fishers, of which 9,541 were boat fishers and 2,536 were foot fishers (Marine Waters fisheries Frame Survey 2008 report). The latter category of fishers mainly target lobsters and other reef fishes since they can walk or dive deep into the water and use hooked sticks as their main type of fishing gear. The number of fishing crafts which were used during the period under review was 2,687, of which 312 were motorized, 1,021 used paddles, 1,227 used sails while 137 used pole/pondo as a means of propulsion.

Dugout canoes were the most widely used fishing craft owing to their simplicity and low cost of manufacturing and maintenance constituting 53% of all the crafts. These were followed by: Sesse with one flat end (23%), Hori (10%), Sesse pointed at both ends (7%), and the Dau (7%).

Table 8: Marine Fish Landings by Species, Weight and Value 2006 to 2008 (Pelagics)

Species	2006			2007			2008		
	M. Tons	000 Kshs.	US$	M. Tons	000 Kshs.	US$	M. Tons	000 Kshs.	US$
Pelagics									
Carvalla Jacks	157	9,431	147,359	176	12,125	186,538	219	15,014	230,985
Mullets	221	12,147	189,797	201	15,423	237,277	236	15,274	234,985
Little mackerels	145	9,078	141,844	197	14,513	223,277	212	16,853	259,277
Mackerels									
Barracudas	246	14,968	233,875	248	18,017	277,185	325	25,988	399,815
Milk Fish	55	3,379	52,797	64	3,876	59,631	91	6,929	106,600
King Fish	81	7,052	110,188	111	9,553	146,969	77	7,276	111,938
Queen Fish	54	2,937	45,891	57	3,435	52,846	85	5,640	86,769
Sail Fish	148	9,501	148,453	83	6,261	96,323	105	9,609	147,831
Bonitos/ Tuna	233	14,706	229,781	185	14,096	216,862	320	23,229	357,369
Dolphins	11	694	10,844	21	1,466	22,554	28	2,674	41,138
Mixed Pelagics	336	19,851	310,172	436	29,572	454,954	539	39,670	610,308
Not Acc. For	253	15,562	243,156	267	19,251	296,169	335	25,223	388,046
Total	**1,940**	**119,306**	**1,864,156**	**2,046**	**147,588**	**2,270,585**	**2,572**	**193,379**	**2,975,062**

Table 9: Marine Fish Landings by Species, Weight and Value 2006 to 2008-Demersal

Species	2006			2007			2008		
	M. Tons	000 Kshs.	US$	M. Tons	000 Kshs.	US$	M. Tons	000 Kshs.	US$
Demersal									
Rabbitfish	412	22,570	352,656	420	27,702	426,185	484	34,546	531,477
Scavenger	477	25,185	393,516	431	27,586	424,400	499	33,769	519,523
Snapper	193	11,045	172,578	220	14,485	222,846	244	19,326	297,323
Parrot fish	217	8,815	137,734	259	14,169	217,985	315	18,303	281,585
Surgeon fish	34	1,467	22,922	55	4,258	65,508	75	4,618	71,046
Unicorn fish	31	1,487	23,234	55	3,397	52,262	107	6,655	102,385
Grunter	88	5,554	86,781	94	7,171	110,323	135	9,909	152,446
Pouter	138	6,924	108,188	128	8,428	129,662	127	9,046	139,169
Black skin	127	6,448	100,750	153	9,268	142,585	179	11,813	181,738
Goat fish	73	4,375	68,359	87	6,305	97,000	98	7,463	114,815
Steaker	25	1,705	26,641	27	1,807	27,800	56	3,642	56,031
Rock cod	99	6,323	98,797	108	7,464	114,831	127	9,069	139,523
Cat fish	85	4,426	69,156	83	4,598	70,738	74	4,978	76,585
Mixed dermesal	955	39,937	624,016	929	53,700	826,154	1,039	65,201	1,003,092
Not Acc. for	444	21,940	342,813	458	28,551	439,246	533	35,750	550,000
TOTAL	**3,398**	**168,201**	**2,628,141**	**3,508**	**218,888**	**3,367,508**	**4,092**	**274,088**	**4,216,738**

7.1.2 Commercial fishery

The 200 nautical mile EEZ is believed to have vast fishery resources that are under-exploited. The EEZ is mainly exploited by foreign flagged vessels due to lack of appropriate local fishing vessels, fishing gears and safety gear to venture into the open waters among the local fishermen. With an estimated potential of between 150,000 to 300,000 metric tons per year, the Kenyan EEZ is currently being exploited by Distant Water Fishing Nations (DWFN) whose main targets are Tuna and Tuna like species. During the year 2007 a total of 33 purse seiners and around 30 long liners operated in the EEZ under Kenyan licenses. From available records, these foreign vessels transhipped a total of 16,564 metric tonnes of Tuna and Tuna like species through port of Mombasa during the year. Basing on the average price in the world Market of 100 US$ per ton, this would translate into a total of USD 1.7 million per year.

The annual license fees per foreign vessels cost US$ 30,000. The licenses can be paid monthly (US$ 5,000), quarterly (US$ 7,000) or annually (US$ 12,000). Charge rates for national vessels amount to about US$ 1,300, but this sum is currently under review. The offshore fishing operations in 2005, 2006 and 2007 in Kenya's EEZ involved an average of DWFN vessels, 37 PS and 30 LL. All were foreign vessels licensed by the Government of Kenya through the Ministry of Fisheries Development. The 125 number of licensed vessels (mainly PS) has increased steadily since 2003, when the Government took a keen interest in illegal fishing and occasionally used the Kenya Navy to patrol the EEZ. The increase in number of vessels applying for EEZ licenses can be also be attributed to the recent efforts through the SADC-EU MCS Program for the emerging management of the EEZ fishery. The annual average revenue earned by the GoK from EEZ licenses during the period 2005 to 2007 was around US$ 1 million.

7.1.3 Sport fishing

Sport fishing as a recreational activity has been taking place along the Kenyan Coast within the confines of various registered clubs and at times on an individual basis. Sport fishing activities do take place as far as 15 nautical miles out, along the entire coastline. It is reported that in the year 2007, there were 48 sport-fishing clubs under the umbrella of the Kenya Association of Sea Anglers. Sport fishing is seasonal with the low season occurring between May and September and peak season in October to March. Targeted species are mainly billfishes especially sailfish, swordfishes, the marlins, sharks and some tunas. The popular sport fishing areas are Malindi, Watamu and Shimoni. The sport fishing clubs do keep records on catches and in 2007 a total of 95,287 kg of the above named species were landed and recorded by the clubs.

7.1.4 Aquarium Fishery

Ornamental fish from the country are exported and have a very small local market. Some of the most frequently exported species include: surgeonfish, angelfish, blennies, butterflyfish and wrasses. In the year 2007, Kenya exported over 184,314 individual live aquarium fish worth slightly over US$ 153,642 (Kshs 11.6 million). There are 8 aquarium dealers along the Kenyan coast.

7.2 Exports of Fish and Fishery Products

A total of 1,718.19 metric tonnes of fish and fishery products valued at US$ 3,925,828 (Kshs. 296,400,000) were exported from the country to different destinations in 2007 (Table 10). The exports mainly comprised Octopus, Shark fins, Sword fish, Prawns, Lobsters, and Crabs.

During the 2007 review a total of 16,564 metric tonnes of tuna were trans-shipped through the port of Mombasa. Worth approximately US$ 600 per tonne, this translates into about US$ 9.9 million. Table 10 provides the summary of fish and fishery product exported during the year 2008.

Table 10: Exports of Fish and Fishery Products 2008

Commodity	Quantity (M. Tonnes)	Value (000 Kshs.)	US$
Swordfish	159	15,800,000	210,667
Sharks	462	20,146,000	268,613
Shark Fins	34	1,204,000	16,053
Big Eye	14	969,000	12,920
Cuttlefish	1	277,000	3,693
Lobsters	47	44,711,000	596,147
Octopus	487	106,340,000	1,417,867
Live Lobsters	8	3,844,000	51,253
Live Crabs	45	4,869,000	64,920
Prawns	68	20,144,000	268,587
Fish Oil	2	58,000	773
Total	1327	218,362,000	2,911,493
Tuna Loins	15,069	677,749,000	9,036,653
Grand Total	16,396	896,111,000	11,948,147

7.3 Coastal Ecosystem Services

Coastal forests in Kenya are estimated to cover a surface area of about 660 km^2. However, the majority of them are now degraded due to clearing for agriculture and settlements and also due to over-exploitation for timber, charcoal and fuelwood.

Main goods and services from main forest blocks

Coastal Forests

Virtually all coastal forests in Kenya have globally unique biodiversity values and most contain at least one endemic species and all deserve some form of recognition and protection. The high levels of poverty in the region means that the population is highly dependent on forests resources for their daily needs (food, medicines, and general livelihoods), which may be destructive to the environment. Agriculture and pastoralism are the major livelihood sources for most people at the coast. This sector, however, is characterized by inappropriate land use practices resulting in degradation and loss of land productivity leading to widespread encroachment on public land to grow more food and extract resources from the forests in means and rates that are not sustainable (cf. Blackett 1994, Bliss-Guest 1983).

Local values

Coastal forests have many uses, including timber production, pole collection; pit-sawing; religious (spiritual) sanctity and ceremonies; gathering of medicinal plants, and sources of building wood and charcoal energy (90% rural house-hold energy and 85% of urban household consumption) to the growing towns of Malindi, Watamu, Kilifi and Mombasa. Mangroves are also used as building materials for boats: *Sonneratia alba* is used for ribs of boats while *Heretiera littoralis* is used for boats though it is very scarce in Kenya. Large trunks of *Avicennia marina* are used to make dugout canoes. Of the total number of mangroves poles sold in Mombasa -from 6,500 score (in bad years) to 14,000 scores (in good years) some are exported to Middle East countries. A total of 3,262,000 poles (equivalent to a volume of 24,262 m^3) are estimated to be consumed annually in house building (Wass 1995).

Other coastal forests uses and values (especially mangrove) include: high quality mangrove honey (available at Malindi, Kipepeo in Arabuko-Sokoke Forest and Nature Kenya office in Nairobi), poles for fishing traps, fishing net floats, tannin for fishnets and leather industries, fisheries (fish use mangrove areas and creeks as shelter, feeding and nursery grounds) and oysters (oysters fix themselves on mangroves predominantly *Sonneratia alba* and *Rhizophora mucronata*. Coastal forests are important sources of water that sustains the local people and wildlife.

The woodcarving industry at the coast has potential for generation of wealth and employment. Currently it generates between US $ 20 - 25 million annually in export revenues. The main products include carved bowls, lion, elephant, buffalo, rhinoceros and giraffe. The main plant species being exploited at the coast are *Brachylaena huillensis* (Mhugu, Muhuhu or Mahogany mainly from Arabuko Sokoke Forest) and *Combretum schumanii* (Mkongolo). The main wood carving species, *Dalbergia melanoxylon* (African black wood - Mpingo) have been depleted from source areas in Ukambani. There are few commercial exotic plantations for production of timber at the coast compared to other regions, however, the available few are important at the national level as they provide raw materials for construction and should be targeted for improved management and production.

National level values

Due to their proximity to Mombasa and Malindi, coastal forests are important tourist destination areas. Tourism development is well established in two of these forests, Shimba Hills and Arabuko Sokoke forest reserves. In the two roads, foot trails, camp-sites, car-parks, gates and signs facilities are available though improvement is needed. Revenue is mainly collected for entrance and use of other facilities. Watamu Marine Reserve and the Mida Creek board walk are other tourist destinations with benefits flowing to local people.

The coastal forests are rich in minerals (mainly titanium and lead) making mining valuable not only to local people but also to the national economy. Silica sand for glass manufacture was formerly mined in Arabuko-Sokoke Forest.

Biodiversity Value

The coastal forests of eastern Africa are recognised as an area of global importance for their endemic plants and animals (Statterfield *et al*. 1998, Olson and Dinerstein 1998, Mittermeier *et al*. 1998). Half of Kenya's threatened woody plants occur in Coastal forests (Wass 1995). These Coastal forests, combined with Taita Hills complex and the mountains east of the Rift Valley, account for almost all the rare forest biodiversity in Kenya, with a few other rare species scattered across the large blocks of montane forests. Overall, of the forest-dependent and nationally threatened species in Kenya's forests, about 50% of the plants, 60% of the birds and 65% of the mammals are found in the Coastal forests, which show the national, regional and global importance of this region despite its relatively small forest cover.

The Kenya coastal forests are part of the EACF hotspots. Conservation International ranks it 11th in species endemism and BirdLife International ranks it as one of the most globally important Endemic Bird Areas (Bennun and Njoroge 1999). It is ranked by WWF as among the top 200 out of the worlds 850 ecoregions that are most important for global biodiversity conservation. The region contains many strictly endemic species, comprising 1,366 known endemic plants and 100 endemic animals, and shares many species with the adjacent Eastern Arc mountain ecoregion that is also of global biodiversity significance. In the whole EACF ecoregion, there are more than 4,500 plant species in 1050 plant genera with around 3,000 animal species in 750 genera (WWF-US 2003). The Kenyan Coastal forests have more than 554 strictly endemic plants (40% of the total) and 53 strictly endemic animals. According to Burgers and Clark (2000) and CEPF (2003), the area is considered to be a major global conservation priority because of the high endemism and severe degree of threat. It has a high congruence for plants and vertebrates, and ranks first for densities of endemic plants and vertebrates out of the 25 most important global biodiversity hotspots. This is because of the number of endemic plant and vertebrate species per unit area (Myers *et al*. 2000). From http://coastalforests.tfcg.org/pubs/National-Synthesis-Ken.pdf

7.4 Mangrove Forests

The area of mangroves in Kenya is estimated at 52,980 ha, spread over 18 forest formations along the coast. Lamu District, with 34,000 ha of mangroves, contains the largest mangrove area. All the nine mangrove species recorded in the Western Indian Ocean region occur in Kenya with the two species of *Rhizophora* and *Ceriops* being dominant and accounting for 70 percent of total mangroves (GOK 2007).

Mangrove forests are an important habitat for a variety of terrestrial and aquatic plants and animals. Terrestrial fauna include many species of birds, reptiles including crocodiles, mammals (pigs and monkeys) and insects; while terrestrial flora mainly comprises fungi, lichens and mistletoes. At the Tana River Delta near Kipini as well as at the Ramisi River, the animal life is abundant when compared to other mangrove areas in Kenya. Very large crocodiles are very evident here as are herds of hippopotamus. Other smaller mammals found in the mangroves of Kenya are baboons, duikers, rodents and fruit bats. Bird life is rich and most varied in most mangrove forests but especially so in Mida creek.

Aquatic flora and fauna are much more diverse. Many (possibly up to 90%) of the species found in the mangrove forests are known to spend their entire life, or at-least a major part of their life cycle in these areas. These species include a number of prawns (*Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *Matapenaeus monoceros*), crabs (*Scylla serrata*, *Uca* spp., *Sesarma* spp. and *Birgus latro*), mollusca (oysters such as *Brachydontes* spp. and *Crassostrea cucullata* and cockles, *Donax* spp.).

7.5 Seagrass Beds

Approximately 12 species of sea grasses have been reported on the Kenya Coast with some of the most common species being *Thalassodendon ciliatum*, *Halodule wrightii* and *Halophla minor* (GOK 2007). Sea grass beds cover a surface are of about 33.6 km^2, with the most important sites in the region lying between Lamu and Kiunga. In the north of Kenya (Kiunga Marine Reserve), 11 species were identified in estuary, bay and reef habitats. In Diane-Chale lagoon, preliminary studies indicate that *T. ciliatum* beds experienced a loss of more than 50 percent of cover. These degraded sites were also found to have a density of the sea urchin *Tripneustes gratilla* of more than 37 individuals/m^2, while healthy sites had a density of only 4 individuals/m^2 (WIO-LaB 2008). It is estimated that the sea grass beds are valued at US$ 65 million. Table 11 summarizes the ecosystem values in Kenya's coastal zone.

Table 11: Valuation of Ecosystem Goods and Services in Kenya (UNEP 2008)

Coral Reefs		Mangroves		Coastal Forests		Sea Grass Beds		Total
Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Value (million US$)
630	383	500	500	660	133	34	65	1,079

7.6 Coastal Agriculture

National records classify 87% of coastal land as agricultural, with 70% of the labour force in the area engaged in this activity (Mwaguni and Munga 2003). Demands to maximise food production have encouraged farming activities in this area to adopt irrigation schemes. The sector supplies about 70% of raw materials for domestic agro-industry and makes up 80% of total export earnings and 45% of government revenue. Agriculture and forestry is clearly the most dominant sector in the Kenyan economy. Agricultural activity in the coastal zone is also significant, producing food and non-food products for both subsistence and commercial use, with cashews, bixa, sisal, as well as fruits and vegetables; some being produced for export.

7.7 Tourism Sector

The tourist industry in Kenya is promoted as a destination for sun, sand and safari, and is one of the highest foreign exchange earners, only surpassed by tea and coffee. Europe is the main source continent for Kenyan tourism, accounting for 69.3 percent of the market share. Indeed, in the early 1990's the industry surpassed the traditional cash crops of tea and coffee, contributing 22% to foreign exchange earnings and 12.5% of the GDP, taking into account all linkages with the sector (CLS 2010). The sector makes up 4% of total employment in the country, providing nearly 483,000 jobs in 2008, and contributes 18% to total foreign exchange earnings, between 52% and 68% of which is derived from coastal tourism activity. The sector has also been strong in recent years, with arrivals increasing from 814,000 in 1990 to over 2 million in 2007 and revenue increasing from US$864 million (Kshs 56.2 billion) to US$ 1 billion (Kshs 65.4 billion) between 2006 and 2007, representing an 11.6% growth rate. Taking 60% of these revenues as due to Coastal tourism will imply that Coastal Tourism generated a total amount of between US$ 518 and 604 million. Coastal tourism is conducted with a mass orientation and strong cultural component. The primary attractions are the warm climate, the beautiful coastal scenery and clean sandy beaches. Thus, tourism infrastructure and related facilities have mushroomed along the beach areas.

The coastal area generates the highest number of bed occupancies in Kenya with an average of 55% of total bed nights in Kenya. In 2006 for example, the coastal province of Kenya accounted for 3,420,300 bed nights (57%) of bed nights compared with 1,204, 000 (20%) bed-nights for Nairobi. The average length of stay for a visitor in the country in 2005 was 14 days with 6.8 million overnight stays. The Coast also has the highest number of tourism enterprises in Kenya accounting for close to 50% of hotels and 43% of tour operators (Table 12). The sector is also a major source of Government Revenue in the form of taxes, duties, licence fees and entry fees.

In the major tourist centers, various facilities and services have also mushroomed to meet the demands of the tourist industry. Such services include tour operators, banking and recreation services. Indeed, the rapid growth of Ukunda near Diani Resort, Malindi and Watamu are directly attributed to the development of tourist facilities. In Malindi and Watamu the main activity driving the local economy is tourism, which accounts for approximately 60% of business. The tourism industry also supports local livelihoods and economy through the provision of employment, and also through provision of services and the supply of commodities such as agricultural products, seafood and building materials.

Table 12: Table showing contribution of Coast province in bed occupancy (CLS 2010)

	1998	1999	2000	2001	2002	2003	2004
Coastal Beach	1,505.3	1,625.2	2,065.2	1,438.2	2,171.8	1,269.6	1,883.5
Other	109.1	73.9	85.8	136.1	108.2	36.5	29.4
Coastal Hinterland	43.9	48.7	76.3	56.6	44.9	60.9	52.9
Total occupied in Kenya	2,813.0	2,951.0	3,687.8	2,764.10	3,479.4	2,605.9	3,791.5
Coastal Province Contribution	58.9%	59.2%	60.4%	59%	67.6%	52.4%	52%

7.8 Harbours and Ports

Port activity along the Kenya coast is mainly concentrated in Mombasa and Lamu. The port of Mombasa, Kenya's largest port provides one of the country's economic strongholds, maintaining maritime trade, commerce and harbour activities. Other ports are generally smaller, mainly serving fishing boats and some small craft transporting consumer goods. These include Lamu (which has also historical significance in maritime trade), Malindi, Kipini, Kilifi, Mtwapa and Shimoni. Developments at the Mombasa port have a long-term perspective in order to extend facilities for oil reception and the container terminal, indicating extensive use of land (Hoyle 2000).

7.9 Coastal mining

Other coastal mineral resources of minor local importance include barites, galena, iron ore, gypsum and rubies. However all of these may be dwarfed by the development of titanium mining in Kenya. There are vast Titanium reserves in the Magarini Sands Belt, which stretches from Shimoni in the south coast to Mambrui in the north. Titanium has traditionally been used to make a white pigment for paint, plastic and paper, but is increasingly in high demand for applications in the armaments and space industries. Since 1995 a Canadian-based company (Tiomin Resources Inc.) has been negotiating an agreement with the Kenyan government to mine titanium. Tiomin hopes to start its activities in the Kwale District and expects to generate around US$ 47 million in annual cash flow. Noteworthy, mining is a desired evil and must be properly managed to ensure that other coastal forest values e.g. timber, energy, pole wood, medicine, biodiversity, tourism, ecotourism, carbon sinks and water catchments are not compromised.

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