Resilience of Coastal Systems and Their Human Partners

Ecological and social profile of coastal systems in Kenya, Mozambique and Tanzania

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www.unep.org/nairobiconvention/

Resilience of Coastal Systems and Their Human Partners

Ecological and social profile of coastal systems in Kenya, Mozambique and Tanzania

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Front cover photo: Machui milkfish farmers, Tanga coast, Tanzania. *Credit: M. Samoilys*

Back cover photo: Chole rocks (Kisiwakikubwa), Dindini, Tanzania. *Credit: M. Samoilys*

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ABBREVIATIONS AND ACRONYMS

AIDS.....acquired immune deficiency syndrome
ASCLME.....Agulhas and Somali Current Large Marine Ecosystems
AMCEN.....African Ministerial Conference on the Environment
AMCOW .....African Ministerial Council on Water
AU .....African Union
BMU.....beach management unit
CBD.....Convention on Biological Diversity
CBO.....community-based organization
CCA.....crustose coralline algae
CDA.....Coast Development Authority
CITES.....Convention on International Trade in Endangered Species of Wild Flora and Fauna
CO_2 .....carbon dioxide
COMESA.....Common Market for Eastern and Southern Africa
CORDIO.....Coastal Oceans Research and Development in the Indian Ocean
CSO .....civil society organization
DfID.....Department for International Development
EAC .....East African Community
EAME.....Eastern African Marine Ecoregion
EBSA .....Ecologically or Biologically Significant Area
EEZ.....exclusive economic zone
EFA.....environmental flow assessment
EIA.....environmental impact assessment
EMA .....Environmental Management Act
EMCA.....Environmental Management and Coordination Act
ENSO .....El Niño Southern Oscillation
EU.....European Union
FAO .....Food and Agriculture Organization
GDP .....gross domestic product
GEF.....Global Environment Fund
GMPP .....Global Marine and Polar Programme
GNI.....gross national income
HDI.....human development index
HIV.....human immunodeficiency virus
IAEA.....International Atomic Energy Agency
ICZM .....Integrated Coastal Zone Management
ID.....identification card
IMO .....International Maritime Organization
IOC .....Indian Ocean Commission
IOD.....Indian Ocean Dipole
IOTC.....Indian Ocean Tuna Commission
IUCN ESARO .....IUCN Eastern and Southern Africa Regional Office
IUCN .....International Union for Conservation of Nature
KFS.....Kenya Forest Service
KMFRI .....Kenya Marine and Fisheries Research Institute

KWS .....Kenya Wildlife Service
LAPSSET .....Lamu Port Southern Sudan–Ethiopia Transport Corridor
MICOA.....Ministry for Coordination of Environmental Affairs
MOU.....memorandum of understanding
MPA.....marine protected area
MPRA.....Marine Parks and Reserves Authority
NEMA.....National Environment Management Authority
NEMC.....National Environment Management Council
NEPAD .....New Partnership for Africa's Development
NGO .....non-government organization
POP.....persistent organic pollutant
RFMO.....regional fisheries management organization
RUMAKI.....Rufiji-Mafia-Kilwa (Seascape Programme)
SADC .....Southern Africa Development Community
SAPPHIRE .....WIO Large Marine Ecosystems Strategic Action Programme Policy Harmonization and Institutional Reform
SCUBA.....self-contained underwater breathing apparatus
SNV .....Netherlands Development Organisation
SSG.....Shark Specialist Group
SST .....sea-surface temperature
SWIOFish1 .....Southwest Indian Ocean Fisheries Governance and Growth Project
SWIOFC.....Southwest Indian Ocean Fisheries Commission
SWIOFP.....South West Indian Ocean Fisheries Project
TFS .....Tanzania Forest Services
UN .....United Nations
UNCLOS .....United Nations Convention on the Law of the Sea
UNDP .....United Nations Development Programme
UNEP.....United Nations Environment Programme
UNESCO .....United Nations Educational, Scientific and Cultural Organization
UNESCO-IOC.....Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization
USA .....United States of America
USAID.....United States Agency for International Development
USD .....United States dollar
WCS .....Wildlife Conservation Society
WIO .....Western Indian Ocean
WIO-C .....Consortium for Conservation of Coastal and Marine Ecosystems in the Western Indian Ocean
WIO-LaB.....Addressing Land-based Activities in the Western Indian Ocean
WIOMSA.....Western Indian Ocean Marine Science Association
WIO-SAP.....Implementation of the Strategic Action Programme for the Protection of the Western Indian Ocean from Land-based Sources and Activities
WWF .....World Wide Fund for Nature
WWF-EARPO.....WWF Eastern Africa Regional Programme Office
WWF-ESARPO....WWF Eastern and Southern Africa Programme Office

EXECUTIVE SUMMARY

This report explains the ecology and social profile of coastal systems in Kenya, Mozambique and Tanzania in order to contribute to the development of effective strategies to enhance the resilience of marine and coastal systems in the Western Indian Ocean. Special consideration is given to the effects and consequences of climate change and economic development.

Eastern Africa's coastal habitats host rich marine biodiversity with more than 6,000 documented species. Six major rivers flow into the Western Indian Ocean (WIO): the Tana and Athi-Sabaki Rivers in Kenya, the Rufiji and Ruvuma Rivers in Tanzania, and the Zambezi and Limpopo Rivers in Mozambique. Their deltas are ideal nursery grounds and breeding areas for prawns, crabs, sea cucumber, snapper, emperor, grouper and several offshore commercially important tuna and mackerel. However, dams built upstream have reduced water flow and sediment and nutrient discharge to the coast. The resulting decline in productivity has had an adverse effect on fisheries.

The WIO, a subset of the Indo-West Pacific Region, has about 5% of the world's mangrove cover with 10 species. Mangrove forests are valued as carbon sinks that counter the effects of climate change through their high productivity and by trapping carbon in biomass and sediment. They thrive in river mouths where they trap sediments that would otherwise be washed out to sea. They host fishes, crabs, molluscs and flora.

Mangrove forests in eastern Africa are in a relatively good state of health. They experienced an attrition rate of about 8% between 1980 and 2005 compared with a global loss of more than 30% over the last 50 years. Nevertheless, economic opportunity tends to overshadow biodiversity and conservation in their management. The great majority are subject to forestry regulations so that they can be utilized as a natural resource. Mangrove harvesting provides benefits to local communities, but when harvesting is excessive, it stunts trees and leads to sparse distribution. Mozambique has 60% of mainland eastern Africa's mangroves. In Cabo Delgado Province, the forests are increasing in size because there is very little logging.

Mangrove forests function as service providers to coral reefs, fisheries, prawn farms and land protection, but this carries little weight in the face of alternative incentives. Tourism development, port construction, agriculture and the insatiable demand for fuel wood are causing indiscriminate cutting of primary mangrove forest. There is little or no replanting in the aftermath. Oil and gas extraction is a potential threat to mangroves. Drilling started in 2013 offshore from Cabo Delgado Province in Mozambique in what is one of the largest natural gas reserves in the world. Safeguarding ethical extraction practices will be critical, hence the development of initiatives such as the Fair Coasts Programme[1], aimed at facilitating direct dialogue between local communities, the government of Mozambique and the drilling companies.

Recently considered port construction is a certain threat to the region's mangroves forests. Local community groups, environment managers and conservationists have voiced concern over expansion plans for the ports at Mtwara and Tanga to accommodate the shipping traffic generated by oil and gas companies. The mangrove forests around Manda and Pate Islands will be removed or damaged when work begins on the Lamu Port Southern Sudan–Ethiopia Transport Corridor (LAPSSET). Mariculture, which is expanding in response to a growing market demand, poses yet another threat. Prawn farmers must not repeat the mistakes made in Asia where a landscape denuded of mangroves exacerbated the catastrophic destruction caused by the 2004 tsunami.

Mozambique's northern reefs in the Quirimbas Archipelago of Cabo Delgado Province are some of the healthiest, most resilient and diverse coral reef systems in the WIO and have been recommended as a World Heritage site. Tanzania's southern reefs in Mnazi Bay, Mafia Island and the Songo Songo Archipelago are also highly diverse and resilient to climate change.

Warmer sea-surface temperatures caused by global warming bleach corals and eventually kill them. The reefs in northern Mozambique and southern Tanzania have demonstrated resilience to bleaching and an ability to return to a coral-dominated state after the extreme temperatures of the 1998 El Niño event. The presence of crustose coralline algae on the reefs around Mafia Island and the Songo Songo Islands, a prescursor to coral growth, suggests that if conditions are ideal, their recovery from a bleaching event will take 10–15 years. Coral cover is higher in the Songo Songo Islands than in Mafia Island, probably because the reefs were protected by the turbid water of the Rufiji Delta, which resulted in lower mortality. Kenya's reefs have suffered mortality levels of more than 80%.

Mozambique has a biodiverse coral-reef system with nearly 15% of the WIO's coral reefs, up to 400 coral species and 295 fish species, primarily in Cabo Delgado and Nampula Provinces. Tanzania has the largest area of coral reefs with 3,500 km^2 covered by fringing reefs. However, dynamite fishing is a widespread and uncontrolled practice that has destroyed the reefs to such an extent that many are now dominated by macroalgae. Kenya's coral reefs, while the fewest, are protected by a network of established marine

[1] The Fair Coasts Programme was developed with the support of the Mechanism for Strengthening Capacity of the Civil Society (MASC), the Mitsubishi Foundation for Europe, Middle East and Africa (MCFMEA), the We Effect and Irish Aid. The programme was developed by IUCN ESARO in collaboration with a consortium of national and regional partners.

parks and marine reserves that encompass neighbouring seagrass beds and mangrove forests. The marine parks have allowed fish populations to recover over the past 20 years, and the marine reserves are relatively well managed. The Lamu Archipelago hosts rare, endemic species with limited ranges.

To maintain a healthy and vibrant coral reef ecosystem in eastern Africa, its countries must commit themselves to creating a large-scale network that can oversee marine protected areas and manage fisheries regionally in an ecosystem-based approach. This is particularly relevant for the northern reefs, which will be more vulnerable to bleaching events than the southern reefs.

Mozambique, Tanzania and Kenya have the WIO's greatest diversity of seagrasses with 12 widely distributed species. These unusually productive ecosystems are found next to shallow fringing coral reefs and serve as nursery grounds and foraging areas for *Dugong dugon*, turtles and more than 100 species of fish. Seagrass beds are poorly understood, neglected ecosystems that have yet to be recognized for their efficiency in maintaining biodiversity and safeguarding threatened species. Like the mangroves, they combat climate change by storing up to 500 tonnes per hectare of carbon, equivalent to the carbon stored in primary tropical forests. They also stabilize sediment, protect shorelines, purify water and recycle nutrients. Further research is called for to understand better their resilience to climate change and their economic contribution to coastal communities.

Seagrass beds continue to be damaged by trawling, seine netting and dynamite fishing. Upstream agriculture also damages seagrass beds, notably the Athi-Sabaki and Tana Deltas in Kenya and the Rufiji Delta in Tanzania. When coastal development is not well managed, it destroys seagrass beds through the unregulated dumping of solid waste, sewage and dredge soil. The proposed Lamu Port, for example, could significantly affect large tracts of seagrass beds that are important turtle and dugong feeding grounds. Marine spatial planning which incorporates segrass beds into national marine conservation policy is needed in the three Resilient Coasts target countries.

Many fauna species across the three countries are under stress from human predation, ranging from uncontrolled offshore commercial fishing with foreign longliners and purseiners that accidentally net sharks and rays to targeted fishing for shark fins and meat. Sharks, turtles, dugongs and coelacanths are in particular danger.

The population status of almost 50% of all sharks is unknown due to insufficient data. Of those species that have been assessed by the IUCN Specialist Shark Group, 22 are Critically Endangered, 41 are Endangered, 116 are Vulnerable and 133 are Near Threatened. Not a single reef shark was recorded during recent surveys of coral reefs at 74 sites in Mozambique and Tanzania.

The state of turtle populations is a good indicator of the overall health of coastal and marine ecosystems. Five out of seven species of the world's marine turtles occur in Mozambique, Tanzania and Kenya. All five species are on the IUCN Red List either as Critically Endangered (hawksbill, leatherback) or Endangered (green, olive ridley and loggerhead). Extensive turtle research in the WIO dating back to the 1990s has been central to marine planning exercises for mainland East Africa. However, more specific data are needed on turtle feeding and breeding, and juvenile and adult migratory routes. Very little is known about the dugong population, but it is believed to be declining to the point of extirpation in the WIO.

Marine and coastal ecosystems and coastal communities live in critical interdependence with the vulnerability and resilience of one directly affecting the other. However, this interdependence is not properly recognized in legislative frameworks, institutions and social systems. Coastal poverty, as opposed to rural poverty, has distinguishing features. Many coastal resources are less dependent on short-term weather patterns than on terrestrial resources, allowing more reliability, although the 'fugitive' nature of other marine resources, particularly fish, adds a level of uncertainty to coastal livelihoods. The open-access nature of many coastal resources, while providing opportunities for people without property or capital, also exposes resources to competition from other users, and to expropriation for other uses, including tourism or conservation.

Small-scale fisheries supply up to 98% of the marine catch and are the principal income-generating activity for a large number of households. The diminishing access to resources among the poor, as demand for these resources increases, encourages artisanal fishers to resort to using illegal gear or fishing in protected areas. The fishing industry's profitability would improve if there were more processing facilities to create added value (in particular in Mozambique and Tanzania), and feeder roads to provide access to markets.

Coastal forests and mangroves are important sources of wood, firewood and non-wood products for local communities. More and more coastal forests and wetlands are being cleared not only for subsistence farming but also for irrigated cash-crop plantations sited near rivers. Mangroves are being exploited for timber, firewood and charcoal.

Today's world is increasingly complex and unpredictable. With rapidly changing demographics, economies and climates in a globalized world—we can no longer afford to engage as 'business as usual'. Effective responses are required at multiple scales and by multiple actors.

This report describes the richness and the complexity of coastal systems and their human partners across Mozambique, Tanzania and Kenya. In doing so, it is our hope that it will stimulate new ways of thinking and working together—breaking down the existing sectoral and organizational silos that do not encourage exchange and cooperation, and giving rise to new approaches that better enable alliances, collaborative learning and adaptive management.

1. INTRODUCTION AND BACKGROUND

This report was developed for the Resilient Coasts initiative, a partnership[2] driven programme that 'builds knowledge, supports action on the ground and enhances governance and policy processes in support of building resilience of coastal systems against global change, including climate change.'

The Resilient Coasts initiative builds on the experiences of Mangroves for the Future (MFF)[3] in Asia. The early successes of MFF led to a request by the governments of Kenya and Tanzania for development of a programme specifically tailored to the needs of the Western Indian Ocean.

Resilient Coasts is aimed at 'strengthening the resilience of coastal socio-ecological systems in the Western Indian Ocean region' with a focus on four focal areas: i) Strengthening adaptive capacities of local communities dependent on coastal and marine resources; ii) Enhancing resilience of critical coastal ecosystems and habitats; iii) Influencing coastal economic development to be more environmentally sustainable and socially equitable; iv) Improving the effectiveness of local governance in managing and influencing coastal ecological and social systems.

Resilient Coasts adopts a reef-to-ridge approach, engaging with territorial waters, river basins and catchments affecting and being affected by coastal systems. The Programme's focus is centrered around a knowledge-practice-policy nexus, integrating the establishment of mechanisms for the longer term sustainability of benefits realized. The programme applies a multi-stakeholder and multi-sectoral approach, bringing together governments, private sector, NGOs, academia and community stakeholders.

Coastal ecosystems are natural infrastructures that are important to the wellbeing of local populations as well as to national and regional economic development. The purpose of this report is to understand the ecology and social profile of coastal systems in eastern Africa to contribute to the formulation of effective strategies for their conservation, restoration and sustainable management by the stakeholders of the Resilient Coasts initiative.

The report addresses the following questions:

- Are coastal systems[4] sufficiently resilient[5] to global climate change to enable sustainable development[6] ?
- What are the key factors affecting the resilience of coastal systems (illustrated in Figure 1.1)?
- How effective are local, national and regional responses to vulnerability?

This study is a desk review using a resilience-based analytical framework, illustrated in Figure 1.1. The framework identifies four critical spheres within coastal systems: i) Institutional; ii) Socioeconomic; iii) Ecological; and iv) Climate. Each of these systems is viewed as being interrelated with the relationships within and between them having a bearing on the resilience of coastal systems. The framework further defines critical elements within each of these spheres identified as being necessary for understanding resilience. The information extracted from published papers and reports has been used to develop an understanding of the ecological and socioeconomic resilience of coastal systems. This understanding can then be used to identify the areas where Resilient Coasts can make valid geographic and socioeconomic contributions.

For the purpose of this report, global change is defined as change caused by increased greenhouse gas emissions resulting in a high CO_2 world and the direct and indirect changes that ensue. Increased greenhouse gas emissions affect the ocean in three major ways. They warm the sea-surface temperature (SST) and cause ocean acidification and deoxygenation (Turley et al. 2011). The latter two effects are poorly understood, particularly in eastern Africa. One secondary effect is rising sea levels caused by melting polar ice caps. Another is coral bleaching and coral death caused by rising SST. These latter conditions, which have been extensively studied and measured in the Western Indian Ocean (WIO) (Obura 2005, McClanahan 2009) and elsewhere (Hoegh-Guldberg 1999; Hughes et al. 2003), suggest likely ecosystem phase shifts as coral reefs become dominated by macroalgae (brown algae such as Turbinaria, *Sargassum* spp.) (Bellwood et al. 2004; Hughes et al. 2005).

Acidification will have a significant impact on marine resources and fisheries (Turley et al. 2011) because the changes to ocean chemistry will affect marine organisms that rely on pH-sensitive chemical reactions. This field is relatively recent, but reports predict trophic shifts

[2] The main implementation partners are IUCN - ESARO, the Nairobi Convention, WIOMSA, CORDIO in collaboration with participating governments.

[3] Known as MFF, Mangroves for the Future is a partnership-based initiative promoting investment in coastal ecosystems for sustainable development. Initially catalysed by the December 2004 Indian Ocean tsunami, MFF provides a collaborative platform to help countries, sectors and agencies in the MFF region tackle the growing challenges to coastal sustainability. For additional detail: http://www.mangrovesforthefuture.org/who-we-are/about/who-we-are/#sthash.LJRwqWbB.dpuf

[4] Coastal systems are defined here as both social and ecological.

[5] Resilience is defined here as being able to anticipate, minimize and absorb disturbances and reorganize while undergoing change.

[6] This incorporates economic and social developmental goals alongside the protection of biodiversity.

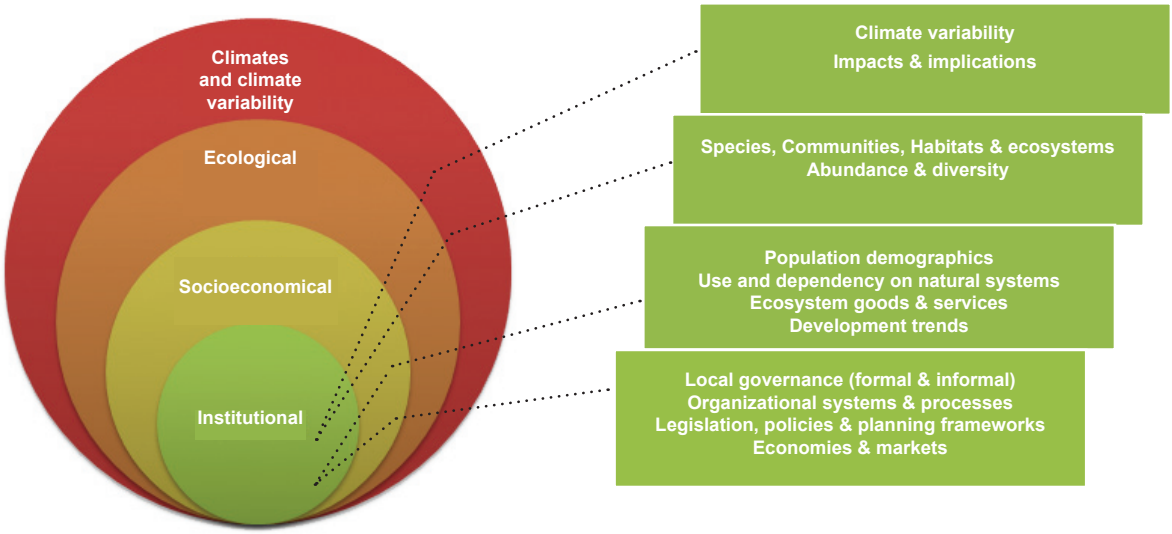


Figure 1.1: Resilience framework for the report.

as molluscs, corals and other organisms with calcium carbonate skeletons are compromised. Deoxygenation is caused by ocean warming as oxygen becomes less soluble. This results in less growth of most marine organisms and a shift to low-oxygen-tolerant organisms, often micro-organisms. At the same time, economic development and population growth are having a marked effect on coastal environments and the people who live there. These changes are a result of a multitude of factors including unchecked urbanization, port development, the mechanization of fisheries, population growth, pollution, and oil and gas extraction.

This report is laid out in three chapters **(2,3,4)** that serve to answer the questions posed at the beginning of the report and a final chapter **(5)** that is an institutional analysis, as follows:

2) **State.** The current state and trends of the principal components within three spheres—ecological, socio-economic, institutional. The critical natural external forces affecting these three spheres are identified and factored into the situation analysis.

3) **Relationship.** The relationship between the environmental and socioeconomic spheres and the extent to which each sphere reinforces or undermines the resilience of the other.

4) **Adaptability.** This chapter was to analyse the environmental and socioeconomic spheres and the institutional analysis to assess the adaptability of the different components. It became apparent that this was a huge task that required a consultative workshop with key partners and stakeholders. This workshop is intended during the first phase of the Resilient Coasts programme. Here, concepts of adaptability are discussed within the context of the report's findings.

5) **Institutional analysis.** Details the institutions and governance frameworks involved in marine and coastal management in Mozambique, Tanzania and Kenya. It also looks at international and regional institutions and frameworks involved with coastal and marine issues.

The geographic scope of the report covers Mozambique, Tanzania and Kenya (Figure 1.2) and uses a reef-to-ridge approach, focusing on territorial waters, river basins and catchments (Table 1.1). The reef-to-ridge approach was put forward in the Caribbean in the late 1990s when the links between land-based activities upstream and the marine and coastal environment became increasingly evident. This approach has been taken forward in Australia and Asia (e.g. Geoghegan et al. 2003; Golbuu et al. 2011). Links with offshore marine systems have also been taken into account where there is a significant relationship to coastal systems. Territorial waters are generally defined as being within 12 nmi[7]. This value is used here as a useful benchmark since marine jurisdiction invariably refers to territorial waters as available exclusively for citizens and residents. In contrast, the exclusive economic zone (EEZ) ocean waters that extend beyond the 12nmi zone to 200nmi are typically exploited by foreign fisheries vessels and hydrocarbon and mineral extraction industries.

This report makes some reference to information from neighbouring countries such as Madagascar, South Africa, Seychelles and Somalia (Figure 1.2) because these countries have the potential to partner with the Resilient Coasts programme as they are either part of Mangroves for the Future-Asia (Seychelles), or have sufficient internal resources and experience (South Africa), or have expressed interest in being part of Resilient Coasts in the future (Madagascar).

[7] The nautical mile (nmi) is a unit of length set by international agreement at 1,852 metres.

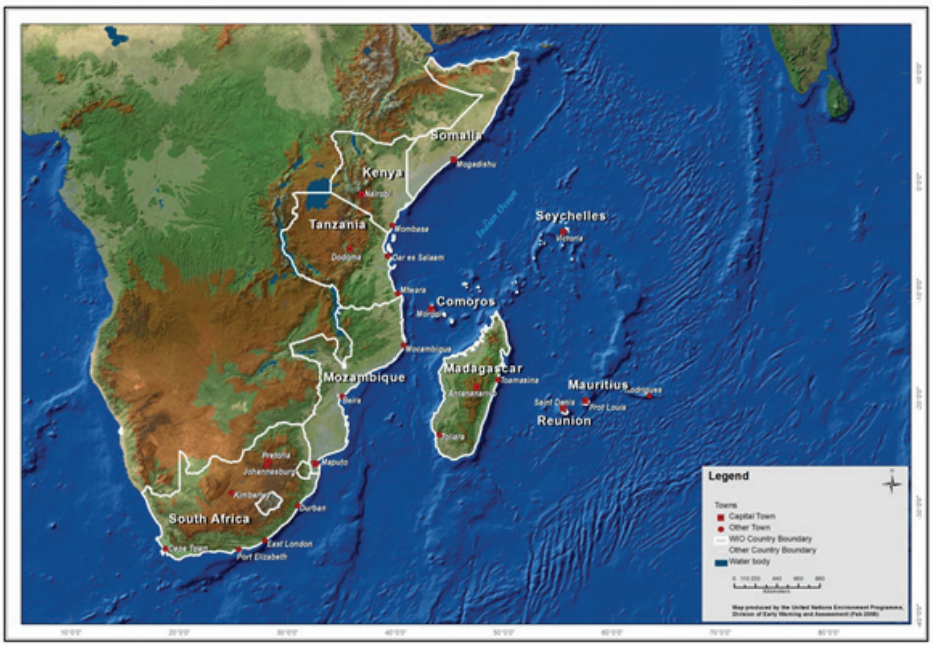


Figure 1.2: Countries of the WIO showing towns and national boundaries. (Source: UNEP Division of Early Warning and Assessmen).

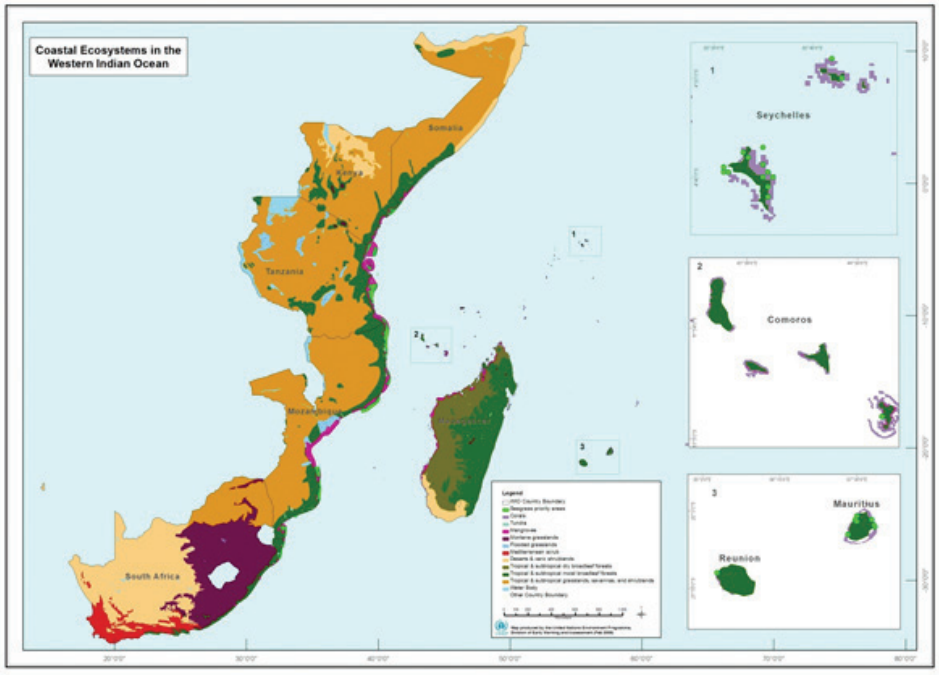


Figure 1.3: Regional map showing key coastal habitats of mangroves, coral reefs and seagrass beds. (Source: UNEP Division of Early Warning and Assessment).

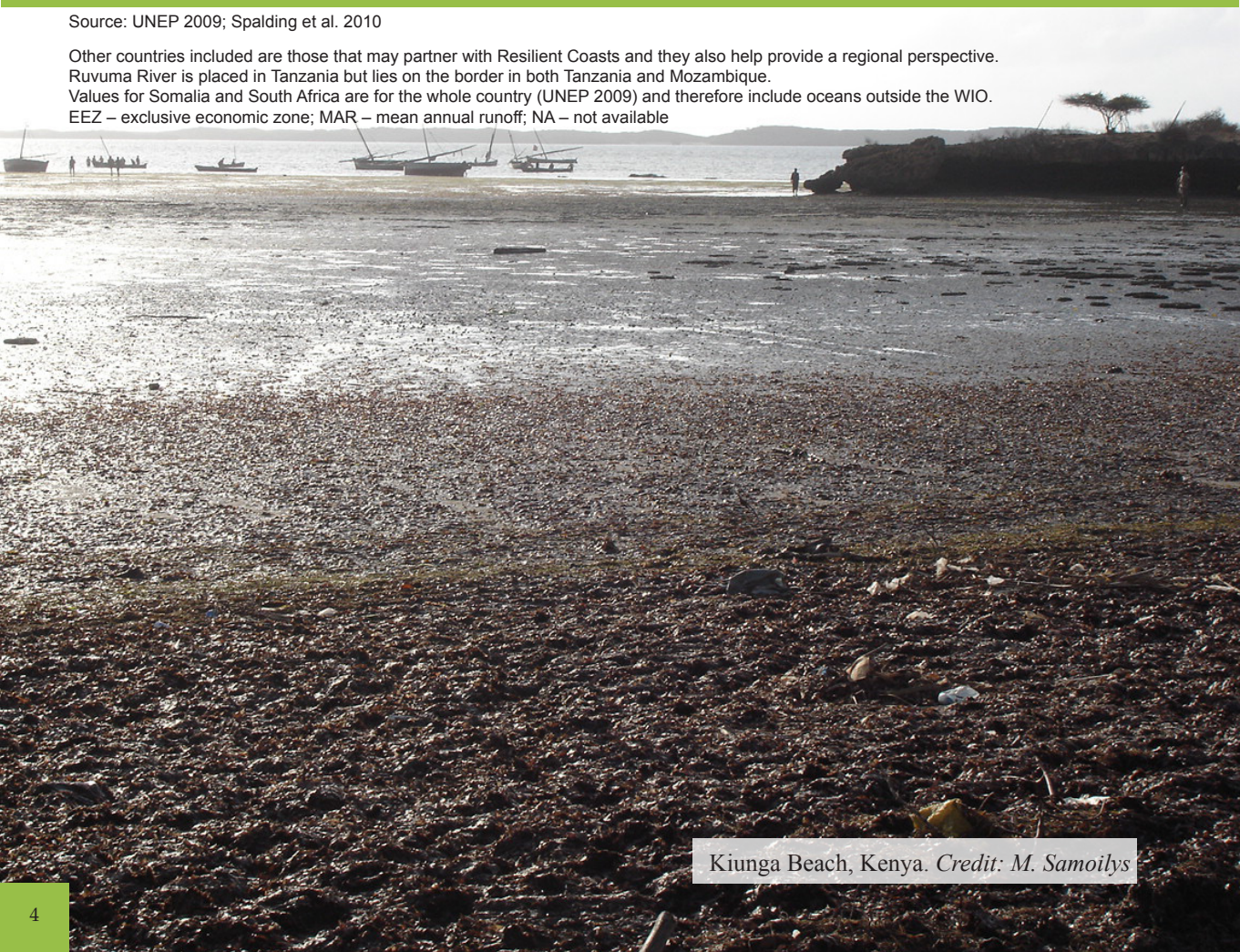
Figure 1.3 and Table 1.1 provide an overview of the biophysical and geographic features of the three countries and their neighbouring countries in the WIO. They illustrate the major rivers that form coastal deltas and estuaries; the extent of coastal waters; how these differ widely between the three countries; and the extent of mangroves, coral reefs and seagrass habitats in each country.

Table 1.1: Biophysical and geographic characteristics of Mozambique, Tanzania and Kenya within the WIO region

Country	Coastline (km)	Territorial waters (km^2)	Continental shelf (km^2)	EEZ million (km^2)	Major rivers and length	River MAR (m)	River sediment load (Mt/yr)a	Coral reef area (km^2)	Mangrove area (km^2)	Seagrass area (km^2)
Kenya	536	12,832	8,460	0.104	Tana – 1,102 Sabaki – 650	38 35	6.8	630	610	33.6
Madagascar	4,828	124,938	96,653	1.079	Betsiboka – 525	NA	NA	2,230	2,991	NA
Mozambique	2,470	70,894	73,300	0.493	Zambezi – 2,650 Limpopo – 1,750	67–190 13	22–43 10–34	1,860	2,909	439
Seychelles	491	45,411	31,479	1.288	none	—	—	1,690	32	NA
Somalia	3,025	68,849	40,392	1.200	Juba–Shebelle	NA	NA	710	48	NA
South Africa	2,881	74,699	160,938	1.1016	Incomati – 480	46	7	~50	31	~7
Tanzania	1,424	36,578	17,903	0.204	Ruvuma – 800 Rufiji – ~ 600	96 NA	NA 15–17	3,580	1,287	NA

Source: UNEP 2009; Spalding et al. 2010

Other countries included are those that may partner with Resilient Coasts and they also help provide a regional perspective.
Ruvuma River is placed in Tanzania but lies on the border in both Tanzania and Mozambique.
Values for Somalia and South Africa are for the whole country (UNEP 2009) and therefore include oceans outside the WIO.
EEZ – exclusive economic zone; MAR – mean annual runoff; NA – not available



Kiunga Beach, Kenya. *Credit: M. Samoilys*

2. STATE OF THE COASTAL AND MARINE ECOSYSTEMS

Ecological characteristics

This chapter describes the ecological and the socioeconomic situation of the coastal and marine zones of Mozambique, Tanzania and Kenya. The coastal margins of Mozambique, Tanzania and Kenya are at the western extremity of the western Indo-Pacific biogeographic realm (Figure 2.1, Spalding et al. 2007). Based on taxonomic configurations, evolutionary history, dispersal and isolation, Spalding and co-workers defined this region as the WIO Province (Province No. 20) with three mainland ecoregions (Figure 2.1).

Coastal ecosystems are natural infrastructures that are important to both the wellbeing of local populations as well as national and regional economic development. The purpose of this report is to understand the ecology and social profile of coastal systems in eastern Africa to contribute to the formulation of effective strategies for their conservation, restoration and sustainable management by the stakeholders of the Resilient Coasts initiative.

Obura's analysis (2012) of the diversity and distribution of reef-building corals revises definitions of the marine ecoregions of the world (Spalding et al. 2007) and defines the five ecoregions (Table 2.1) used in this report. These ecoregions are defined by the WIO's five main ocean circulation patterns (Figure 2.2), originally described by Schott and McCreary (2001). They were further described in the National Marine Ecosystem Diagnostic Analysis reports for each of the three countries. These reports were produced by the Agulhas and Somali Current Large Marine Ecosystems Project (ASCLME 2012 a,b,c). Readers seeking more information and greater detail can refer to them.

This report highlights the features of eastern Africa's oceanography that are important for providing resilience to climate change. It should be noted that research on this topic is still in the early stages. Three ocean circulation patterns are likely to boost resilience: the South Equatorial Current; Comoros gyre and related eddies in the Mozambique Channel; and the East African Coastal Current. The South Equatorial Current flows west across the northern part of the Mozambique Channel linking Madagascar and Comoros to mainland eastern Africa. It bifurcates at Cabo Delgado Province to join the East African Coastal Current flowing north and Comoros gyres and eddies flowing south (Figure 2.2). These flows across the Mozambique Channel are important to consider in regional management planning (Obura et al. 2012).

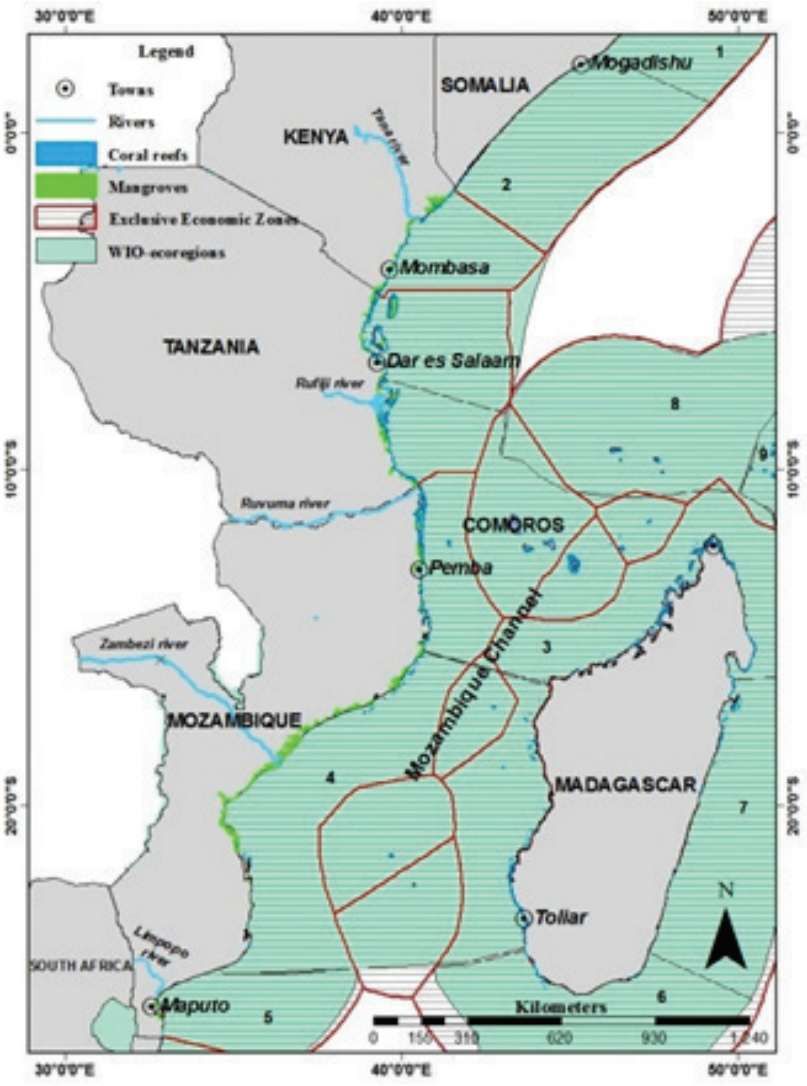


Figure 2.1: Seychelles, Somalia and South Africa. Ecoregions are those defined by Obura (2012) based on the distribution of hard-coral species.

Table 2.1: Marine ecoregions of the study area

No.	Geographic range
1	Somalia
2	Southern Somalia, Kenya, northern Tanzania – monsoon coast
3	Northern Mozambique Channel: southern Tanzania, northern Mozambique
4	Southern Mozambique Channel: central southern Mozambique
5	Delagoa: southern Mozambique, northern South Africa

Source: Spalding et al. 2007; Obura 2012

This biogeographic description of the WIO helps put in context the vulnerabilities and resilience to climate change of the different marine ecosystems of eastern Africa.

Climatically the WIO is characterized by monsoon rains which drive the weather, river flows and sea conditions. The northern part of Mozambique, Tanzania, Kenya and southern Somalia receive long and heavy rains during March to May before the onset of strong southeast monsoon winds. Short rains occur between October and December and herald the start of the lighter northeast monsoon winds. This cycle has become less predictable in recent years with erratic rainfall patterns and inconsistent monsoon periods. This is mentioned frequently by coastal communities as their livelihoods are closely aligned to these weather patterns (Maina et al. 2012; Laizer et al. in press).

In central and southern Mozambique the climate shifts between tropical and subtropical regimes while the weather pattern is driven by the Aguhlas Current (Figure 2.2). Tropical cyclones are common in the southern Mozambique Channel and have a devastating effect on economic development. Their proximity to the coast strongly affects the weather patterns over Mozambique, increasing convection and rain showers along the Intertropical Convergence Zone[8].

[8] Review of the 2010/2011 and 2011/2012 cyclone seasons, World Meteorological Organization Tropical Cyclone Committee for the southwest Indian Ocean, 20th session, Maputo, Mozambique, 3–7 Sep 2012.

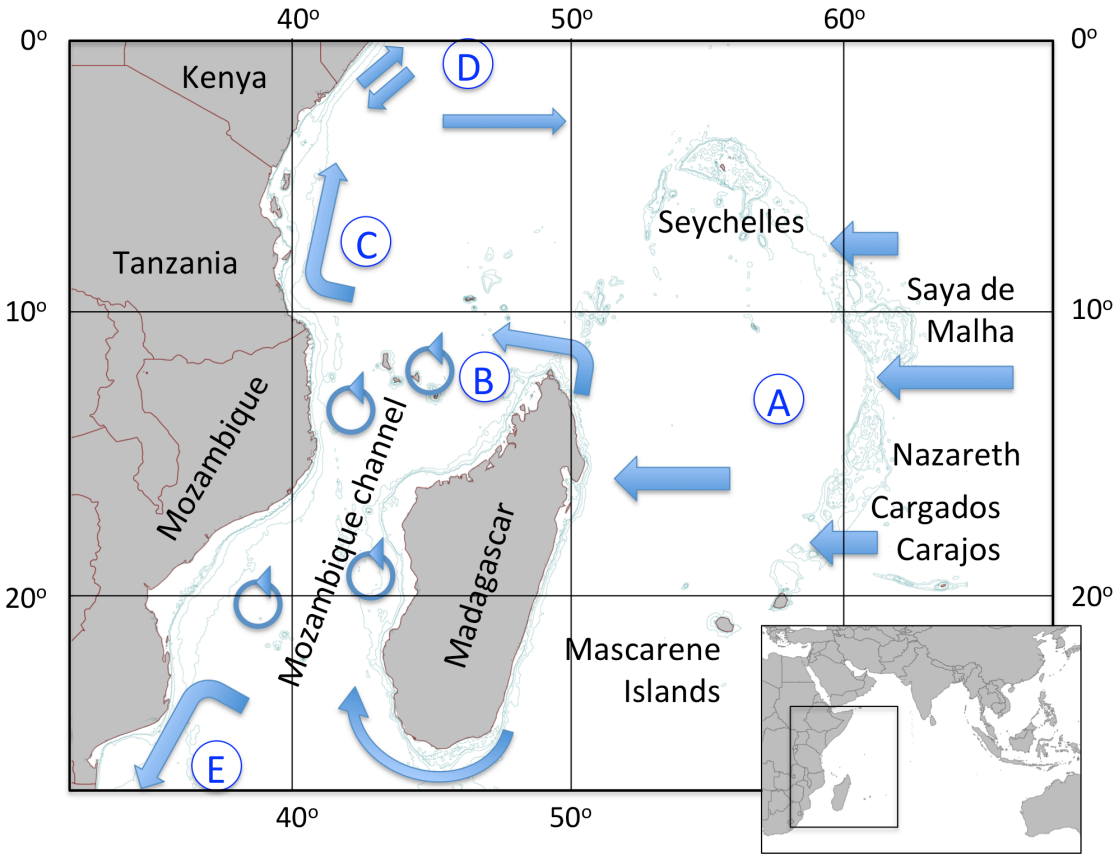


Figure 2.2: WIO showing the main ocean currents that define the region. A = South Equatorial Current; B = eddies and Comoros gyre in the Mozambique Channel; C = East African Coastal Current; D = Somali Current; E = Agulhas Current. ©David Obura (2012)

The most relevant climate phenomena affecting the eastern African marine environment are the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). ENSO is a system of interactions between the equatorial Pacific Ocean and the atmosphere above it. The state of the ENSO system fluctuates from year to year. One of the main ways to observe these fluctuations is through changes in the SST of the equatorial Pacific Ocean. El Niño and La Niña events are opposite states of the ENSO system. El Niño occurs when the equatorial Pacific is warmer than average, La Niña when it is cooler than average.

The ENSO phenomenon is a fundamental and quasi-periodic feature of the ocean atmosphere system, ranging in frequency from seasonal to about eight years (Rasmusson and Carpenter 1983; Halpert and Ropelewski 1992). Some extreme rainfall anomalies in East Africa have been associated with ENSO (Indeje et al. 2000). The ENSO has also affected the world's coral reefs. The most significant episode was the 1998 El Niño, which caused the strongest oceanic warming in recorded history. This was associated with severe coral bleaching and mortality globally with the greatest devastation in the WIO (Enfield 2001; Sheppard 2003; Ateweberhan and McClanahan 2010).

The IOD is a coupled ocean atmosphere phenomenon in the Indian Ocean (Saji et al. 1999). The IOD involves a periodic oscillation of SST between 'positive', 'neutral' and 'negative' phases. The positive phase is normally characterized by anomalous cooling of SST in the southeastern equatorial Indian Ocean and anomalous warming of SST in the western equatorial Indian Ocean. Associated with these changes the normal convection situated over the eastern Indian Ocean warm pool shifts to the west and brings heavy rainfall over East Africa (Behera et al. 2005; ASCLME 2012a,b,c).

The IOD and ENSO are similar phenomena, but the ENSO is driven by a larger ocean basin and is strong. This means that its effects are greater on a global scale. However, given East Africa's location in the Indian Ocean, the IOD signal can sometimes be stronger than the ENSO in driving climate patterns in the region.

Mozambique

After Somalia, Mozambique's coastline is the longest in eastern Africa, extending 2,700 km from 10 to 27 degrees south (Table 1.1, Figure 1.2) across the three climate zones of the northern Mozambique Channel, the southern Mozambique Channel and Delagoa (Table 2.1). The northern coastline of Cabo Delgado Province is notably complex with its myriad islands and bays. In several places close to the shore the precipitous slope of the continental shelf has created coral reef drop-offs of several hundred metres. These deep trenches are associated with cold up-wellings and strong currents. Mozambique's southern coast is characterized by the Limpopo and Zambezi deltas, two of eastern Africa's largest (Table 1.1, Figure 2.3). They commonly have large bays, mud and sand beaches, extensive mangrove forests and seagrass beds. The northern coastline of Cabo Delgado Province is narrow; the continental shelf off Sofala Province is much wider. It includes the offshore Sofala Bank, an area renowned for its rich fisheries of prawns and finfish. This latitudinal division of habitats along Mozambique's coastline results in different uses of the natural resources, particularly fisheries and mangrove timber, and lends itself well to marine spatial planning for developing a national integrated coastal zone management (ICZM) plan (Agardy 2010; Agardy et al. 2011).

The biogeography and biodiversity of Mozambique's coastal and marine ecosystems are directly influenced by the prevailing ocean currents in the Mozambique Channel (Figure 2.2), particularly the South Equatorial Current and the eddy formations that drive currents in all directions. These current systems are thought to boost biodiversity and productivity through larval supply, retention and cold up-wellings. The northern Mozambique coastline in Cabo Delgado Province has some of the most species-diverse coral reefs in the region (Obura 2012; Samoilys et al. 2012; see 'River basins, estuaries and deltas' below). Diversity and productivity are important factors in making coral reefs resilient to climate change. A recent review of the WIO recommended that the northern Mozambique coastline be listed as a World Heritage site (Obura et al. 2012).

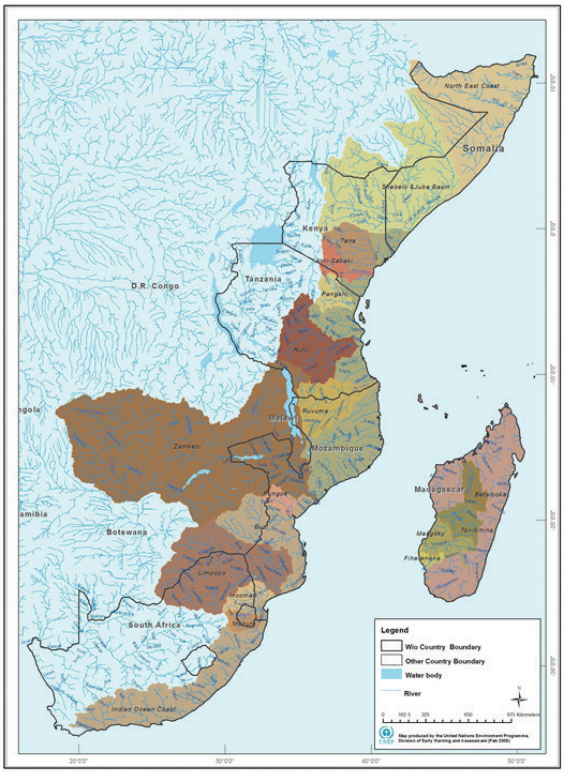


Figure 2.3: Regional map showing the major river catchments (Source: UNEP Division of Early Warning and Assessment 2008).

Tanzania

Tanzania's coastline is 1,424 km long (Table 1.1; Figure 1.2, ASCLME 2012b). Although it has extensive territorial waters, its generally narrow continental shelf means that its total shelf area is only a quarter the size of the Mozambican shelf. Its two major river systems are the Rufiji and the Ruvuma (Figure 2.3). The delta of the Rufiji River extends to Songo Songo near Mafia Island. It has one of the largest mangrove forests in eastern Africa (Figure 1.3). The Ruvuma River straddles the Tanzania–Mozambique border and also has extensive mangrove forests. The Tanzanian side is a national marine park. Tanzania has the third largest stands of mangrove forest in the WIO after Madagascar and Mozambique (Table 1.1). Tanzania also has several large islands such as Pemba and Unguja (informally known as Zanzibar) in the north and Mafia to the south. They are all rich in coral reefs. Tanzania's mainland coastline is fringed by coral reefs except where there are major rivers. They are frequently associated with shallow seagrass beds (see 'Mangroves' below). The northern coastline around Tanga has several offshore submerged coral reefs. Many have been destroyed by long-term dynamite fishing, a problem that is confined to Tanzania (Burke et al. 2011). Tanzania's coast consists of two ecoregions (Table 2.1). The southern region (no. 3), which extends into northern Mozambique, is influenced by the oceanography of the Mozambique Channel. It is where the South Equatorial Current meets the African coast. The northern region (no. 2) is the monsoon coast. It extends north through Kenya and into southern Somalia, driven largely by the north-flowing East African coastal current (Figure 2.2; Schott 2001; ASCLME 2012b; Obura 2012).

Kenya

Kenya's coastline is only 536 km, the shortest of the WIO countries. Consequently its territorial seas, continental shelf and EEZ area are much smaller (Table 1.1; UNEP 2009). As in Tanzania, the coast is dominated by fringing coral reefs, often enclosing a shallow lagoon and often associated with seagrass beds (Figure 1.3). Kenya has two major rivers that drain into the WIO, the Tana and the Athi-Sabaki (Table 1.1, Figure 2.3). The largest is the Tana River to the north, which has extensive mangrove forests. Its delta flows into the large, mud-sand Ungwana Bay, which has minimal reef systems. Northeast of the bay lies the North Kenya Bank, a broad area of shallow continental shelf. Research on this bank has been minimal (Samoilys et al. 2011a), but it probably supports large populations of valuable offshore fishery species. Kenya's coast is contained within one ecoregion, the monsoon coast (Table 2.1), which extends into southern Somalia and includes the Bajuni Islands. The northern extent of this climatic zone is tempered by the Somali Current and cold up-wellings off the Somali coast (Figure 2.2) that delimit the northern boundary of the eastern African coral reef fauna (Schott 2001; ASCLME 2012c; Obura 2012).

Habitats

The mainland countries of the WIO are characterized by coastal and marine ecosystems that include rivers and estuaries, coral reefs, mangrove forests, seagrass beds, sandy and muddy beaches and bays and rocky headlands. This variety of tropical coastal habitats hosts rich marine biodiversity with more than 6,000 documented species (Table 2.2). However, detailed breakdowns for the different taxonomic groups by country are unavailable, highlighting a gap in knowledge. High species diversity and endemism are also found in the coastal flora, which comprise mangrove forests and tropical dry forests within a mosaic of grassland habitats and wetlands (UNEP 2009; ASCLME 2012c).

The following section presents information and data by major habitat in order to identify key areas and effective strategies through which Resilient Coasts may contribute to the conservation, restoration and sustainable management of coastal ecosystems in a way that supports the wellbeing, resilience and security of the local communities.

River basins, estuaries and deltas

There are 12 main river basins that flow into the WIO of which 6 are in the three countries of this review (UNEP 2009): the Tana and Athi-Sabaki Rivers in Kenya, the Rufiji and Ruvuma Rivers in Tanzania, and the Zambezi and Limpopo Rivers in Mozambique (although the Ruvuma straddles the border between Tanzania and Mozambique) (Table 1.1, Table 2.3, Figure 2.3). The Zambezi and Limpopo Rivers are two of the nine largest river basins in Africa (ASCLME 2012a). The Zambezi River flows for some 2,700 km through nine countries (Zambia, Angola, Namibia, Democratic Republic of the Congo, Botswana, Zimbabwe, Malawi, Tanzania and Mozambique) and is Africa´s fourth-longest river (Figure 2.4).

The significant freshwater discharge into the sea from the rivers of eastern Africa (Table 1.1) reflects rainfall patterns in their catchments. The long rains (see 'Ecological characteristics' above on climate and monsoons) are the principal source of freshwater flow. The volume of water flow and terrigenous sediment load combined with catchment area are the principal factors for governing the size of the river estuaries and their mangrove forests. The greatest volume of river discharge is found in the rivers of Mozambique, which in turn support extensive mangrove forests (Table 1.1). These mangrove forests are often associated with seagrass beds, which are usually found in shallow, protected waters in bays. The nutrients that flow downstream make these mangrove–estuarine systems highly productive. They provide nursery grounds and breeding areas for numerous important fishery species such as snapper, emperor, grouper, prawns, crabs and sea cucumber. Several offshore commercially important tunas and mackerel (scombrids), such as the Spanish mackerel (*Scomberomorus commerson*, locally known as 'kingfish')

Table 2.2: Indices of marine biodiversity: principal marine taxa and the number of species per country in eastern Africa. Numbers pooled across countries refer to the entire WIO region.

Taxa	Mozambique	Tanzania	Kenya
Mangroves[a]	10	9	9
Seagrasses[b]	12	12	12
Hard corals[c]	254 (297)	265 (280)	203 (239)
Coral reef fishes[d]	295 (322)	286 (320)	NA
Coastal bony fishes[e]	> 2,200		
Sharks[e]	> 50		
Rays[e]	15		
Echinoderms[e]	400 (shallow) –600 (deep)		
Molluscs[e]	3,270		
Marine mammals EA[f]	33 (17 whales, 13 dolphins, *Dugong dugon*)		
Marine mammals WIO[h]	37 (23 whales, 13 dolphins, *Dugong dugon*)		
Turtles[g]	5		
Sea birds[g]	~150		

Source: [a]Spalding et al. 2010; [b]UNEP 2009; [c]Obura 2012; [d]Samoilys et al. 2012; [e]Richmond 2002; [f]Berggren and Coles 2009; [g]Obura et al. 2012; [h]this study
Numbers in parentheses indicate predicted total numbers using species accumulation curves
NA – not available

use mangrove estuaries for their early life stages (Samoilys et al. 2011a; Waycott et al. 2011). Many migratory bird populations rely on river deltas, wetlands and mangrove forests as a winter stopover.

The major rivers of the three countries (Table 2.3) have been dammed to varying extents for hydropower, water supply or irrigation. This has in some instances reduced water flow and nutrient discharge to the coast (UNEP 2009), which has inhibited mangrove growth. The decline in productivity has had an adverse effect on fisheries. Baseline data prior to damming are scant, and quantified estimates of the decline in the ecosystem health and productivity of these mangrove river basin systems are not available. Mangrove harvesting and removal occurs in all three countries and tends to be poorly managed. Despite this, the relative health and productivity of these major deltaic mangrove ecosystems is good (Spalding et al. 2010). Using the criteria of delta size and productivity and the relationship to neighbouring seagrass beds and coral reefs, the Rufiji, Ruvuma, Tana and Zambezi river basins are considered to be of national, regional and global significance.

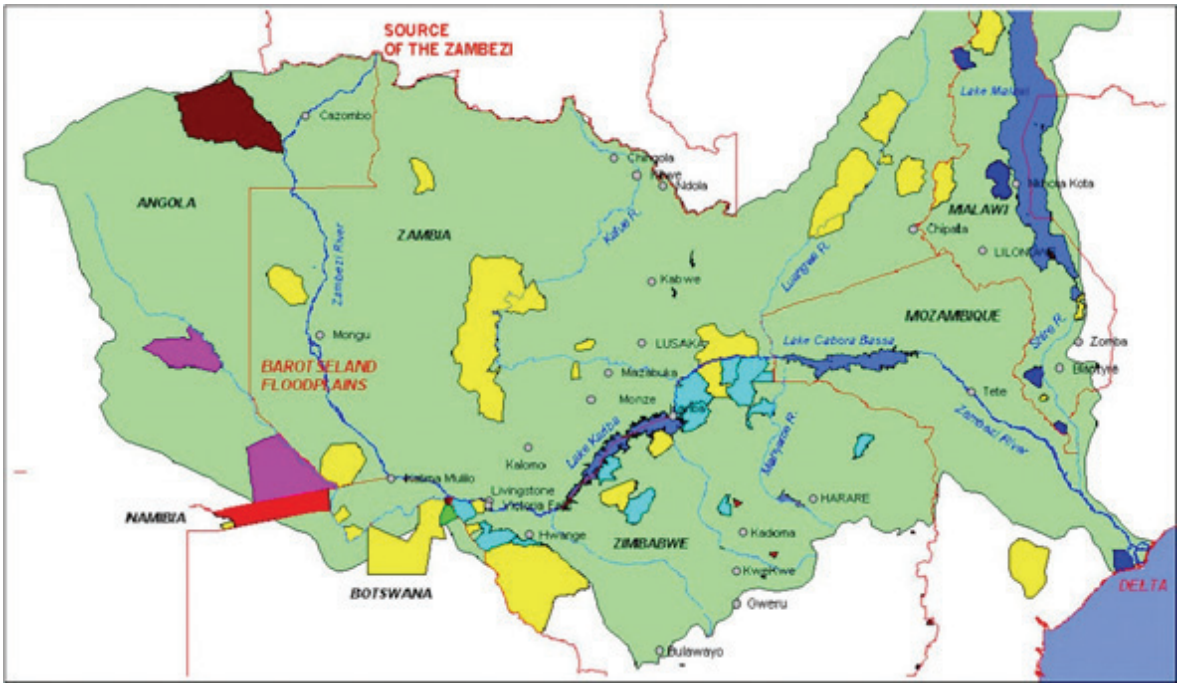


Figure 2.4: Map showing the Zambezi River and its catchment area. (Source: http://www.zamsoc.org/?page_id=636).

Table 2.3: Major river basins, their deltas and ecological functions in eastern Africa

Country	River	Key features	Ecological function
Mozambique	Limpopo	Small estuary 6 km long	Limited mangrove forests
	Zambezi	Delta is ~ 100 km long, 120 km wide at the coast, covering 15,000 km^2; has been extensively dammed in all 9 states it flows through causing significant damage to the estuary	Sustenance of rich offshore fishery stocks (fish, prawns) on Sofala Bank; largest dugong population in eastern Africa
Tanzania	Ruvuma	Delta ~ 100 km^2 within Mnazi Bay Ruvuma Estuary Marine Park (MBREMP)	94 km^2 of mangrove forests on the Tanzanian side, linked to large seagrass beds
	Rufiji	Delta is 23 km long, 65 km wide, covering 1,200 km^2; 3 sub-basins, 13 lakes in the river floodplain	480 km^2 of mangrove forests, the largest contiguous mangrove forest in eastern Africa; linked to coral reef systems offshore at Songo Songo archipelago and Mafia Island
Kenya	Tana	Several estuaries (Kipini, Mto Tana, etc.), extend 10 km inland, some relatively deep. Delta erosion due to extensive damming upstream; extensive floodplain and freshwater systems	41 km^2 of mangrove forests; sustains rich fishing grounds of Ungwana Bay and offshore North Kenya Bank
	Athi-Sabaki	Small, narrow estuary near Malindi; high sediment load	Limited mangrove forests; linked to coral reefs of Malindi Marine Park

Source: Wagner et al. 2004; Richmond and Mohamed 2005; UNEP 2009; ASCLME 2012a,b,c

Mangroves

Mangrove forests represent the largest areas of all coastal habitats in Mozambique, Tanzania and Kenya, typically in river deltas or estuaries (Figure 1.3; Semesi 1991, 1998; Kairo and Dahdouh-Guebas 2008; Bandeira et al. 2009; UNEP 2009; Spalding et al. 2010). They are also found in smaller stands adjacent to reef lagoons and on open sea coasts. The most extensive and diverse formations are found in the slightly wetter central coastlines of Tanzania and Mozambique, notably around the large and highly productive deltas of the Rufiji and Zambezi Rivers. Estimates vary, but the WIO has about 7,900 km^2 under mangrove forest cover, 5.2% of the world's total (UNEP 2009; Spalding et al. 2010). Mangrove forests are valued as carbon sinks that can counter the effects of climate change through their high productivity and by trapping carbon in biomass and sediment.

There are 10 species of mangrove trees in the WIO, most of which have a wide distribution (Table 2.4). They are all found in Mozambique (UNEP 2009; Spalding et al. 2010). Nine are found in Kenya and Tanzania. The forests support a variety of shrubs and palms. In the Tana Delta, elephants visit the mangrove forests (Figure 2.5; Samoilys et al. 2011a) to eat the climbing legume *Derris trifoliata*. The WIO mangroves, a subset of the species found in the Indo-West Pacific region, have been isolated from the Pacific region by the expanse of the Indian Ocean and the arid coastlines of the Middle East. They may therefore represent a distinct subregion of the Indo-West Pacific mangrove fauna and flora (Spalding et al. 2010). Mangrove trees have the unique ability to grow in brackish water and seawater because they are resistant to salinity. They also have the ability to extract freshwater from salty seawater. The most well-developed mangrove forests occur around river mouths where they play an important role in trapping sediments in river discharge that would otherwise be washed out to sea where they can affect the productivity of the seagrass beds and coral reefs.

The largest mangrove areas in the WIO are in Madagascar (2,991 km^2) and Mozambique (2,909 km^2) in the Mozambique Channel (Table 1.1). However, the largest contiguous stand of mangroves in the WIO is in the Rufiji Delta (480 km^2) in Tanzania, followed by the mangrove

Table 2.4: Mangrove species found in the Western Indian Ocean. (Source: Spalding et al. 2010).

Family	Species
Avicenniaceae	*Avicennia marina*
Combretaceae	*Lumnitzera racemosa*
Lythraceae	*Pemphis acidula*
Meliaceae	*Xylocarpus granatum*
	X. molucensis
Rhizophoraceae	*Bruguiera gymnorhiza*
	Ceriops tagal
	Rhizophora mucronata
Sonneratiaceae	*Sonneratia alba*
Sterculiaceae	*Heritiera littoralis*

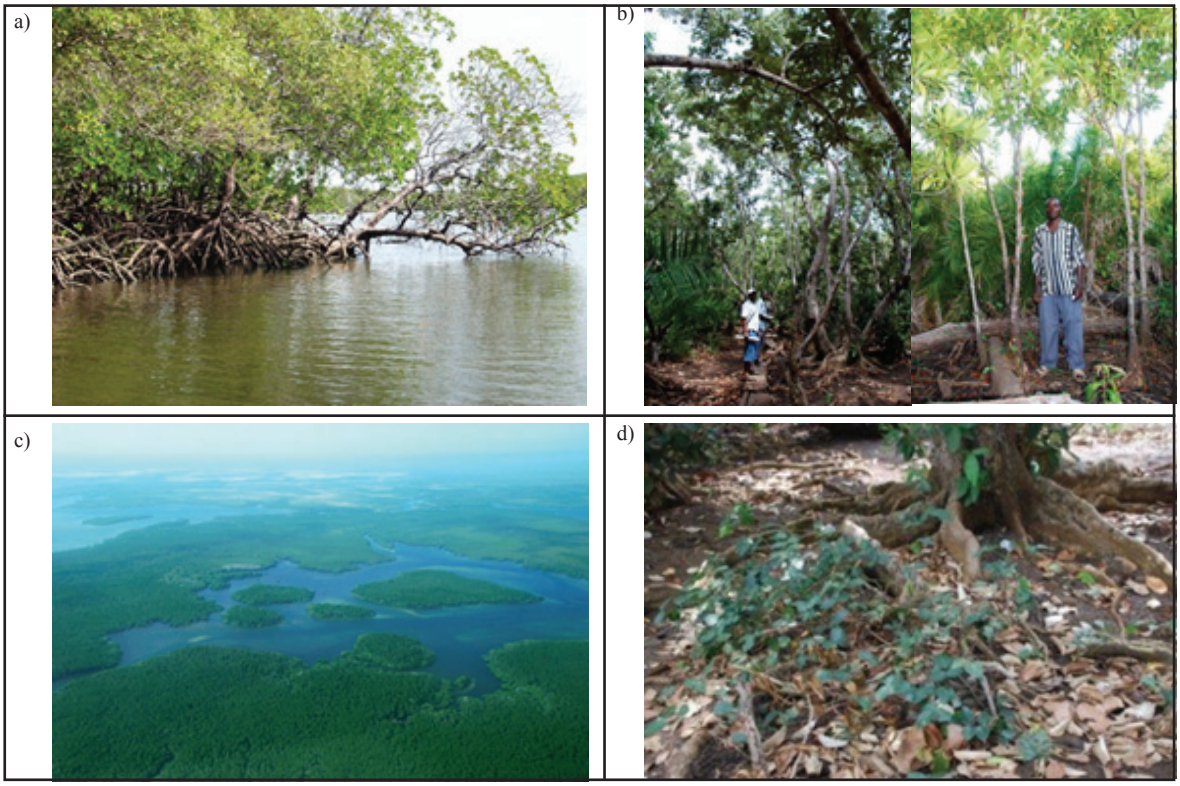


Figure 2.5: Mangrove forests in eastern Africa. a) Kiwaiyu channel, Lamu; b) *Heritiera littoralis* and Hyphenae palm, and replanted *Ceriops tagal* in the Tana Delta; c) Lamu Archipelago, Kenya; d) *Derris trifoliata* legume with *Heriteria littoralis*. © M. Samoilys

forests associated with the Zambezi and Ruvuma Rivers. Coastal island chains, such as the Lamu Archipelago and Tana River Delta in northern Kenya, and Quirimbas in northern Mozambique, also have smaller stands of mangrove forests in deltas, creeks and bays. Mangroves support high diversity of fauna in the form of vertebrates (fishes) and invertebrates (crabs, molluscs) and flora.

Mozambique

Mozambique's mangrove forests account for 60% of mainland eastern Africa's mangroves (Table 1.1; Bandeira et al. 2009; UNEP 2009; Spalding et al. 2010) yet are only contained wthin six Marine Protected Areas of some form, compared wth 24 MPAs in Tanzania and 11 MPAs in Kenya which all include mangrove forests. The central coast around Sofala Bay, from Angoche to the Save River, has 1,900 km^2 of mangrove cover. It is not contiguous, but it is the most extensive in eastern Africa. The gently sloping coastline hosts several major rivers, notably the Zambezi, enabling the formation of large deltaic and estuarine mangrove forests. The tidal influence in central Mozambique is also strong, producing riverine mangroves in the Zambezi and Quelimaine areas which extend 50 km inland. The Zambezi delta mangroves are adjacent to important freshwater and terrestrial ecosystems, including coastal flooded savannah, coastal dunes, freshwater swamps and miombo woodlands, creating a rich diversity of species (UNEP 2009; ASCLME 2012a).

The mangrove forests in Cabo Delgado Province, where there is minimal logging, are remarkably healthy and increasing in size (Bandeira et al. 2009). They are concentrated in four principal locations (Table 2.3) in the Ruvuma River delta and further to the south in protected bays (Figure 2.6). To the south of the Save River, mangroves become more intermittent and are found mainly in embayments and estuaries sheltered by the north-facing headlands of Ponta Sao Sebastiao, Ponta de Barra and Maputo Bay (Figure 2.8).

The southern limit for 3 of the 10 species found in Mozambique, *Sonneratia alba*, *Pemphis acidula* and *Heritiera littoralis*, is the River Save at around 21^o S. Further south mangrove trees are rarely taller than 4 m, though trees of over 27 m have been recorded in the Limpopo estuary at around 25^o S.

Of the three countries, Mozambique has the least government-protected mangrove forest with only 6 nationally protected areas that contain mangroves, compared with 24 in Tanzania and 11 in Kenya.. In October 2003, the government of Mozambique made the Marromeu Complex in the Zambezi Delta its first Wetland of International Importance under the Ramsar Convention (Beilfuss and Brown 2006). A Ramsar review has since recommended the area be expanded to safeguard against possible threats from oil and gas exploration (Ramsar Advisory Commission, No

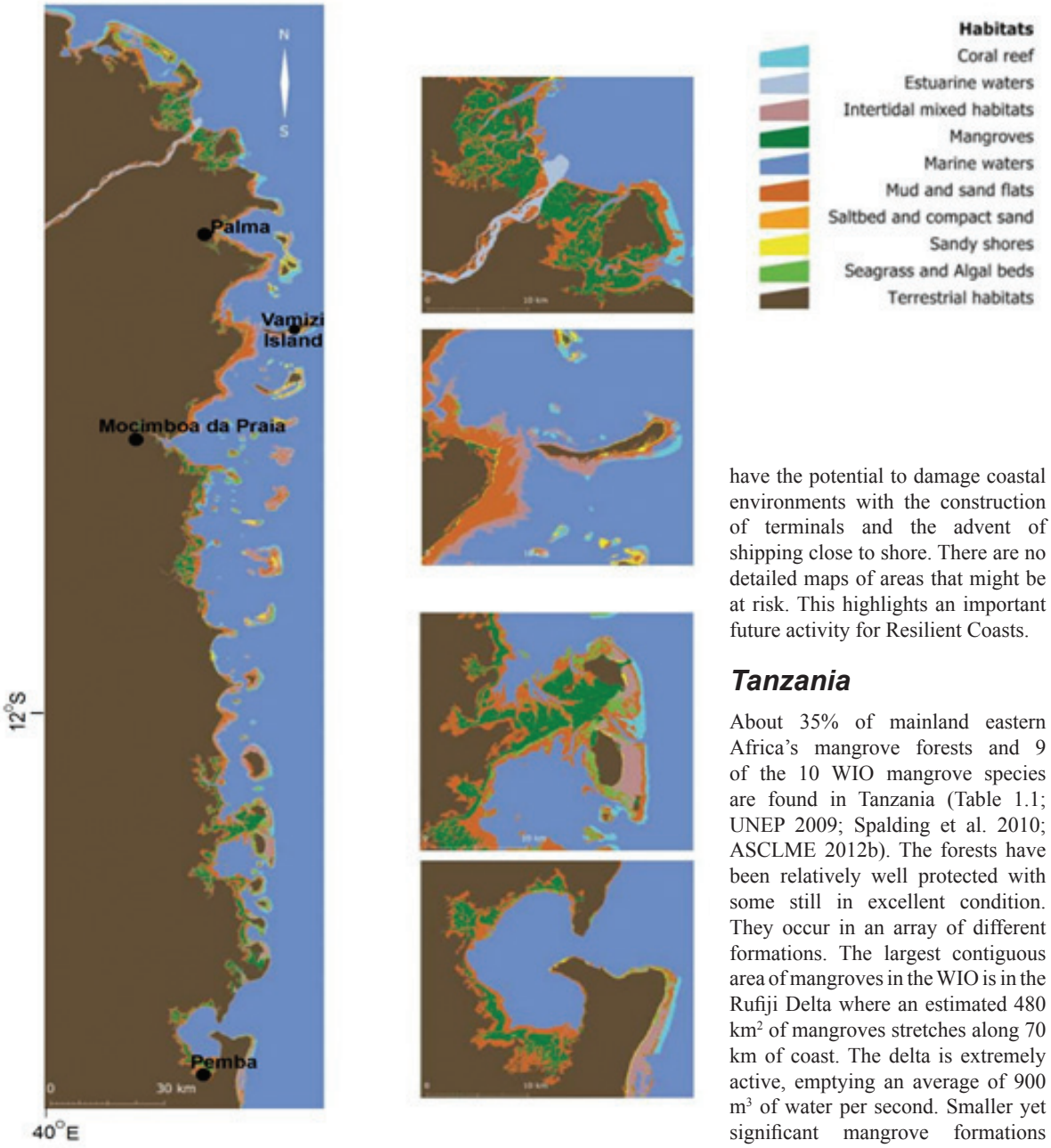


Figure 2.6: Major marine and coastal habitats in Cabo Delgado Province, northern Mozambique showing the extent of mangrove forests around the bays. (Source: TRANSMAP Project Final Report 2010).

62, 2009). In 1998 a legal framework facilitated by World Wide Fund for Nature (WWF) was introduced to protect mangroves and other coastal resources within 100 m of the coastline. The legislation made licensing for mangrove logging mandatory, but it is poorly enforced

Probably the greatest potential threat to the status quo of Mozambique's mangroves is the extensive oil and gas exploration being conducted in the Mozambique Channel. The prospect of offshore oil wells presents the possibility of pollution through oil spills. Both oil and gas extraction have the potential to damage coastal environments with the construction of terminals and the advent of shipping close to shore. There are no detailed maps of areas that might be at risk. This highlights an important future activity for Resilient Coasts.

Tanzania

About 35% of mainland eastern Africa's mangrove forests and 9 of the 10 WIO mangrove species are found in Tanzania (Table 1.1; UNEP 2009; Spalding et al. 2010; ASCLME 2012b). The forests have been relatively well protected with some still in excellent condition. They occur in an array of different formations. The largest contiguous area of mangroves in the WIO is in the Rufiji Delta where an estimated 480 km^2 of mangroves stretches along 70 km of coast. The delta is extremely active, emptying an average of 900 m^3 of water per second. Smaller yet significant mangrove formations include the complex sheltered creeks near Tanga in the north and the large offshore islands of Pemba, Zanzibar and Mafia. Estuarine and deltaic formations are also important and include the Wami Delta, the Ruvu Estuary near Bagamoyo, the Matandu Estuary and the Ruvuma River mouth.

Many of the larger mangrove forests support associated species. For example, hippos and crocodiles live in the mangroves in the Wami Delta. An estimated 40,000 water birds comprising 62 species inhabit the Rufiji Delta (Spalding et al. 2010). In a rare occurrence, 10 dugongs (Vulnerable, IUCN Red List) were sighted in the seagrass beds next to the Rufiji Delta in 2011 (Sea Sense 2011).

Mangroves have been gazetted as forest reserves, which allow regulated extraction, since 1928. As a result, mangrove degradation and loss has occurred though at a slower rate than in most other countries in the region. The greatest losses have been in the environs of Dar es Salaam due to urbanization and cultivation. The widespread and excessive exploitation of mangroves for timber, fuel and tannin is degrading some forests and putting them at risk (Spalding et al. 2010).

Tanzania is the regional leader in its approach to mangrove protection and sustainable usage through the Mangrove Management Project (Semesi 1991, 1998) which was initiated in 1988 by the late Dr Adelaida Semesi. This and other projects have helped to reduce illegal cutting and clearance and have encouraged the replanting of large areas of degraded forest (e.g. Samoilys et al. 2007). In 1996 the government of Tanzania approved plans for a prawn farm in the Rufiji Delta covering 100 km^2. The project was abandoned in 2001 after it became clear that it would displace local communities, destroy the delta and be highly damaging to offshore ecosystems. The Rufiji Delta and Mafia mangrove forests are now included in the Rufiji-Mafia-Kilwa Ramsar site (Ramsar 2004).

Kenya

Estimates put Kenya's mangrove cover at between 5,300 and 6,100 km^2 with 67% occurring in the northern Lamu area and 10% further south in Kilifi and Kwale Counties (Table 1.1). The largest forests are concentrated in the Lamu Archipelago and the permanent Tana Delta. Smaller mangrove areas are found on the south coast in creeks around Shimoni and Vanga; in the bays of Funzi and Gazi, in Mombasa's Port Reitz and Tudor; and in Mtwapa, Kilifi and Mida Creeks. Most of these forests occur not in estuaries but in intertidal areas where there is submarine ground water discharge or seepage (Mwatha et al. 1998). The mangroves of the Lamu Archipelago combined with the nutrient-rich Somali Current (Figure 2.2) create a conducive habitat for some of the greatest inshore densities of finfish and crustaceans in Kenya. They are likely to support highly productive offshore fisheries, but this is not yet quantified. The Lamu mangroves are also a valuable source of wood for local communities.

Kenya has 9 of the 10 species found in the WIO. *Rhizophora mucronata* and *Ceriops tagal* predominate and can be found in almost all mangrove forests. The rarer species are *Heritiera littoralis* and *Xylocarpus moluccensis* with individual trees occurring in the Tana River Delta and the Lamu mangrove forests. Kenya's mangroves form a strong zonation of species controlled by the large tidal regime. The typical sea-to-land zonation pattern is *Sonneratia alba*, *R. mucronata*, *Brugeria gymnorrhiza*, *C. tagal*, *Avicennia marina*, *X. granatum*, *Luminitzera racemosa* and *H. littoralis*.

Mangroves were declared government reserved forests in 1932 and are managed by County Forestry Officers, who supervise licensing, offtake and conservation. Legislation governing mangrove management comes under the Forest Act (2005). However, insufficient attention is paid to mangrove forest ecosystems. The Kenya Forestry Service is primarily concerned with terrestrial forests as their timber is deemed to be of far greater value (Samoilys et al. 2011c). It is estimated that 10,300 ha of mangrove forest have been lost to either agricultural cultivation, excessive exploitation or pollution (Ruwa 1993). Depending on the degree of alteration to the mangrove forest, recovery is lengthy or does not happen at all.

Fortunately, many of the forests are in protected areas such as the Kiunga Marine National Reserve to the north of Lamu; Mida Creek in Watamu Marine Park and Reserve; and the Shimoni-Vanga area in the Kisite and Mpunguti Marine Park and Reserve. Watamu Marine Park and Reserve and Kiunga Marine National Reserve were declared UNESCO Heritage Sites in 1979 and 1980 respectively. Despite the national protection status of these mangrove forests, particularly the two largest formations in northern Kenya's Tana Delta and Lamu Archipelago, they remain under threat from development (Bosire et al. 2008; Kairo and Dahdouh-Guebas 2008; Spalding et al. 2010). Development projects are planned for the Tana Delta ranging from dams and irrigated sugar cane plantations to prawn and jatropha farming. They invariably meet local objections and garner mixed community support (Samoilys et al. 2011a). Since 2012 tensions have been further heightened by periodic and deadly conflicts over access to grazing during the dry season.

Summary

In the last 50 years, about one-third of the world's mangrove forests have been lost (Spalding et al 2010). However, the mangrove decline in Mozambique, Tanzania and Kenya from 1980 to 2005 has been estimated at only 8%, which is exceptionally low compared with global figures. This slow rate of attrition indicates that the mangrove systems of eastern Africa are in a relatively good state of health even though mangrove harvesting and the export of poles to the Middle East have been staple activities for centuries and are still ongoing. Nevertheless, in some parts the ungoverned felling of mangrove trees has cleared large areas of productive forest. Elsewhere unchecked and often illegal exploitation has degraded trees to such an extent that they are stunted and more sparsely distributed. Mangrove forests are also the first to be cleared for the excavation of salt pans, which produce most of the region's sea salt. Pressure from tourism developers, coastal construction, farmers and the ever-growing need for fuel wood further encourages the indiscriminate cutting of swathes of

primary mangrove forest with little or no replanting (Kairo and Dahdouh-Guebas 2008; Spalding et al. 2010; ASCLME 2012 a,b,c).

Oil and gas extraction is one of the greatest potential threats to mangroves in eastern Africa. One of the largest gas reserves in the world has been discovered off Cabo Delgado Province in Mozambique. Offshore drilling to a depth of 1,500 m started in 2013 (IUCN 2013). Safeguarding ethical extraction practices will be critical, hence the development of initiatives such as the Fair Coasts Programme[9], aimed at facilitating direct dialogue between local communities, the government of Mozambique and the drilling companies. Damage to mangroves is expected to be minimal as the drilling rig is far from the mangrove forests, and the onshore support terminal will be sited in Palma Bay to the north where there are very few mangroves. It should be noted that some gas extraction sites in Tanzania such as Songo Songo and Mnazi Bay appear to have had no obvious environmental impact (Samoilys pers. obs. in Mnazi Bay) although this has not been substantiated through formal monitoring.

Prawn farming and other commercial fishing operations pose another potential threat to mangrove ecosystems. Mariculture is expected to expand rapidly to meet the growing demand for food and job creation. Prawn farming needs to practise new methods and technologies to limit the damage to mangroves using lessons learnt from Asia and the Pacific (e.g. Ponia 2010). It is vital that eastern Africa learns from these recent initiatives and does not repeat the mistakes made in Asia, which resulted in the widespread destruction of mangrove forests (Naylor et al. 2000) with disastrous consequences during the Asian Tsunami of 2004 (Danielsen et al. 2005).

Poorly planned coastal development, particularly port construction, is a further threat to the region's mangroves forests. For instance, local community groups, environment managers and conservationists have voiced concern over expansion plans for the ports at Mtwara and Tanga to accommodate the shipping traffic generated by oil and gas companies. The most critical threat to the mangrove forests in the Lamu Archipelago–Tana Delta area is the construction of the Lamu Port. The mangrove forests around Manda and Pate Islands, including the Magogoni and Dodori creeks will be either removed or damaged when work begins on the Lamu Port Southern Sudan–Ethiopia Transport Corridor (LAPSSET). The project is designed to give Ethiopia, South Sudan and Uganda access to a Kenyan port for their exports, primarily crude oil. However, the EIA has only just been released (March 2013) for public scrutiny, and there is a considerable lack of information available to the public on the proposed development.

[9] The Fair Coasts Programme was developed with the support of the Mechanism for Strengthening Capacity of the Civil Society (MASC), the Mitsubishi Foundation for Europe, Middle East and Africa (MCFMEA), We Effect and Irish Aid. The programme was developed by IUCN ESARO in collaboration with a consortium of national and regional partners.

In the region, mangroves are more commonly managed as forest reserves rather than for biodiversity conservation and are subject to forestry regulations that were drawn up with a view to resource utilization rather than conservation. Their role as ecosystem service providers to a broad range of other systems (e.g. coral reefs, fisheries, prawns, land protection) generally goes unrecognized and carries little weight in the face of development alternatives.

Coral reefs

Coral reefs dominate the WIO ecosytems and are widely distributed along the Mozambican, Tanzanian and Kenyan coasts (McClanahan et al. 2000). They are typically shallow fringing reefs, often enclosing a lagoon, and often closely associated with seagrass beds (Figure 2.7a; Obura et al. 2012). The reefs in southern Tanzania at Mnazi Bay and in northern Mozambique in Cabo Delgado Province are the exception. They are more developed, covering extensive submerged areas. They are also deeper and tend not to be associated with seagrass beds (Davidson et al. 2006; Hill et al. 2009; Samoilys et al. 2011b). For example, good coral cover and growth were recorded to maximum depths of 35–40 m off Pemba in Mozambique and Mnazi Bay in Tanzania (Figure 2.7b, MS pers.obs.).

Obura (2012) recorded 369 hermatypic (hard) coral species in the WIO region. The IUCN Red List has a total of 398 species for the WIO, from which Obura estimated a potential species pool of at least 450 across the WIO. The highest coral species diversity was recorded at sites in the northern Mozambique Channel ecoregion from northern Mozambique, southern Tanzania, northwest Madagascar and Comoros (Figure 2.8).

Corals that are unique to the WIO and are of rare and ancient lineage are found on the eastern African mainland, particularly on the coastline of Cabo Delgado and Nampula Provinces in Mozambique and in Kiunga, Kenya (Figure 2.9). They have only recently being discovered (Obura 2012) and warrant much more research to understand their extent and distribution.

Standardized SCUBA-based surveys to assess coral-reef fish diversity across four countries in the WIO Region (Comoros, Madagascar, Mozambique and Tanzania) using a checklist of 19 families of fish that are associated with coral reefs (see Samoilys and Randriamanantsoa 2011 for details) recorded a total of 375 species. The greatest number of species was located at sites in Cabo Delgado Province, northern Mozambique, together with Mafia Island and one site in Mnazi Bay, both in Tanzania (Figure 2.10).

Corals are threatened by an increase in the SST caused by global warming. The warmer water bleaches corals and eventually kills them if raised water temperatures persist. This threat has been well documented in the WIO (Linden and Sporrong 1999; Wilkinson 2008; McClanahan et al. 2011). Levels of coral bleaching from the extreme temperature during the 1998 El Niño event and the subsequent recovery of coral reefs have been quantified in the WIO. They show that recovery rates and resilience to

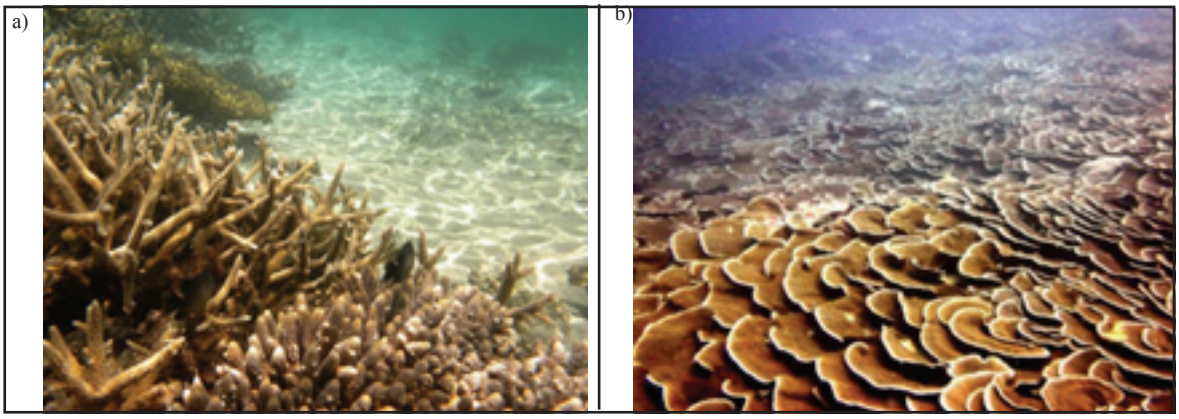


Figure 2.7: a) Typical shallow fringing coral reefs of eastern Africa at Mafia Island, Tanzania, 3 m depth. b) Coral cover at 35 m depth at Pemba, Mozambique. (©Melita Samoilys)

bleaching vary considerably within the region. The northern Mozambique and southern Tanzanian coral reefs appear to be the most resilient with the quickest rate of recovery (Obura 2005; McClanahan et al. 2007a; Obura 2011).

Mozambique

Only Madagascar and Tanzania (Table 1.1; UNEP 2009) have more coral reefs than Mozambique, which has 14.4% of the WIO's coral reefs. They are concentrated in the north in Cabo Delgado and Nampula Provinces. Further to the south, the silt and sand discharged into the mouths of the Limpopo and Zambezi Rivers inhibit coral growth.

The northern Mozambique Channel region has the greatest species diversity of corals in the WIO (Figure 2.10) and is an important contributor to biodiversity in the Indian Ocean (Obura et al. 2012). The reefs of Cabo Delgado and Nampula Provinces contain some of the highest numbers of coral species in the WIO (Figure 2.8). Obura's (2012) sampling in Cabo Delgado Province was limited, and it is likely that future surveys will show that there are between 350 and 400 coral species on the northern Mozambique coastline. Maps from Veron (2000) and related publications suggest a diversity of some 300 species. Davidson et al. (2006) surveyed the Vamizi Island area and reported 183 coral species in 46 genera from

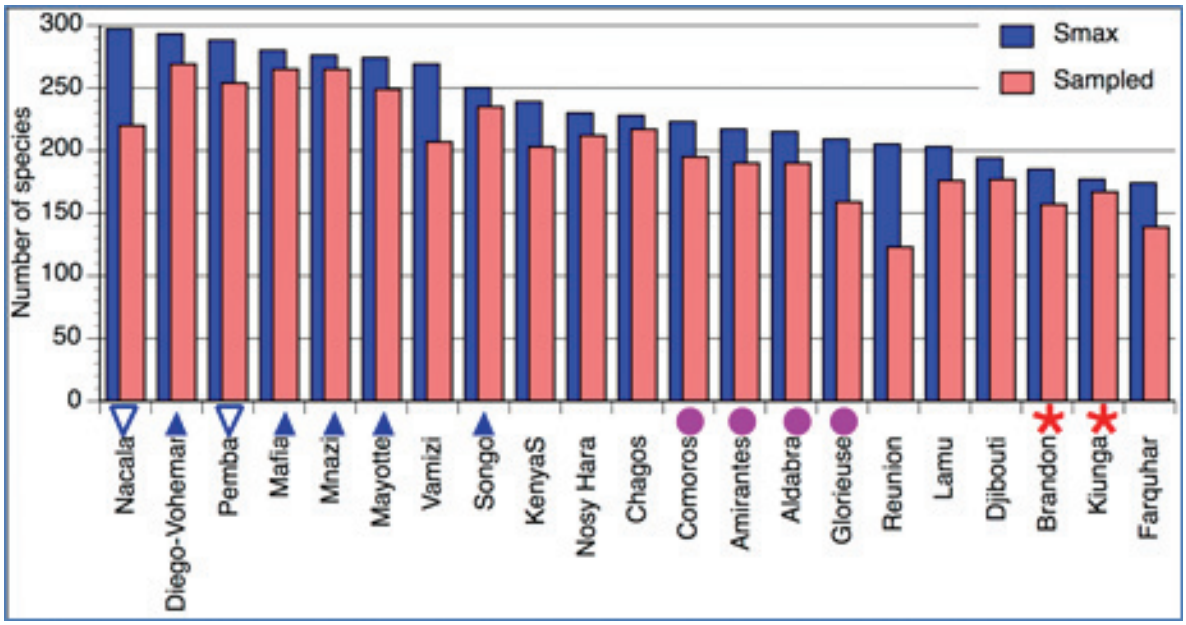


Figure 2.8: Estimated maximum species richness of reef-building corals at survey locations in the WIO region, ordered by decreasing diversity. The graph shows Smax, derived from the Michaelis-Menten regression equation on presence or absence from a pool of 369 coral species across all locations, and the number of species sampled. Symbols against the x axis correspond to the significant clusters of sites: blue triangles—northern Mozambique Channel; purple circles—smaller islands in the Mozambique Channel and NW Seychelles; red stars—low-diversity outliers.(Source: Obura 2012).

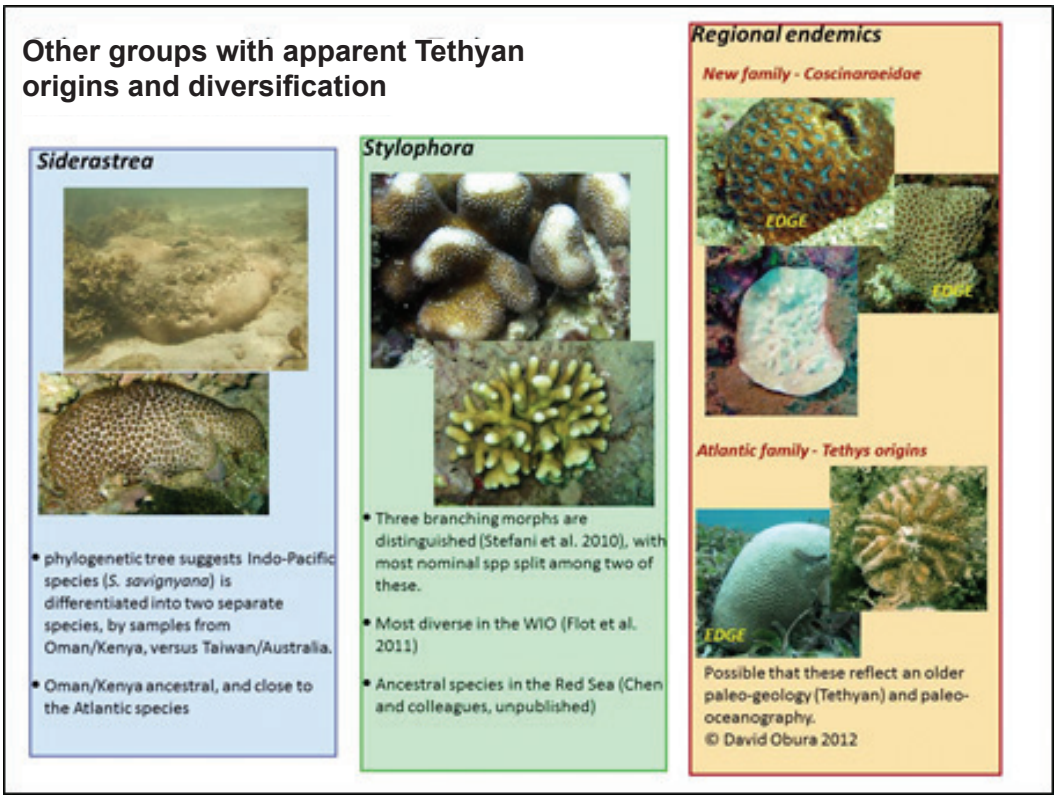


Figure 2.9: Rare and endemic corals from the Western Indian Ocean.(©David Obura)

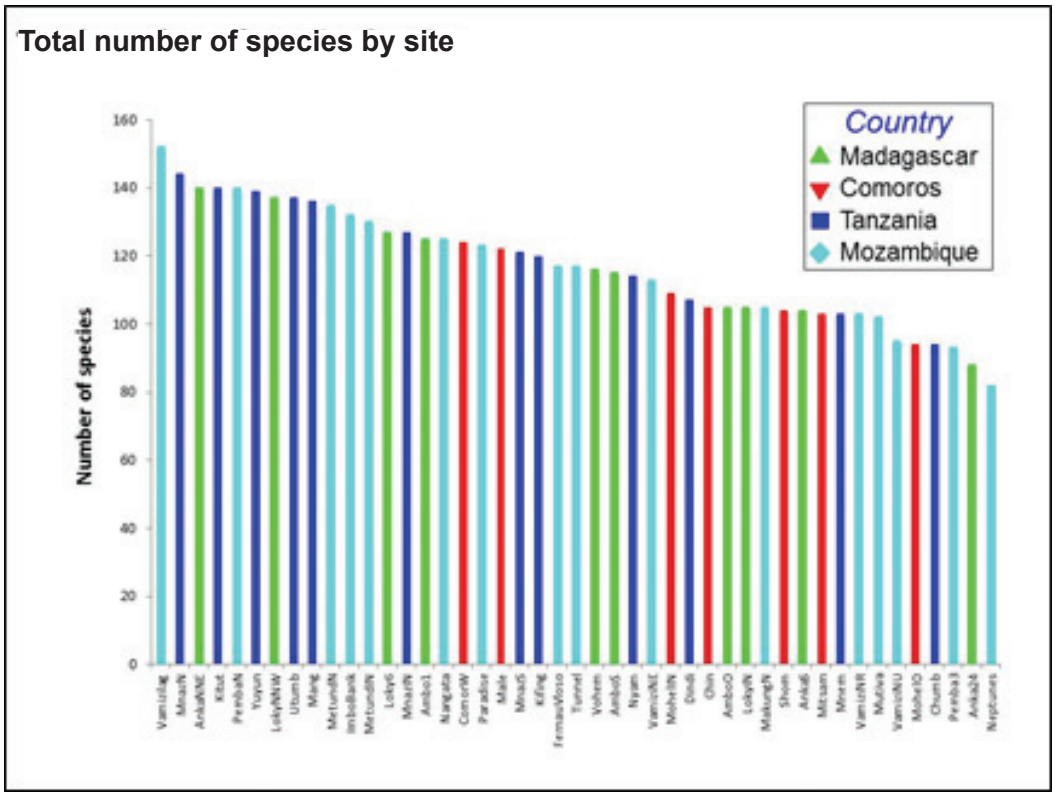


Figure 2.10: Total number of coral-reef fish species at 45 sites across four WIO countries based on a standardized SCUBA method. (Source: Samoilys et al. 2012).

14 families. Surveys in 1999 for the Mozambique Coral Reef Monitoring Programme built up lists of 127 species. A later survey in Pemba Bay (Obura 2003) found 208 coral species in 54 genera and 16 families. Obura's (2012) most recent figures use a survey technique that gives an actual number of coral species found and a predicted maximum number based on species accumulation curves simulating unlimited surveys. This method gives 254 (288) actual (predicted) species for Pemba Bay, and 207 (269) for Vamizi Island. By comparison, 219 (297) species were reported for Nacala, in Nampula Province, and 265 (276) in Mnazi Bay Marine Park in Tanzania. Given the low sampling rate at specific areas in Mozambique, a more accurate coral diversity for the northern coastline (Cabo Delgado and Nampula Provinces) can be estimated by combining Pemba, Vamizi, Nacala and Mnazi Bay to give a total actual number of 307 species (Obura 2012).

A total of 295 fish species associated with coral reefs were counted in Mozambique, the highest in the WIO (Table 2.2), with a predicted total of 232 species based on cumulative species curve analysis (Samoilys et al. 2012). This is not surprising given the region's remarkable coral diversity. The highest number of species was located at sites in Cabo Delgado Province and Mafia Island in Tanzania (see Figure 2.10).

Tanzania

Tanzania has by far the largest area of coral reefs within the WIO (3,500 km^2, Table 1.1, Figure 2, UNEP 2009). They fringe most of the mainland coastline, except where there are large river basins, Zanzibar's Unguja and Pemba Islands, and Mafia. The southern reefs around Mafia Island and Mnazi Bay, where protected, are some of the most biodiverse in the region due to their location in the WIO current systems (see above). However, unchecked dynamite fishing along much of the mainland coast has had a serious impact on Tanzania's reefs (Burke et al. 2011; see also www.wri.org/reefs/stories) and altered them to such an extent that many are now dominated by macro-algae (Samoilys et al. 2007; Wells 2009; Wells et al. 2010). This practice is seriously undermining Tanzania's marine biodiversity and coastal fisheries as well as the protection of its shoreline (see chapter 3).

Obura (2011) describes high resilience and an excellent recovery rate for reefs around Mafia Island and the Songo Songo Islands near the Rufiji Delta. This resilience rate is based on an index combining hard coral and crustose coralline algae (CCA) to give a more integrated picture of the ability of reefs to return to a coral-dominated state. CCA is often a precursor to increased coral growth, particularly after a mortality event. The index indicates that even though Mafia reefs are vulnerable to bleaching, they are very resilient and have the ability to return to their prior state. Long-term monitoring data from the Mafia Island Marine Park suggests that, given ideal conditions, the recovery trajectory for reefs in this system is about 10–15 years.

Despite the mass coral bleaching and mortality in 1998 that affected the entire Indian Ocean, the region's coral community has not changed. The dominant genera are *Acropora*, which is present across all sites and reef zones, and *Galaxea*, which forms large stands in sheltered, turbid locations. Reefs throughout this region have been reported to be on a clear recovery trajectory (Obura 2011). Obura also found that coral cover was higher in Songo Songo than in Mafia. It is likely that the turbid water from the Rufiji Delta protected the reefs in Songo Songo from the high temperatures in 1998 which resulted in lower coral mortality.

Kenya

Kenya has the fewest coral reefs in the WIO (630 km^2, Table 2.1, Figure 2.5, UNEP 2009), but they are some of the best protected and managed in the region. This is largely due to Kenya's long-standing and well supervised national marine parks (McClanahan et al. 2007b, Samoilys and Obura 2011). More recently, a network of community conservation areas (Maina et al. 2011) has been established. In the past, the government of Kenya tended to choose coral reefs to gazette as parks because of their aesthetic appeal and rich biodiversity. Later the government introduced marine reserves that were larger than the parks and encompassed neighbouring seagrass beds and mangrove forests. The reserves provide a more balanced ecosystem-based approach to marine conservation and management (Samoilys and Obura 2011). Unlike the parks, they allow carefully managed fishing by local communities.

The good management of marine parks has led to significant recovery in fish populations over the last 20 years (McClanahan and Graham 2005, McClanahan et al. 2007b). Even so, reefs in the Lamu Archipelago were badly damaged by the El Niño event in 1998 with mortality levels of > 80% (Obura and Church 2004). Their recovery, which has been monitored from 1998 to 2008, has progressed slowly in the shallow inner and outer reefs to levels varying from 20 to 80% of pre-bleaching levels (Obura pers. comm.).

The Lamu Archipelago is situated at the northern extreme of the eastern African coastline in ecoregion 2 (Figure 2.1, Table 2.2). Together with southern Somalia it hosts an interesting mix of coral species that are rarely encountered elsewhere (Samoilys et al. 2011a). Species of special interest that are either rare, endemic or have limited ranges include *Horastrea indica, Siderastrea savignyana, Porites nodifera, P. columnaris,* and an undescribed Coscinaraea.

Summary

Mozambique's northern reefs in the Quirimbas Archipelago of Cabo Delgado Province are some of the healthiest, most resilient and diverse coral reef systems in the WIO, which is why they have been recommended as a World Heritage site (Obura et al. 2012). Tanzania's southern reefs in Mnazi Bay, Mafia Island and the Songo Songo Archipelago are also highly diverse and resilient to climate change (Obura 2011). However, the mainland reefs are being destroyed by dynamite fishing to the point where the damage is likely to be irreversible. Kenya's coral reefs, though less diverse and less resilient, are among the best protected and healthiest, particularly in terms of their fish population densities.

Looking at these three countries in the Resilient Coasts area of action, there is a clear gradient of coral species and general reef diversity from Cabo Delgado Province to northern Kenya. This also applies to coral reef complexity and resilience. Because the ocean currents flow in a northerly direction, the southern region is a critical source of larvae for all species, including important fisheries species. To maintain a healthy and vibrant coral reef ecosystem in eastern Africa, its countries must commit themselves to creating a large-scale network that can oversee MPAs and manage fisheries regionally in an ecosystem-based approach. This is particularly relevant for the northern reefs in the WIO, which will be more vulnerable to bleaching events than the southern reefs.

Seagrass beds

Seagrasses, marine angiosperms, are widely distributed in both tropical and temperate coastal waters. They are credited with creating one of the most productive aquatic ecosystems on earth (Green and Short 2003). Their habitat ranges from high intertidal to shallow subtidal soft bottoms such as sandy bays, mud flats, lagoons and estuaries where they tend to form extensive mono- and multi-specific meadows. They often occur in close proximity to coral reefs and mangroves. They generally occur in shallow water because they depend on sunlight for photosynthesis. They have been known to grow at depths of up to 70 m in water of exceptional clarity in places other than the WIO. Seagrasses are the preferred food of the *Vulnerable* Dugong.

Of the 60 seagrass species identified worldwide, 13 are found in the WIO. Mozambique and Tanzania, and Kenya have the greatest diversity of seagrasses with 12 species widely distributed in each country in extensive seagrass beds (Table 1.1). The seagrass species of eastern Africa are as follows (UNEP 2009):

Cymodocea serrulata
Cymodocea rotundata
Enhalus acoroides
Halodule wrightii
Halodule univernis
Halophila ovalis
Halophila minor
Halophila stipulacea
Syringodium isoetifolium
Thalassia hemprichii
Thalassodendron ciliatum
Zostera capensis

Mozambique has 439 km^2 covered with seagrass beds whereas Kenya has only 34 km^2 (UNEP 2009). Tanzania has not yet fully mapped its seagrass beds and urgently needs to do so. The only area that has been studied is Mnazi Bay where 50 km^2 of seagrass beds have been recorded (Richmond and Mohamed 2005).

Seagrass beds are closely associated with the shallow fringing coral reefs of the narrow continental shelf of eastern Africa (see 'Mangroves' above). They occur in bays and back-reef lagoons that are connected to the sea by narrow channels. Existing detailed research on seagrasses is primarily from Mozambique (e.g. Bandeira and Bjork 2001; Bandeira and Gell 2003) and Kenya (e.g. Uku 2005).

Seagrass beds provide important habitats for a diverse array of associated fauna and flora including more than 50 species of macroalgae; 18 species of algal epiphytes; 75 species of benthic invertebrates; 7 species of sea urchins; various shrimp, lobster, crab, starfish and sea cucumber; and more than 100 fish species (Green and Short 2003). They serve as nursery grounds and as foraging areas for dugong, turtles and fish. Numerous fish and invertebrates seek refuge from predators in seagrasses. They are recognized as important to the local fisheries too. Food fish such as rabbitfish (Siganidae), surgeonfish (Acanthuridae) and seagrass parrotfish (*Leptoscarus* spp.) preferentially graze the epiphytes on the seagrass while larger fish such as snappers, groupers and barracuda feed on the in-fauna of the seagrass beds.

Not enough attention has been paid to eastern Africa's seagrass beds by conservationists and environmental managers even though the future of this ecosystem is uncertain. Trawling and seine netting, particularly beach seines, pose the greatest threat to eastern Africa's seagrass beds. These activities are widespread along the coasts of all three countries. Trawling for prawns occurs in Ungwana Bay adjacent to the Tana Delta in Kenya; and in Mtwara adjacent to the Rufiji Delta in Tanzania. In Tanga, 80% of prawn trawl catches have been known to consist of seagrass fish species (Ochieng and Erftemeijer 2003). Farming activities in river basins have also led to reduced seagrass beds in estuarine and deltaic areas such as the Athi-Sabaki and Tana Rivers in Kenya and the Rufiji River in Tanzania.

Oil pollution, port construction and other coastal developments are emerging threats. The proposed Lamu Port in northern Kenya will affect the large tracts of seagrass beds in the Pate, Wange and Dodori Channels, which are important turtle and dugong feeding grounds. Similarly, further port development at Mtwara in southern Tanzania will damage the seagrass beds at the edge of the channel, as will the planned reclamation of the Selander bridge coastal waterfront in Dar es Salaam. When coastal development is not well managed, it can destroy seagrass beds through the unregulated dumping of solid waste, sewage and dredge soil. Water pollution indirectly affects seagrass beds too as these ecosystems are invariably close to shore in shallow protected waters (Green and Short 2003).

Mozambique

The largest seagrass beds in Mozambique occur at Fernao Veloso, Quirimbas and Inhaca-Ponta Do Ouro. Of the total of 439 km^2 there are 25 km^2 around Inhassoro and Bazaruto Island; 30 km^2 at Mecufi-Pemba and 45 km^2 in the southern Quirimbas Archipelago (Bandeira et al. 2009).

There are 12 seagrass species in Mozambique. They occur in mixed seagrass stands, especially in intertidal areas (Bandeira and Bjork 2001; Bandeira and Gell 2003; UNEP 2009). The three predominant mixed seagrass communities on the sand substrates of southern Mozambique (southern coastline to Save River) are combinations of *Thalassia hemprichii, Halodule wrightii, Zostera capensis, Thalassodendron cilitum* and *Cymodocea serrulata*. In contrast, the seagrass communities of the northern limestone areas from Zambezia Province to Cabo Delgado Province are quite different. They are typically surrounded by coral reefs and tend to be intermingled with algae (seaweed) such as *Gracilaria salicornia, Halimedia* spp. and *Sargassum* spp. The predominant seagrass species are *Thalassia hemprichii* and *Halodule wrightii*. They cover up to 88% of the shallow intertidal soft-bottom areas in Cabo Delgado Province (Bandeira and Gell 2003).

Some species such as *Enhalus acorodies*, *Halophila stipulacea* and *Halophila minor* are only found in the north while pure stands of *Zostera capensis* are largely confined to the south (Bandeira and Bjork 2001).

Drag netting, port construction and other coastal developments threaten Mozambique's seagrass beds. Further, the authorities do not fully recognize the value of this ecosystem although they have taken steps to protect it by creating Bazaruto and Quirimbas Marine Parks. Research recently conducted on the importance of seagrass beds to the *Vulnerable* Dugong (Green and Short 2003; IUCN Red List 2012; Obura et al. 2012) as a habitat and food source may help to raise the ecosystem's profile.

Tanzania

The most extensive seagrass beds of the back reef lagoons and bays in Tanzania are found in Tanga, Bagamoyo, Mohoro, Kilwa, Mtwara and Mnazi Bay (Green and Short 2003). Mnazi Bay has some of the most studied seagrass beds. They cover 50 km^2 and are in good condition with luxuriant growth and high diversity (Richmond and Mohamed 2005).

Tanzania's first two marine protected areas were established in 1995 and included seagrass beds, but as in Kenya, there were no management practices or guidelines for seagrass beds. Further, outside the protected areas they were ignored. Trawling and dynamite fishing are the principal threats. The National Integrated Coastal Management Strategy process (see undated USAID report: pdf.usaid.gov/pdf_docs/pdacq826.pdf) went some way to raising the profile and level of understanding of seagrasses and other marine resources. Even so, there still is not much information on the seagrass beds of Tanzania as there has been little research and management focus on this particular ecosystem. Moreover, poor fishing practices such as the use of beach seines and dynamite fishing have accelerated since 2005 and continue to damage seagrass beds and their associated fauna and flora.

Kenya

The most extensive seagrass beds of the back reef lagoons and bays in Kenya are found in the bays of Gazi (8 km^2) and Funzi; in Mida, Kilifi and Mtwapa Creeks; and in the back lagoons around Mombasa and Diani–Chale Island (4.5 km^2). Gazi Bay and the lagoons of Diani–Chale Island are more or less continuous and represent the largest seagrass area in Kenya (Ochieng and Erftemeijer 2003).

Kenya has been very proactive in marine conservation. It established its first marine park in Malindi in 1968. The national guidelines for establishing marine parks and reserves and for protecting rare species, such as turtles and dugong, were adopted by UNEP's Action Plan for the East African Regional Seas Programme (UNEP 1998). Even though these protected areas include seagrasses, there are no detailed distribution maps of seagrasses for Kenya. Similarly, there are no management practices for protecting seagrass beds and their ecosystem as they are not viewed as an important resource for the national economy. As a result, there is little attempt to control the exploitation of fauna in seagrass beds outside protected areas.

Summary

Seagrass beds are one of the world's most productive aquatic ecosystems. They provide habitats for a wide range of species including *Vulnerable* dugong and turtles. They are important nursery, breeding and feeding grounds for numerous fish and invertebrates (Green and Short 2003; Waycott et al. 2011). They are therefore vital to commercial, subsistence and recreational fisheries.

Because they are highly productive and trap carbon in biomass and sediment, seagrass beds, like mangroves, are shallow-marine carbon sinks that are of great significance in carbon sequestration to reduce the greenhouse gas build-up in the atmosphere and oceans. They have the capacity to store up to 500 tonnes/ha (or 50 g/m^2) of carbon, nearly all of which is trapped in the sediment (Green and Short 2003). This is equivalent to the amount of carbon stored in primary tropical forests. There does not appear to be any targeted research in eastern Africa on this topic although a related study on carbon uptake strategies by different seagrass species in Kenya provides interesting insights into the possible direction of future research (Uku 2005).

The threats to seagrasses worldwide are similar and widespread. Seagrasses everywhere are vulnerable to eutrophication from nutrient over-enrichment of the environment and to a high sediment load caused by upland clearing and disturbance. Both these conditions reduce light availability, which is essential for sustaining the productivity of seagrass beds. People have no use for seagrass plants, but the beds support coastal fisheries worldwide. These are often subsistence fisheries because they occur in easily accessible, shallow, sheltered areas.

Seagrass beds have many functions such as sediment stabilization and coastal protection, water purification and nutrient cycling, mitigating climate change, maintaining biodiversity and safeguarding threatened species. They provide food, shelter and nurseries for fish as well. It is clear that these ecosystems have received insufficient attention in terms of research and management, due in part to their low visibility and less aesthetic appeal compared with, for example, coral reefs. Further research is called for to understand better their resilience and adaptability to climate change and their economic contribution to coastal communities in eastern Africa.

Coastal forests and other flora

The coastal flora of eastern Africa stretches from southern Somalia, through Kenya and Tanzania to southern Mozambique (Burgess and Clarke 2000). The forests are found inland from the coast with outliers occurring along rivers. In several locations the forests grade into submontane forests in the foothills of mountain ranges (CEPF 2005). The characteristics of the areas interspersed between the forests vary. Kenya has predominantly farmland. Tanzania and Mozambique generally have savannah woodland and thicket although farmed areas are on the increase (Masanja 2004). The coastal strip also includes the larger offshore islands of Pemba, Zanzibar, Mafia and the Bazaruto Archipelago as well as the smaller Indian Ocean islands close to the coastline (Burgess and Clarke 2000).

Eastern African coastal vegetation has long been isolated from other regions of tropical moist forests by expanses of drier savannahs and grasslands. This accounts for its exceptionally high plant endemism. Recently part of this ecoregion was classified as the Swahili Centre of Endemism (CEPF 2005). Studies at a few sites in Somalia and Mozambique have noted the occurrence of endemic trees, but overall the number of endemic species is thought to be greatly underestimated as insecurity has prevented any extensive exploration and field research. The coastal forests of eastern Africa have been defined as a biodiversity hot spot by Conservation International because of high levels of endemism and the threat of destruction by human activities (http://www.conservation.org).

Although the surviving forests scattered throughout the hot spot's 291,250 km² are typically tiny and fragmented, they contain remarkable levels of biodiversity. These forests also vary greatly in their species composition, particularly among less mobile species (Table 2.5). For example, forests that are only 100 km apart may differ in 80% of their plant species. Within the hot spot, the region of highest endemism stretches from northern Kenya to southern Tanzania and, to a certain extent, northernmost Mozambique. Kwale-Usambara on the Kenya–Tanzania border and Lindi in southern Tanzania are recognized as subcentres of endemism (Burgess and Clarke 2000).

Forests in Mozambique are at risk as a result of poor management and conservation methods and clearing land for cultivation. An ever-growing population of subsistence farmers still uses the slash-and-burn method of farming in search of soil that has not been leached of nutrients. This coupled with the expansion of commercial farming is devastating more and more of the region's coastal forest habitat. Given the diversity of habitats along the length of Mozambique's coastline and the economic importance of its littoral waters, remarkably few coastal areas are protected (Soto 2007). They include Marromeu Reserve (150,000 ha), Licuati Forest Reserve (3,500 ha), Maputo Elephant Reserve (70,000 ha), Pomene Reserve (20,000 ha), Bazaruto National Park (8,000 ha), Zinave National Park, Banhine National Park, Gile Reserve, Quirimbas National Park and Niassa Reserve. The Marromeu Reserve in the Zambezi River Delta system comprises mangrove swamps, freshwater swamps and miombo forest. The Maputo Elephant Reserve to the south is part of the Maputaland Centre of Endemism. It has dune vegetation, grasslands, floodplains, swamp forests and mangroves. The Licuati Forest Reserve is mainly sand forest, which lies within the complex vegetation of the Maputaland Centre of Endemism. This region includes Maputo Elephant Reserve and part of the Natal region in South Africa (Soto 2007).

Tanzania has about 33.5 million ha of forest and woodland. Some 13 million ha have been gazetted as forest reserve. Yet only 0.5% (70,000 ha) of these forest reserves are coastal forests. Coastal forests are usually rich in endemic tree species, but only scattered remnants are left of the original forests (Burgess and Clarke 2000; Conservation International 2007). Examples include the evergreen tree-cover type of *Newtonia buchananii*, *Allanblakia stuhmannii* and *Parinari excelsa* that occur in the Kwamkoro area, East Usambara Mountains, Tanga; Kimboza on the bottom slopes of Uluguru Mountains; and the lower slopes of the Udzungwa escarpment in Morogoro region.

The coastal forests that have been gazetted (not necessarily for their protection) include the Mnazi Bay–Rovuma Estuary Marine Park (65,000 ha); the Mafia Island Marine Park (88,200ha), the Jozani Chwaka Bay National Park and the Saadani National Park (1,062 ha) (http://en.wikipedia.org/wiki/List_of_protected_areas_of_Tanzania). Illegal and destructive logging, pit sawing, shifting cultivation, forest fires, poaching, hunting and other cultural practices, tourism and other commercial development all pose a threat to sustainable conservation.

Table 2.5: Hot spot vital signs of the eastern African coastal forests.

Species/area	Number
Hot spot vegetation remaining (km²)	29,125
Endemic plant species	1,750
Endemic threatened birds	2
Endemic threatened mammals	6
Endemic threatened amphibians	4
Extinct species	0
Human population density (people/km²)	52
Area protected (km²)	50,889
Area protected (km²) in IUCN categories i-iv	11,343

In Kenya considerable areas of coastal forests are under some sort of protection (Gachanja and Kanyanya 2004). They include Arabuko Sokoke Forest Reserve (37,000 ha); Madunguni Forest Reserve (5,300 ha); the forest-grassland mosaic of Shimba Hills National Reserve (21,400 ha); the mixed forest and woodland Kaya Forest Reserve (28,400 ha); the Medium Kwale Forest Reserve (5,100 ha); the Marafa Brachystegia Trust Land (3,000 ha); Tana River Delta; Witu Lamu Forest Reserve (1,500 ha); the predominantly woodland-type Boni-Lungi Forest Reserve (9,500 ha); the Tana Gallery Forest Trust Land; the Dodori-Boni Forest Reserve and National Reserve (22,000 ha); the thicket, forest, woodland mosaic of Ras Tenawi Trust Land (2,000 ha); the Kilibasi County Council Forest (200 ha); the Mwangea Trust Land Forest (1,500 ha); and the Mwangea Hill Trust Land and Private Forest (500 ha).

Coastal forest conservation in Kenya is subject to stresses such as encroaching human populations using inefficient farming methods; forest encroachment; grazing; insecure land and tree tenure; poor governance; charcoal burning; bush fires; mining; and double gazetting. For instance, the Shimba Hills are double gazetted as a forest reserve and a national reserve which may exacerbate stresses fom surrounding populations unless managed cooperatively.

Species

This section looks at species of special significance in eastern African marine environments based on some or all of the following criteria.

- IUCN Red List
- endemic to the WIO
- known functional ecology in resilience
- important food species for local fisheries
- global rarity and aesthetic value
- vulnerable or resilient to climate change

Coelacanth

The coelacanth is likely to be the sole remaining representative of a once widespread family of sarcopterygian (fleshy-finned) fish that were thought to have become extinct 70 million years ago. Marjorie Courtenay-Latimer discovered a coelacanth in a fishing trawler's catch netted off East London, South Africa, in 1938. The description of the fish by Dr JLB Smith of Rhodes University was met with scepticism and excitement in scientific circles. It was considered the zoological discovery of the century.

Two species of coelacanth are extant: the WIO species *Latimeria chalumnae*, which is listed as *Critically Endangered* (IUCN Red List), and an Indonesian species, *L. menadoensis*, which is less widely distributed. Coelacanths are commonly found on sloping continental shelves. Initial reports suggested they occurred at depths of 300–400 m in sheltering caves and canyons that provided habitat for their prey. They were sighted in the submarine canyons of the east and west coasts of the Mozambique Channel; the steep volcanic slopes of Comoros; and areas off the northern Mozambique coastline. More recently they have been seen in much shallower depths of 75–100 m on the upper slopes of Pemba Channel canyons around Tanga. The African Coelacanth Ecosystem Programme is the result of international and regional concern over rising incidents of accidental catches in deep-water gill nets, particularly in northern Tanzania. It worked with the Tanzanian government to establish the Tanga Coelacanth marine protected area (MPA). However, the proposed deep-water harbour in Mwambani Bay near Tanga is likely to compromise its activities and put the local population of this extraordinary and rare species of coelacanth at risk.

Sharks and rays

Sharks and rays, the unique and large group of relatively primitive cartilaginous fishes (Class: Chondrichthyes) are extremely vulnerable due to a combination of very slow reproduction rates and the lucrative Asian market for their fins, which are the principal ingredient of shark-fin soup. It is estimated that between 26 and 83 million sharks are killed each year for their fins (IUCN Shark Specialist Group (SSG)). Sharks have slow reproductive rates with many species only producing a handful of offspring when the adults are 10–15 years old. The more primitive species lay eggs, while the most advanced species are viviparous, meaning the foetal sharks are connected in the uterus by placentas and are born live.

There are 1,044 described chondrichthian species around the world consisting of sharks (468 species), rays and skates (batoids) and ratfishes (chimaeras). The population status of almost half of all sharks is unknown due to insufficient data (IUCN Red List), particularly in the WIO. Of those species that the IUCN SSG has assessed, 22 are *Critically Endangered*, 41 are *Endangered*, 116 are *Vulnerable*, and 133 are *Near Threatened*. These numbers are being revised through further conservation assessments.

In the WIO there are 137 species of sharks and rays, of which 15 are endemic to the region (Smith and Heemstra 1991). Ten species are endemic exclusively to South African waters. The highest elasmobranch diversity in the region has been recorded in Mozambique's waters: 73 sharks and 35 rays.

Uncontrolled offshore commercial fishing with foreign longliners and purseiners that accidentally net sharks and rays has raised global concern. They are also under threat from inconsistently managed and regulated national fisheries, the destruction of near-shore nursery grounds, and the shark-fin trade. The demand for shark fins, for traditional medicine as well as soup, has been growing steadily over the last decade, especially in China and its territories. This demand has generated the inhumane and widespread practice of shark finning, slicing off the shark's fins and throwing the shark back into the water to die a slow death. According to the IUCN SSG, this unregulated trade is one of the most serious threats to shark populations worldwide (Buckley 2007).

Estimates of the global value of the shark-fin trade range from USD 540 million to USD 1.2 billion (Clarke et al. 2006; Clarke et al. 2007). Shark fins are among the most expensive of seafood products worldwide, commonly retailing at USD 400 per kg (Buckley 2007). In the United States, where finning is prohibited, a bowl of shark-fin soup can sell for up to USD 150. For trophy species like the whale shark and basking shark, a single fin can fetch USD 10,000 to USD 20,000 (Clarke et al. 2007).

Studies estimate that 26–73 million sharks are harvested every year for their fins. The annual median from 1996 to 2000 is said to be 38 million. This is nearly four times the number recorded by the FAO (Clarke et al. 2006) but considerably fewer than the estimates of many conservationists. About 30% of the shark harvest comes from the Indian Ocean, mainly from the southwestern part. Although catching sharks for their fins is banned in other countries (Republic of Palau, USA and Canada), it is not regulated in the WIO (Obura et al. 2012).

As top predators, sharks play a key role in the food chain. The depletion of shark populations is likely to create worrying 'trophic cascades', causing dramatic changes in food webs (Robbins et al. 2006; Sandin et al. 2008). A total absence of reef-associated sharks (grey reef, black tip, white tip) was recorded during surveys in 2010-2011 of coral reefs in Comoros, Madagascar, Mozambique and Tanzania (Samoilys pers. obs.). The only sighting was in Cabo Delgado Province, Mozambique.

The general public, decision-makers and managers all have a poor understanding of the ecological importance of sharks and rays and their value to coastal tourism. Dive tourism in the Red Sea relies on healthy shark populations. A live grey reef shark has been valued at thousands of US dollars compared with a dead grey reef shark, which fetches USD 25 (Cousteau Society unpubl., Sudan). Rays are usually caught by local gill net fishermen, who salt their catch and sell it. This unsophisticated method has been popular in the region for decades. In Tanga, Tanzania, rays comprise 72% of the catch from gill nets (Anderson 2004).

Published data on sharks and rays in the WIO are rare, although an emerging interest in their ecological and conservation importance is likely to produce more data (Obura et al. 2012). Data on the small (< 2 m) coastal species are notably sparse as they are paid scant attention by management and conservation bodies (Table 2.6). It is likely they are being fished to extirpation, thanks to their small home ranges (with the exception of the milk shark) and attachment to home sites. They occur in coastal waters, which makes them accessible to local fishermen. Shark fisheries have existed for centuries in eastern Africa because the meat preserves well when salted and dried and is traded along the coast.

From Lamu to Kiunga in northern Kenya, shark fishing through set gill nets has been in practice for decades. Catch rates have declined by about 85% over the last 40 years. Prices have not increased significantly except for shark fin, which has risen from USD 2 per kg in 1998 to USD 28 per kg in 2008 (Samoilys and Kanyange 2008). A profitable quantity of shark fin (10 kg dry weight) can take a fisherman up to a year to accumulate as it requires the fins of about 150 sharks. It is worth it for the fisherman as it will fetch at least USD 555 from buyers for the Asian market (Samoilys and Kanyange 2008). It should be noted that, unlike in some areas, sharks landed in eastern Africa are used in their entirety. For example, the liver oil is used to treat wooden boats.

Recent research has focused on specific species (the great white shark (*Carcharodon carcharias*); whale sharks (*Rhincodon typus*) and manta rays (*Manta alfredi*)). It has been conducted in specific areas such as Tofo Beach in southern Mozambique. The findings are summarized below.

Great white shark *(Carcharodon carcharias)*

The population of great white sharks has always been low. They range from cold temperate waters to tropical waters, where they tend to prefer cooler, deeper waters. Most research on *Carcharodon carcharias* has been conducted in South Africa. Only a few sightings have been recorded off Mozambique, Tanzania and Kenya (Figure 2.11). Individuals have been caught or sighted throughout the region, most of them large pregnant females. This suggests they pup in warmer waters. Records for East Africa include a 5-m male trapped in a net off Malindi by a local fisherman in 1989; a 3.5-m male caught off Zanzibar Island in the 1990s; and a 6.1-m specimen caught in a tuna net 3.2 km off Unguja Island in Zanzibar.

Great whites have low reproductive potential, probably have a low natural mortality, and presumably possess a low capacity for density- dependent compensation to rapid declines in population size. It is therefore reasonable to conclude that populations are vulnerable to recruitment overfishing and all forms of non-natural mortality. Their population status is poorly known over the species range due to the difficulty in assessing the population abundance of wide ranging and rare animals.

Whale sharks *(Rhincodon typus)*

From the first whale shark described in the Indian Ocean in 1828, the region continues to be one of the most important areas for this species. Whale sharks are a planktivorous, broad-ranging species. Their seasonal migration patterns cover thousands of kilometres. They can also be resident year-round in equatorial zones. They are found in many areas with surface seawater temperatures of 18–30°C and range across the entire Indian Ocean. Unusually for sharks, the females can give birth to thousands of young in their lifetime. Unfortunately, whale sharks are sought after by fisheries for their liver oil to waterproof traditional fishing vessels. In India, Pakistan and the Maldives in particular they have suffered a massive and sudden decline in numbers.

Whale shark tourism has rapidly grown in importance with regular seasonal sightings in Kenya (Diani), Tanzania (Mafia) and Mozambique (Tofo). The relationships among

Table 2.6: Small coastal species of shark in eastern Africa: little is known of their population status.
(Source: Smith and Heemstra 1995; Compagno 2002; IUCN Red List 2012).

Species name	Common name	Red List global status	Notes
Carcharhinus amblyrhynchos	Grey reef shark	Not assessed	Little known about their movements but thought to be highly site attached; known to form daytime aggregations in favoured places
C. dussumieri	Whitecheek shark	Undetermined	—
C. melanopterus	Black tip reef shark	Near threatened	Top predators on coral reefs
C. sealei	Blackspot shark	Undetermined	Coastal shore usually at depths < 40 m
C. sorrah	Spot-tail shark	Undetermined	Top predators on corals reefs, in depths of 20–75 m
C. wheeleri	Black tail reef shark	Undetermined	Juveniles in shallow inshore waters, adults usually at depths of > 80 m
Rhizoprionodon acutus	Milk shark	Undetermined	Inshore species
Triaenodon obesus	White tip reef shark	Near threatened	Top predators on coral reefs

these populations are not fully known. Satellite tagging studies from Seychelles and Mozambique are examining these dynamics (Rowatt 2008; Brunnschweiler et al. 2009) and offer an excellent opportunity for mixing conservation and research with economic development.

Mozambique—Tofo

High densities of whale shark (*R. typus*) gather year-round in a narrow (c. 20 km^2) corridor close to the coastline around Tofo in southern Mozambique. Frequent sightings and the sharks' habituation to boats have encouraged a burgeoning marine tourism industry. The migratory routes of these fish and their behaviour patterns are not understood, but the population structure (81% males) suggests that they constitute a subset of a larger population. A female *R. typus* that was tagged off Tofo had swum across the Mozambique Channel and around the southern tip of Madagascar in 87 days, a minimum distance of 1,200 km. These sharks have been recorded diving to depths well into the mesopelagic and bathypelagic zones (1,286 m maximum depth) (Brunnschweiler et al. 2009).

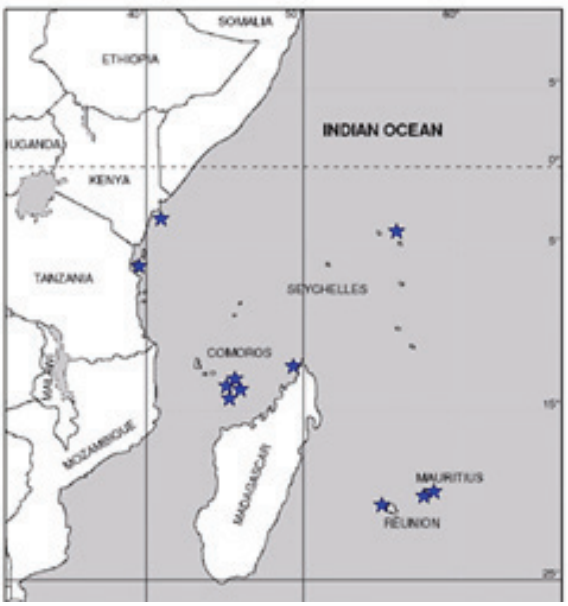


Figure 2.11: Observations of great white sharks in the WIO. The stars correspond to sparse observations or catch.(data from Cliff et al. 2000 and MAYSHARK; unpubl. data in Kiska et al. 2009).

Kenya—Diani

Along the southern coast of Kenya the numbers of whale shark (*R. typus*) appear to have increased, particularly around Diani, Galu and Chale Island. In 2011, an average of 20 whales was spotted daily whereas the previous average had been 20 in a year. There has been speculation that the increase in shark numbers is linked to greater volumes of mantis shrimp. It may also be related to better monitoring as a result of greater interest in this species.

Sharks are mentioned in many global conservation instruments. The following refer to the whale shark (Obura et al. 2012):

- IUCN Red List – The whale shark is listed as *Vulnerable*.
- CITES – Appendix II, 2003 – This status should lead to stricter monitoring of the international trade in whale shark products and the imposition of restrictions. This would have global benefits for the conservation of the species.
- Convention on Migratory Species – Appendix II, 1999 – This called for cooperative action by 2001–2002. In November 2005 the convention approved a recommendation proposed by Australia, New Zealand and Seychelles for the conservation of migratory sharks.
- UNCLOS – Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks – It recognizes that coordinated management and assessments of shared migratory populations would bring an understanding of the effect of fishing on shared populations. No such measures have been proposed yet.

- FAO – International Plan of Action for Sharks – This offers a potential framework for whale shark conservation. Unfortunately the implementation of national plans of action by FAO members has been extremely limited, which has hampered plans for an international instrument.

Sawfish and guitarfish

The *Critically Endangered* knifetooth sawfish (*Anoxypristis cuspidate*) and longcomb sawfish (*Pristis zijron*) have been sighted on rare occasions in Kenya in the lower reaches of the Tana River and in Ungwana Bay to the river's north (Samoilys et al. 2011a). All sawfish are listed on Appendix 1 of CITES. They are the sole living family Pristidae within the order Pristiformes. Guitarfish also occur in the WIO, but there are no data and since they are likely to be exploited they are probably highly depleted.

***Manta rays** (Manta alfredi)*

Manta rays are the largest batoid fishes in the world. Pelagic planktivores, they are are widely distributed throughout most of the world's tropic and subtropic oceans (Last and Stevens 2009; Marshall et al. 2009). These large rays are most commonly found in productive coastal areas and are often encountered by divers around island groups, in shallow bays, tidal channels and offshore seamounts and pinnacles (Dewar et al. 2008; Luiz et al. 2009; Marshall et al. 2009). There is not much information about their population size and structure, demography and movement patterns in the WIO. A large aggregation of manta ray at Tofo in southern Mozambique has been studied for several years (Marshall et al. 2011). Annual population estimates range from 149 to 454 while the estimate for the superpopulation is 802. Tofo is also a birthing ground, with females typically giving birth in the austral summer period after a year-long gestation. Manta rays typically give birth every two years although some birth annually. Normally they produce a single pup but occasionally two. This reproductive pattern renders the species highly vulnerable to exploitation.

Manta rays in eastern Africa have been included in the dried shark-meat trade for centuries (see above). The effect on the species has not been documented. Research at Tofo has contributed to the limited baseline data on *M. alfredi* and *Rhincodon typus* and highlights the need for more research and better conservation strategies.

Other sharks and rays

Reef and oceanic sharks are widely dispersed, but they have been taken in fisheries either targeted or as by-catch, which has reduced their populations. In eastern Africa the bull shark or Zambezi shark (*Carcharhinus leucas*) is often implicated in attacks on people, fuelling the general fear of sharks and diminishing enthusiasm for commitment to their conservation. The charismatic scalloped hammerhead sharks (*Sphyrna lewini*) used to be abundant near steep reef slopes off Pemba Island, Tanzania, but their numbers have dwindled (Last and Stevens 2009), probably due to the gill netting of juveniles in inshore waters and the overfishing of adults by foreign offshore fishing fleets.

Bony (teleost) fishes

The teleost fish species occurring in the WIO that merit mention are those listed as threatened on the IUCN Red List or that are rare and have regional or global significance. Examples are given in Table 2.7.

The Napoleon wrasse is threatened because of crashing populations worldwide and demand generated by the Asian live reef-fish market. Two or three eastern Africa locations have relatively healthy populations. They merit attention for their global as well as national and regional significance. Surveys of all these species are limited and further surveys are needed to fully understand their population status and distribution and to evaluate areas of particular importance for these threatened species. For instance, in Kenya, a population of Napoleon wrasse on Pate Island's Pazarli Reef in the channel of the proposed Lamu Port will be destroyed if port construction proceeds as planned (Samoilys et al. 2011a).

Turtles

Five out of seven species of the world's marine turtles occur in Mozambique, Tanzania and Kenya: green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricate*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*) (UNEP 2009; Obura et al 2012) The species with the greatest abundance is the green turtle, next is the hawksbill. All five species are on the IUCN Red List either as *Critically Endangered* (hawksbill, leatherback) or *Endangered* (green, olive ridley and loggerhead).

Sea turtles use a variety of habitats during their complicated life cycles. They lay and incubate their eggs in beach sand, but post-hatchlings are pelagic and live in the surface waters of convergence zones and major gyre systems throughout tropical and temperate oceans. Juveniles migrate along ocean currents for thousands of kilometres. Most adult turtles also migrate over long distances, but this varies among species. The feeding grounds of the bottom-feeding sea turtles (green, hawksbill, olive ridley and loggerhead) include seagrass beds, coral reefs, sand and mud flats, and mangrove ecosystems. The pelagic leatherback feeds in the oceanic surface waters of tropical, temperate, and even polar seas.

The state of turtle populations is a good indicator of the overall health of coastal and marine ecosystems. Findings from the Caribbean suggest that the demise of the macro-herbivorous green turtles in the wake of European colonization had a major effect on the ecosystem as few other species feed on seagrasses.

Turtle research in the WIO has been extensive since the early 1990s, but this information is still relatively scattered and methods are not always standardized. Even so, turtle information has been central to subregional and ecoregional marine planning

Table 2.7: Species of teleost fishes that are threatened, rare and merit conservation attention.

Common name	Latin name	Red List or population status	Notable locations
Napoleon wrasse	*Cheilinus undulatus*	Endangered; CITES Appendix 2	Pate Island, N. Kenya Mafia Island, Tanzania Vamizi Island, N. Mozambique
Humphead parrotfish	*Bolbometopon muricatum*	Vulnerable	—
Giant grouper	*Epinephelus lanceolatus*	Vulnerable	Rare throughout its range; preliminary data on a Zanzibar fishery based on a spawning aggregation
Red Sea, Arabian Gulf angelfish	*Apolemichthys xanthotis*	Least concern	Found only in northern Kenya at its southern limit

Source: Samoilys et al. 2011a; IUCN 2012 Red List data; Samoilys et al. 2013; Samoilys pers. obs.

exercises for mainland East Africa (WWF 2004a). More specific data are needed on turtle feeding and breeding, and juvenile and adult migratory routes in the WIO. Important nesting and feeding areas in eastern Africa are listed in Table 2.8.

Loggerhead and leatherback turtles

Nesting areas for both loggerhead and leatherback turtles have been identified in Mozambique, particularly in the Maputo Bay–Machangulo Complex and the Bazaruto Archipelago. Foraging populations of both species are found off all three countries.

Olive ridley

With the exception of Mozambique, little information is available on the olive ridley's behaviour patterns such as nesting and feeding grounds and juvenile movements. Olive ridleys have been sighted in northern Kenya at Lamu, Tenewi Island, Kiunga Marine National Reserve, Watamu and Malindi. Deaths have been recorded near Rufiji Delta, Tanzania (Muir 2005; West 2011). The northern coastline of Mozambique is one of the most important nesting sites in the WIO (Costa et al. 2007).

The many turtle conservation groups need support and their methodology should be standardized to build a single regional database that can inform a universal management policy.

Marine mammals—dugong, whales and dolphins

There are some 37 species of marine mammals in the WIO. There are 8 baleen whales, 2 or 3 sperm whales, 13 toothed whales, 13 dolphins and 1 dugong (Table 2.2). The eastern African coastline harbours important breeding grounds for several whale species (Figure 2.12). About 17 whale and 13 dolphin species are thought to occur in Mozambique, Tanzania and Kenya (Berggren and Coles 2009). The exact number is yet to be determined as marine mammal surveys in the WIO have not been thorough. Some of the principal sources of information are reviews of the Indian Ocean Whale Sanctuary to assess the threat status and trends of cetacean populations (Clark and Lamberson 1982). Marine mammal surveys have also been conducted in northern Mozambique as part of the EIAs for oil and gas exploration (Samoilys et al. in press).

Whale populations that have shrunk include blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*) and humpback whales (*Megaptera novaeangliae*) (Obura et al. 2012). The severe depletion of almost all stocks of 'great whales' is well documented although most information comes from the the Atlantic and Pacific Oceans (Kiszka et al 2008) rather than the Indian Ocean and only through inference can it be assumed that populations in the Indian Ocean are showing similar depletion.

Dugong *(Dugong dugon)*

Dugongs live close to shore in the tropical and subtropical waters of the Indian and Pacific Oceans between southern Mozambique in the west and Vanuatu to Japan in the east. They are usually found in beds of seagrass, which is their preferred food. Very little is known about the status of the dugong, but their numbers have been depleted significantly in most locations. In fact, the dugong population is believed to be in sharp decline over more than two-thirds of its range. In some locations it is locally extinct. The species is listed as *Vulnerable* (IUCN Red List 2012). The dugong once ranged from Somalia to Mozambique and across to western Madagascar (Kemp 2000; WWF 2004b), but numbers have plummeted since the 1960s as it is hunted for its meat and is the accidental victim of seine, gill-net and trawl fishing. Habitat destruction and human encroachment have also contributed to its decline. Dugongs are protected in all three countries, but enforcement is weak.

The scarcity of sightings underscores the rarity of these animals and lends credence to the view that dugongs are one of the most endangered mammals on the African continent (Samoilys et al. 2011a). There are probably fewer than 500 animals left in the WIO. The only viable population (>300) is in the Bazaruto Archipelago in Mozambique, which is being monitored (www.dugong.org). Only one dugong was recorded in aerial surveys of the Quirimbas Archipelago in northern Mozambique in 2007. A lone dugong was sighted again in 2009.

Table 2.8: Locations of importance to green and hawksbill turtles (Source: Obura et al. 2012).

Area	Importance
GREEN TURTLES	
Bazaruto, Mozambique	Nesting, feeding grounds and important for the juveniles
Quirimbas – Mnazi Bay, Mozambique	Important nesting and feeding grounds, up to 200 nests per year
Mafia – Rufiji, Tanzania	Key feeding grounds and some key nesting sites, particularly Mafia (since 2001–2011 had over 1179 nests recorded*
Kiunga and Lamu, Kenya	Key feeding and nesting area with up to 130 nests in Kiunga and over 100 nests in Lamu area per year
Mozambique Channel	Used by all 5 species, genetic differentiation likely due to oceanography of the channel, separating northern and southern populations
HAWKSBILL TURTLES	
Bazaruto, Mozambique	Nesting, feeding grounds and important for the juveniles
Quirimbas – Mnazi Bay, Mozambique/Tanzania	Important nesting and feeding grounds

Source: Obura et al. 2012

*Seasense report 2011: http://www.seasense.org/fileadmin/documents/reports/Sea_Sense_2011_Annual_Report.pdf

There are scattered remnant populations in Tanzania (~20) and Kenya (<10). Seasense, a local non-government organization (NGO) working with coastal communities in Tanzania to protect endangered marine species, has been observing a small breeding herd of 37 dugong in the Rufiji Delta since 2004. A few individual dugongs have also been sighted off the western coast of Mafia Island.

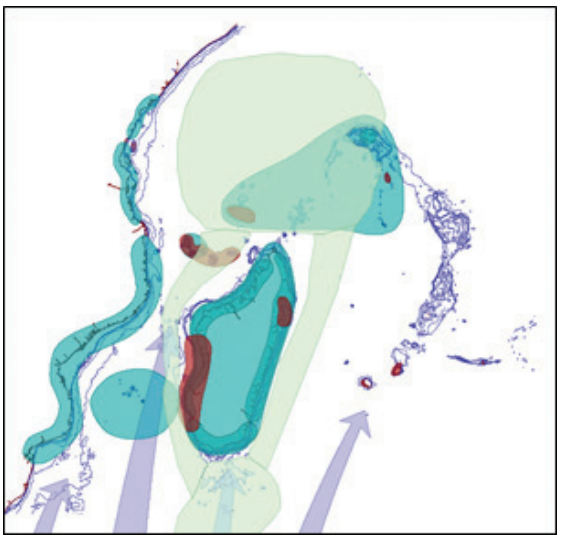


Figure 2.12: Cetacean zones in the WIO, emphasizing the primary zones of cetacean sightings (green), blue whale sightings (blue), primary feeding grounds for all cetaceans (pink), wintering grounds for humpback whales (red), and migration routes for humpback whales (arrows). (Source: RAMP@COI from Obura et al. 2012)

The Tana Delta seagrass beds may support one of the few remaining dugong populations in Kenya (Samoilys et al. 2011a). It is believed that dugongs may now remain only in very small numbers in the Lamu-Kiunga region (Dutton 1998) and in Funzi Bay in the south of the country. There has been only one recent sighting in the northern area of Lamu-Kiunga (WWF/KWS 2010, pers. comm.). One dugong has been sighted each year (2007–2009) in Funzi Bay in southern Kenya. There have been two sightings off Kisite-Mpunguti Marine Reserve further south (Global Vision International pers. comm.).

Humpback whales

Humpback whales (*Megaptera novaeangliae*) are listed as *Vulnerable* (IUCN Red List). Like many whales, they feed in the Antarctic but breed further north in the tropics and subtropics during the austral winter (Figure 2.12). Seven breeding stocks of humpback whale populations (A to G) have been designated by the International Whaling Commission. They range from the western South Atlantic to the eastern South Pacific (Cerchio et al. 2008). Breeding stock C is the population that winters in the WIO from the east coast of South Africa to Kenya (Cerchio et al. 2008). Most of the humpbacks are mothers with calves, and the busiest months are July to August.

The WIO breeding stock is divided into four subpopulations:

- > 6000 animals from South Africa to Kenya
- a smaller aggregation in the Comoro Islands, many mothers and calves sighted off Mayotte, peaking late in the season
- 7,000–8,000 animals around Madagascar, likely the largest substock
- a smaller aggregation in the Mascarene and Seychelles Islands, a possible range expansion following a population increase from whaling protection

Evidence suggests these whales may be divided into two distinct genetic substocks (the mainland and the islands) while the Comorian substock may represent a connection between the two. Recent observations suggest Mozambique's Bazaruto Archipelago is a major wintering ground for humpbacks with significant concentrations around Zanzibar too. Humpback migration routes are primarily along a north–south axis with populations from the southern Indian Ocean heading north up the East African coast (Figure 2.12). The principal areas for humpback sightings above the water and for hearing whalesong underwater are Tofo in southern Mozambique; the port of Nacala and Quirimbas Archipelago in northern Mozambique; Maziwe and Pemba Islands in Zanzibar; Mnazi Bay in Tanzania; and Malindi and Watamu in Kenya (see Table 2.9).

The Humpback Whale Network which was established in 2008 by the Kemya Marine Mammal Network (http://kenyammnetwork.wix.com/kmmnetwork#!humpbak-whale-network/c137l) encourages people to report humpback whale sightings. All information from Mozambique, Tanzania and Kenya contributes to a greater understanding of migration routes, behaviour patterns, population abundance and threats. The network has records for 3,200 humpback whales. In 2011 nearly 2,000 sightings were recorded between June and December: ~1,300 in southern Mozambique, 572 in Tanzania, and 69 in Kenya.

Other whales

There is little historical information on other whale species, but research, monitoring and networks are on the increase (Obura et al. 2012).

Rorqual whales

Blue whales (*Balaenoptera musculus*): historical data suggest a population of pygmy blue whales exists northwest of the Seychelles off the Kenyan and Somali coasts. Its current status is not known nor is the migratory connection with southern populations. Blue whale sightings have been primarily in the Mozambique Channel, off the southwest and southeast coasts of Madagascar, and on the Madagascar Plateau (c. 450). Minke whales were recorded off Watamu, Kenya, in 2013.

Sperm whales, pilot whales and orcas

Sightings of sperm whales have been recorded along the coastline from southern Mozambique to northern Kenya. Data and records are limited (Kenya Marine Mammal Network, 2013).

Sightings of pods of up to six orcas have been recorded off Watamu, Kenya, over the past 10 years (Kenya Marine Mammal Network, 2013).

Short-finned pilot whales in pods of more than 100 are reported annually in Pemba Channel on Kenya's south coast and Watamu further to the north. They associate with bottlenose dolphins.

Whales and dolphins are subject to several chronic dangers. They get entangled in fishing nets and drown. Chemical pollution (heavy metals, pesticides and other toxins) accumulates in their bodies from ingesting contaminated prey. Marine debris, particularly plastics, is mistaken for food. Deep-water beaked whales and delphinids are sensitive to acoustic disturbance caused by offshore exploration for oil and gas.

Coastal dolphins

There are 13 widespread dolphin species in the WIO. Four coastal species are of particular interest for conservation:

- Indo-Pacific humpback dolphin (*Sousa chinensis*), *Near Threatened* (IUCN 2012). It is widely distributed along the west coast of Madagascar and the eastern African mainland from northern Kenya to South Africa. The pods are usually small and may be mixed with bottlenose and other dolphins. The humpback prefers sheltered, shallow (< 30 m) coastal waters. It is rare and becoming more endangered.

Table 2.9: Key locations and observers of humpback whales.

Country	Organization	Location
Mozambique	All Out Africa Whale Shark Conservation and Marine Megafauna Foundation	Tofo, southern Mozambique
	Dolphin Care Africa group	Ponta d'Ouro, southern Mozambique
	Association for Coastal Conservation of Mozambique (ACCM-Zavora Marine Lab)	Zavora, southern Mozambique
Tanzania	Friends of Maziwe project	Maziwe and Pemba Islands, northern Tanzania
	Mnazi Marine Park staff and collaborating fishermen	Mnazi Bay, Ruvuma Estuary Marine Park, southern Tanzania
	Collaborating fishermen and individuals	Kilwa, Fanjove, Dar es Salaam and Zanzibar
Kenya	Global Vision International (GVI)	Kisite–Mpunguti, southern Kenya
	Watamu Marine Association	Watamu, central Kenyan coast
	Kiruwitu Conservation Group	Vipingo, central Kenyan coast

- Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), *Data Deficient* (IUCN 2012). It is mainly coastal, unlike the common bottlenose dolphin, *T. truncates*, which is more oceanic. It is common throughout the region and has been quite well documented. It occurs close to shore in shallow waters but is also found in deeper coastal waters. It is not hunted, but it can end up in gill nets as bycatch.
- Spinner dolphin (*Stenella longirostris*), *Data Deficient* (IUCN 2012). It is widely distributed and is common in Mozambique, Tanzania and Kenya. It is typically found close to shore in shallow waters but also frequents deeper coastal waters and can exhibit a diel pattern of resting in shallow water during daylight and feeding offshore in deep water at night. Unlike the other species, they may school in large groups ranging from hundreds to thousands (Berggren and Coles 2009).
- Spotted dolphin (*Stenella attenuata*), *Least Concern* (IUCN 2012). It is the most abundant dolphin species according to surveys conducted in Kenya (WWF 2004a) and Mozambique. However, only one of this species was sighted off Kenya between 2006 and 2013. This may be because they are oceanic, but they are not as common as expected (Kenya Marine Mammal Network).

All four dolphin species have high conservation value. Their coastal ranges, life history and habits make them susceptible to human activity, which makes them indicator species for the broad impact of human encroachment on the coastal marine environment. Another dolphin species of interest is the common bottlenose dolphin (*Tursiops truncatus*), one of the most widespread and best documented dolphins. It is the one most commonly spotted by tourists and occurs in Tanzania and Mozambique but not Kenya. There is also Risso's dolphin (*Grampus griseus*), a little-studied dolphin said to occur in all three countries (Berggren and Coles 2009).

Coastal forests of eastern Africa: A biodiversity hot spot

The tropical and moist coastal forests of eastern African have been designated a biodiversity hot spot by Conservation International.The hot spot extends along the coastline in a narrow strip from Somalia to the mouth of the Limpopo River in Mozambique and includes the islands of Pemba and Zanzibar. The following section breaks down the hot spot by broad taxa.

Plants

The hot spot has about 4,050 vascular plant species, 1,750 (43%) of which are endemic (see Table 2.5). At least 28 plant genera are endemic, most of which are monotypic. About 70% of endemic species and 90% of endemic genera are found in forest habitats. About 40% of the endemic plant species are found in a single forest. For example, in southern Tanzania's Rondo Forest 60 endemic species and 2 endemic genera. of African violets (*Saintpaulia* spp.), which are known around the world, occur in the hot spot.

Birds

More than 633 bird species are found in the hot spot, 11 being endemic. Pemba Island, which is one of BirdLife International's endemic bird areas, has 4 endemic species: the Pemba white-eye (*Zosterops vaughani*), Pemba green pigeon (*Treron pembaensis*), Pemba sunbird (*Nectarinia pembae*), and Pemba scops owl (*Otus pembaensis*). The Tana River cisticola (*Cisticola restrictus*) is endemic to the Lower Tana River, and the Malindi pipit (*Anthus melindae*) is endemic to the coastal grasslands of Kenya. Most of the other endemics are found in the mainland coastal forests of Kenya and Tanzania, including the yellow flycatcher (*Erythrocercus holochlorus*), the *Endangered* Sokoke pipit (*Anthus sokokensis*), Clarke's weaver (*Ploceus golandi*) and the Mombasa woodpecker (*Campethera mombassica*).

Mammals

Of the nearly 200 mammals, 11 are endemic. These include the *Endangered* Ader's duiker (*Cephalophus adersi*) from Zanzibar, Arabuko Sokoke Forest and Boni-Dodori Forest; the *Vulnerable* Pemba flying fox (*Pteropus voeltzkowi)* restricted to Pemba Island, the Kenyan wattled bat (*Glauconycteris kenyacola*), the Dar es Salaam pipistrelle (*Pipistrellus permixtus*), the *Endangered* golden-rumped elephant shrew (*Rhynchocyon chrysopygus*), occurring in a narrow coastal strip in southeastern Kenya, and a recently described species of horseshoe bat (*Rhinolophus maendeleo*) in the Amboni Caves in Tanga District in Tanzania.

Flagship species for the hot spot are the primates, with three endemic monkey species. The Tana River red colobus (*Procolobus rufomitratus*) numbers about 1,100–1,300 and is found in small patches of gallery forest along Kenya's lower Tana River. The *Endangered* population of Tana River mangabey (*Cercocebus galeritus*) which has been reduced to 1,000–1,200. The *Endangered* Zanzibar red colobus (*Procolobus kirkii*), a tourist attraction, has an estimated population of about 1,000–1,500, mostly found in Zanzibar's Jozani Forest but also in a number of village forests. Recent reports suggest it is being hunted by immigrants from the mainland. Two of the four species of galagos (bush babies) are endemic: the *Critically Endangered* Rondo dwarf galago (*Galagoides rondoensis*) in southern Tanzanian forests, and the Kenya coast galago (*G. cocos*) in northern Tanzania spilling over into Kenya.

The hot spot still supports populations of threatened large African herbivores, including the black rhinoceros (*Diceros bicornis Critically Endangered*) and savannah elephants (*Loxodonta africana, Vulnerable*), especially in the larger protected areas and wilderness regions of southern Tanzania and northern Mozambique. There are also populations of African wild dog (*Lycaon pictus, Endangered*).

Reptiles and amphibians

There are about 250 reptile species. More than 50 of these are endemic. The hot spot has one endemic reptile genus, *Scolecoseps*, which is represented by three species.

There are more than 85 amphibian species, six of which are unique to the hot spot. These endemics include the Mafia Island toad (*Stephopaedes howelli, Endangered*), Shimba Hills banana frog (*Afrixalus sylvaticus, Endangered*), Shimba Hills reed frog (*Hyperolius rubrovermiculatus, Endangered*), and the *Endangered* frog *Phrynobatrachus pakenhami*, found only in northern Pemba Island, particularly Ngezi Forest Reserve. One species largely confined to the hot spot is Loveridge's snouted toad (*Mertensophryne micranotis*), the only member of its genus. It is remarkable in that it is one of the few amphibians to breed by internal fertilization, although it still lays eggs rather than giving birth to live young. A new genus of frog, similar to members of the genus *Kassina*, has recently been found in the Jozani Forest on Zanzibar and awaits description.

Freshwater fishes

Nearly 220 fish species live in the fresh waterways. More than 30 are endemic. Of the 34 families represented in the hot spot, minnows (family Cyprinidae) are dominant, followed by killifishes (*Nothobranchius* spp.). Some species of fish have remarkable survival mechanisms. For example, the air-breathing lungfishes *Protopterus amphibious* and *P. annectens* can survive in a dormant state in cocoons beneath dried mud for over a year.

Invertebrates

Levels of endemism within some invertebrate groups are significantly higher than among vertebrates. About 80% of millipedes and 68% of molluscs are unique to the hot spot. It is also home to a Gondwana relict dragonfly species (*Coryphagrion grandis*) that has its nearest relatives in Central and South America.

Other coastal forests and flora

All coastal forests are threatened by unregulated and illegal logging, clearing for development, inadequate management and limited understanding of their biodiversity value.

Dune vegetation and sand forests

The trees and other flora of the dune systems represent some of the most fragile coastal forest types. Species incude *Mimusops caffra, Diospyros rotundifolia, Sideroxylon inerme, Euclea natalensis, Eugenia capensis, Olax* spp., *Bridellia catharrtica* and *Brexia madagascariensis*. Much of this landscape today comprises a mosaic of cleared fields planted with orchards of exotic tree species such as coconut (*Coco nucifera*), cashew nut (*Anacardium occidentale*) and mango (*Mangifera indica*).

Sand forests have a shallow root system. Typical tree species are *Dialium schlechteri, Afzelia quanzensis, Balamites maughamii* (precious), *Newtonia hildebrandtii, Pteleopsis myrtifolia, Drypetes arguta, Hyperacanthus microphyllum* and *Erythrophleum lasianthum*. These forests are encircled with a distinctive boundary (1–2 m) that serves as a natural fire break. As a result, sand forests are a unique environment as they rarely catch fire (Matthews 2001).

Miombo woodlands

Miombo woodlands are found in the north of the Limpopo River coastal area and across vast tracts of Tanzania. They are composed of deciduous woody vegetation frequently dominated by *Brachystagia* spp. and *Strichnos spinosa. Brachystagia* is commonly associated with *Julbernadia globiflora, Pterocarpus angolensis* ('umbila'), *Burkea africana, Bridelia micrantha, Cynometra* spp., *Dalbergia melanoxylon, Swartizia madagascariensis* and *Millettia stuhlmannii*. *Strichnos* is usually associated with *Combretum* spp., *Terminalia* spp. and *Pteleopsis myrtilifolia*.

Other forests

The more open, mixed woodland forests on the coasts is characterized by common, woody savanna species such as *Acacia burkei, Albizia veriscolor, Afzelia quanzensis,* and *Albizia adianthifolia*. Evergreen forests occur along the coast too (Burgess and Clarke 2000), principally in Mozambique's Chiringoma Hills, comprising common species such as *Erythrophloeum suaveolens* ('missanda'), *Millettia stuhlmannii* ('panga-panga'), and *Pterocarpus angolensis* ('umbila'). In some restricted locations in Gaza and Inhambane Provinces, these forests are composed of *Androstschys johnsonii* ('mecrusse' or 'cimbiri').

Social and economic

This section describes the socioeconomic setting of the coastal areas of the three countries to understand their context and trends in order to identify areas and strategies for managing coastal systems experiencing climate change. It details the demographics of coastal populations, their educational standards and levels of poverty to provide the social setting with particular reference to vulnerable groups. It also describes community livelihoods and dependence on natural resources.

The three eastern African countries are all inhabited by coastal people that are strongly reliant on marine resources for their livelihoods, through commercial, artisanal and subsistence use (UNEP 2009). This is exemplified through small-scale fisheries, but increasingly through more commercial extractive use that includes commercial scale fisheries, oil and gas extraction, mariculture and urban development.

Demographic trends

Eastern Africa's coastal population has been steadily increasing as a result of lower infant mortality rates and migration in search of economic opportunity. The percentage of the population that lives within the 25-km coastal strip varies markedly. It is nearly 33% in Mozambique (the highest in the WIO), 13.6% in Tanzania and just 6% in Kenya (UNEP 2009). However, Mozambique has the lowest coastal population density (113 per km^2) compared with Kenya (171 per km^2) and Tanzania (154 per km^2). This population growth has placed heavy demands on inshore marine ecosystems, which has depleted some species. Poverty levels are high in all three countries, both in terms of per capita gross national

income (GNI) and the human development index (HDI). Mozambique has the lowest ratings in the WIO with a per capita GNI of USD 906 and an HDI score of 0.327 compared with Kenya's HDI score of 0.52 and Tanzania's HDI of 0.48[10].

All three countries have ports and harbours, industries, tourist hotels, and road and rail networks. Inland and offshore mining and oil and natural gas exploration and extraction are the latest economic development. It is inevitable that these extractive industries will change the face of coastal habitats.

Rural poverty surpasses urban poverty, ranging from 37% in Tanzania (2007) and 49% in Kenya (2005) to 56.9% in Mozambique (2008), according to the Millennium Development Goal indicator-monitoring website. Specific data for Kenya show that poverty levels in the coastal areas are considerably higher than the national rural average with an estimated 62% below the poverty line (see World Bank Indicators - rural poverty portal[11]). While poverty levels have been gradually reducing in Tanzania and Mozambique, the percentage of rural poor has remained largely unchanged in Kenya in the last two decades.

Coastal poverty fits generally into the patterns of rural poverty, but there are some distinguishing features. Many coastal resources are less dependent on short-term weather patterns than terrestrial resources, allowing more reliability, although the 'fugitive' nature of other marine resources, particularly fish, adds a level of uncertainty to coastal livelihoods. The open-access nature of many coastal resources, while providing opportunities for people without property or capital, also opens the resource to competition or to expropriation for other uses, including tourism or conservation. This may aggravate the historical trend of diminishing access to resources among the poor, as demand for them increases, leading to situations where artisanal fishers are forced to resort to using illegal gear or fishing in protected areas.

The overall livelihoods strategy of coastal households is one of diversification. Many households will be involved both in fisheries and in agriculture and animal husbandry (the main livelihood strategies), using part of the production for self-consumption and selling any surplus to provide income for essential services such as healthcare and education[12].

Education

In Mozambique there is a skills shortage because of the low level of education. Only 22% of children complete their basic education, barely 8% complete secondary school, and just 136 of every 100,000 go on to university (Mozambique Education for All (EFA) Profile[13]).

Among people over 25 years of age living on the Tanzania mainland, 12.3% have completed or dropped out at lower grades of primary schools, 45.8% at higher grades of primary schools and only 5.1% at lower secondary level and 0.7% at upper secondary level (URT 2006a). In contrast, a higher proportion of persons of 25 years and over have attended school at secondary education and higher levels in Zanzibar. Only 6.8% have completed or dropped out at lower grades of primary schools, 21.9% at upper grades of primary schools and 29.8% at lower secondary level.

Kenya's coastal region has one of the lowest literacy levels in the country (15%) with even lower secondary education enrolment rates (14.4 %) (see World Bank Indicators - rural poverty portal). Just under 15% of the coastal population has a secondary education and 66% a primary education while 69% can read and write (GoK 2009). Nearly 20% of the coastal adult population has never attended school, primarily women (63%) and the rural population (76%).

Economic activities

The main economic activities are fisheries, tourism, agriculture, forestry, mining, agro-processing factories and construction. Some coastal areas are excluded from economic activity because they have been gazetted as conservation areas.

Fisheries

Fisheries are usually categorized as small-scale, or artisanal, fisheries and the larger-scale commercial and industrial fisheries. The coastal population is mostly involved in the small-scale fisheries, with only a small percentage of fishers having the means to graduate to commercial fishing (e.g. using larger motorized boats and more advanced gear, carrying ice to preserve the fish).

In the three countries, small-scale fisheries supply 93–98% of the marine catch[14] and are the principal income-generating activity for a large number of households. In Mozambique an estimated 280,000 work as fishers and another 54,000 in fish processing (MOF 2013). Of the total annual marine catch in Mozambique of some 160,000 tonnes (2010) around 85% comes from the artisanal fisheries, representing a monetary value of at least USD 200 million (MOF 2013).

The coastal area in Tanzania supports around 56,000 artisanal fishers (UNEP 2009), while in Kenya it supports around 12,000 people and generates an estimated USD 3.2 million per year (GOK 2009). Population growth, along with high levels of poverty in the coastal regions, has contributed to increases in the number of small-scale fishers in all three countries. This has, in turn, placed great strain on fish stocks along the coast, resulting in the over-exploitation of fisheries

10 http://hdr.undp.org/en/countries

11 http://www.ruralpovertyportal.org/en/country/statistics/tags/kenya

12 Water for domestic use is a 'free' commodity in most areas. This leads to poor maintenance of boreholes and wells which forces people to use water from inland lagoons, dams and rivers.

13 Sources: Pôle de Dakar v14 database, 2012; UIS, 2012; GMR Report, 2011; UNDP HDI, 2011, World Bank Africa SLI, 2011. Unless specifically indicated, data are from 2010, except for the share of resources consumed by the 10% most educated (2003), public resources (2006), adult literacy and repetition (2009) and youth literacy and external aid (2008).

14 Tanzania and Kenya, freshwater fish catches are better documented and considered more important than marine catches.

resources. Total fish catches have been increasing steadily but this amount is now levelling, indicating the maximum harvest potential may have been reached.

The fishing industry's profitability could improve if there were more processing facilities to create added value (in particular in Tanzania and Mozambique), and improved feeder roads to give access to markets. Destructive fishing techniques, such as the use of nets with small meshes and the widespread practice of dynamite fishing in Tanzania, threaten fish resources and related ecosystems (coral reefs in particular) as well as the livelihoods of the people depending on them.

Mariculture

At present, mariculture is practised in only a few places along the coast, as opposed to much of Asia where it is widely practised. Mariculture in eastern Africa needs more training, hatcheries and research. It is also plagued by theft and conflict with those using other coastal resources. Most mariculture activity is concentrated in Tanzania where finfish, seaweed and mud crab are being farmed all along the coast. Pearls and prawns are being farmed in a few places such as Mafia and Tanga.

The potential for mariculture is good, as environmental conditions, suitable land, brood stock, export infrastructure and labour are available. In Tanzania and Mozambique there are good opportunities for shrimp farming.

Agriculture and forestry

Agriculture, the traditional economic mainstay of people living in eastern Africa, is practised by many coastal households. Agriculture is subsistence and rainfed, often combined with livestock rearing, as soils and climatic conditions are generally less favourable along the coasts (except near river estuaries) than in the hinterland. Farm sizes vary from an average of 6 ha in Kenya to 1–2 ha in Tanzania and Mozambique. The importance of agriculture for coastal livelihoods has often been underestimated, with policies for coastal areas focusing primarily on the fisheries sector. This is slowly changing with agriculture receiving more attention in integrated coastal management approaches.

Coastal forests and mangroves are important sources of timber and firewood. Local communities also trade in honey, fruits, nuts, medicinal plants, gums, resins, barks, thatch grasses, natural dyes, aromatics and fibre.

Increasingly, coastal forests are being cleared for agricultural purposes, not only for subsistence farming but also for larger plantations, often near rivers to allow for irrigated crops. Similarly coastal wetlands are often converted into rice fields or sugar cane plantations. Mangroves are being exploited for timber, firewood and even charcoal production.

Tourism

Tourism is a growing sector and the coastal areas of eastern Africa have seen the number of tourists grow substantially over the last decades. In Kenya, coastal tourism now contributes around 60% of overall tourism earnings while in Mozambique almost all tourism is related to the coastal areas and contributed to an estimated 3.2% of gross domestic product (GDP) in 2003, while employing around 350,000 people (roughly the same number of people as employed in artisanal fisheries) (GOK 2009). Tourism in the Tanzanian mainland is concentrated around wildlife in the hinterland, but coastal tourism is an important income earner for Zanzibar.

Tourism development has been suffering from political instability (such as in 2007–2008 in Kenya), natural disasters (floods in Mozambique in 2000) and from a lack of coordination at national policy levels, which leads for example to increased fees for visas and other red tape that do not contribute to a conducive environment. Revenues from tourism activities have also been less than optimal, largely because much of the tourism industry is run by foreign companies, with much of the tourism payments and profits being kept outside the destination country.

Other economic activities

Mining, ports and the emerging natural gas and oil extractive industry are the other principal economic activities in the coastal zones. Mineral-rich dunes (heavy sands) are being mined in northern Mozambique. Coastal mining in Tanzania and Kenya is mostly focused on cement, coral, sand and lime.

The discovery of large gas reserves near the coasts of southern Tanzania and northern Mozambique will have a huge economic impact. While it will create many employment opportunities, the benefits that will trickle down to coastal households is in doubt as education levels are low. The influx of workers and money in these hitherto isolated areas will also have a huge social impact, with people being displaced and the social fabric of coastal communities likely to suffer.

Links between ecosystems and livelihoods

There are strong links between the various coastal and marine ecosystems as well as with river basin ecosystems. However, the role of river basins, estuaries and mangroves as ecosystem service providers to a broad diversity of other systems (e.g. coral reefs, fisheries, land protection) is generally poorly recognized in the legislative frameworks, institutions and social systems. These ecosystems provide different type of services as depicted in Figure 2.13.

Mangroves

Mangroves are among the most productive habitats on earth and have tremendous social and ecological value. Mangroves provide direct provisioning services to the population in the form of timber and fuel wood. The continued damming of river basins for hydropower, water supply or irrigation has a negative impact on water flow and nutrient discharge to the coast, and this directly affects mangrove growth and hence productivity and provision of ecosystems services, which in turn has negative consequences on associated valuable fisheries.

Coral reefs

Coral reefs are known to provide major ecosystem services. Apart from their regulating role in protecting shorelines, their direct provisioning services for the coastal population include artisanal fisheries and their high tourism potential.

Coastal forests

Coastal forests and associated grasslands provide numerous direct benefits for the population, including timber, firewood, charcoal, wildlife, medicinal products, fruit, honey, insects and products used for curios.

Seagrass beds

Seagrass beds are a common but inadequately studied ecosystem, despite the great benefits they generate. Subsistence fishers and gatherers (often women) collect food from seagrass beds, especially during the low tides. These products include fish and shellfish, worms, sea cucumbers for export, clams, oysters and numerous other living marine species.

Provisioning	Regulating	Cultural
• Food/ fish • Timber/ fuel • Building materials • Curios • Fibre • Medicines • Genetic resources	• Atmosphere and climate regulating • Hydrological balance • Disease control • Waste assimilation • Erosion control • Storm/flood protection	• Recreational • Spiritual and religion • Aesthetic • Inspirational • Educational • Heritage • Research
Supporting • Nutrient cycling • Primary production • Provisioning of habitat • Supporting life cycles		

Figure 2.13: Services provided by coastal and marine ecosystems. (UNEP 2009).

Coral reef at Chumbe Island, Tanzania. *Credit: M. Samoilys*

3. RELATIONSHIPS

Overview

This section uses case studies to examine the critical interdependence between the people who live along the coast and their environment. It also discusses the factors that undermine or reinforce the coastal zone's resilience to global climate change. This includes the value of ecosystem goods and services as drivers of development.

Relatively well-researched locations are used for the case studies below, but there is still a gap in our knowledge and understanding of the impact climate change is having on eastern Africa's marine and coastal environments. For example, it is known that raised levels of CO_2 emissions have multiple effects on the ocean, but there have been no specific studies in the WIO on the effects of ocean acidification and the deoxygenation of the ocean. It has been demonstrated that ocean acidification has an adverse effect on many of the organisms that produce a calcium carbonate shell or skeleton such as shellfish (oysters and molluscs) and corals (Hilmi et al. 2015).

Other effects of an increase in CO_2 include changes in growth rate, reproductive success and animal behaviour. The magnitude of the effect depends on the ability of a species to acclimate or adapt. Ocean acidification also affects organisms indirectly as it trickles down through the marine food web. It is likely that the damage caused by high CO_2 will be exacerbated when combined with other stressful events such as higher seawater temperatures, depleted oxygen and pollution. Ocean change may have major consequences for some keystone species. For some this might lead to extinction (Hilmi et al. 2015).

It is now well established that eastern Africa's coastal ecosystems, which are typical of tropical coastal habitats, are more resilient to climate change if they are protected from excessive or unsustainable use (Bell et al. 2011). When fish and timber offtake is managed carefully at sustainable levels these ecosystems have demonstrated a resilience to climate change and the ability to regenerate. It appears that high diversity (coral reefs) and high productivity (mangroves) are characteristics that confer resilience. Mapping the ecosystems detailed in chapter 2 would identify the sites that warrant protection and focused management to reinforce ecological and social resilience. This in turn would enhance the overall capacity of coastal systems to withstand shocks.

The potential blue-carbon value of seagrass beds and mangrove forests is very promising and should be researched. In the meantime, it is vital to protect these areas, particularly by enforcing bans on destructive fishing gear.

River basins, estuaries and mangroves are ecosystem service providers to a diversity of other systems (coral reefs, fisheries, land protection against erosion and inundation). Their role is generally overlooked in legislation, institutions and social systems and rarely favoured over development alternatives (see proposed Lamu Port case study below).

Mozambique has the largest area of mangroves in the region but fewer protected areas and management plans than Kenya and Tanzania. Where mangrove conservation and management is being practised, resilience is not a component of future planning as there is limited understanding of what factors will help mangroves respond to climate change and which mangrove species will be the most and which the least resilient. Tools and strategies to enhance mangrove resilience are urgently needed, especially further research on the vulnerability of the various mangrove species to climate change. This should be a priority for the region's principal mangrove and river-basin areas (see the Zambezi Delta case study below). Studies have been conducted elsewhere, such as in the Pacific Islands, which could provide useful guidance for the WIO (see Waycott et al. 2011).

Climate change, in particular rising sea levels, is a growing threat to mangroves as their vertical zonation is pronounced. Topography and development on the landward boundary will prevent many mangrove systems from retreating inland as seas encroach. The role of mangroves in sequestering carbon dioxide is an emerging issue for the region that offers a scientific basis for not only halting deforestation but for mangrove reafforestation too.

Case study examples

Construction of Lamu Port, Kenya

Kenya has initiated the Lamu Port and Lamu Southern Sudan–Ethiopia Transport Corridor (LAPSSET) to provide a second transport corridor and to open up the north of the country where oil deposits have been discovered. The project is also designed to give Ethiopia, South Sudan and Uganda an outlet for their exports, primarily oil. An integral part of the development is a deep-water port (18 m) immediately north of Lamu. It will have 30 berths sited on 405 ha and a cost of USD 3.5 billion. It is likely that the port will cause irreversible environmental, social and demographic damage to what is an environmentally and culturally unique area (Samoilys et al. 2011a). Further, the environmental impact assessment (EIA) was not adequately consultative and has not been easily accessible to the public.

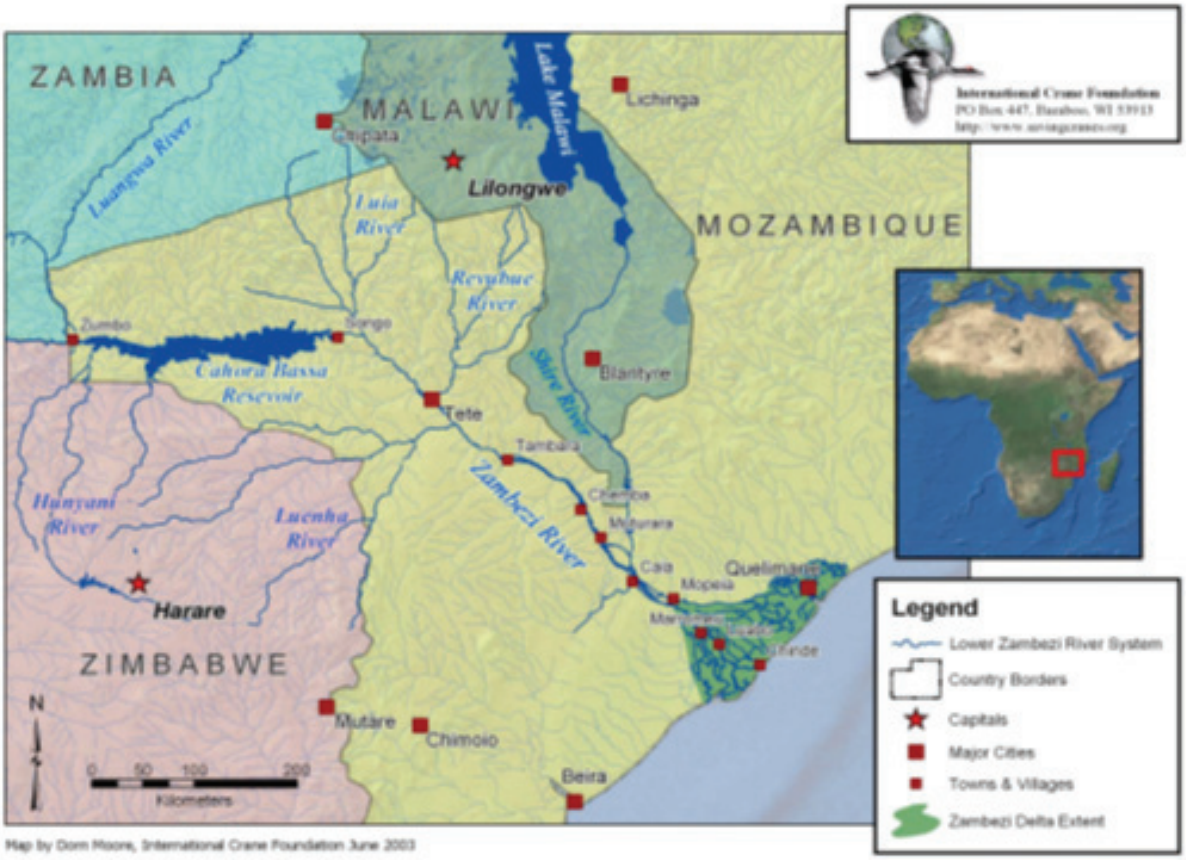


Figure 3.1: Map illustrating the extent of the Zambezi Delta. (Source: Beilfuss and Brown 2006).

Zambezi Delta, Mozambique

The Zambezi Delta is a broad, flat alluvial plain on the coast of central Mozambique. It extends from Quelimane in the north to the Zuni River mouth in the south (Figure 3.1). The delta is triangular in shape, covering an area of approximately 1.2 million ha. It stretches 120 km from its inland apex (near the confluence of the Zambezi and Shire Rivers) to the main Zambezi River mouth and 200 km along the coastline from the Cuacua River outlet near Quelimane in the north to the Zuni River outlet in the south. The port of Beira is located about 200 km to the south. The delta is bordered to the north by the Morrumbala escarpment, which serves as a divide between the Zambezi and Shire River catchments, and to the west by the Cheringoma escarpment that separates the Zambezi and Pungue River catchments. The lower Zambezi basin stretches from the Cahora Bassa Reservoir to the Zambezi Delta (~225,000 km^2) and accounts for more than 27% of the total land area of Mozambique. It supports 25% of Mozambique's population (> 3.8 million).

There are no data on fisheries from this area even though the delta is in the middle of the Sofala Bank, Mozambique's most productive fishing ground. The delta and estuary are extremely important for mangroves. They have some of the largest mangrove trees in eastern Africa, which generate highly productive fisheries (Spalding et al. 2010). Although the fishing industry has had an adverse effect in some places, much of the coast is shielded from overfishing by its innacessibility. The Marromeu Complex of the Zambezi Delta was designated a Wetland of International Importance under the Ramsar Convention in 2003. It has since been proposed as an Ecologically or Biologically Significant Area (EBSA) by the Convention on Biological Diversity (CBD) (UNEP/CBD 2012).

Coral reefs

Coral reefs are indicators of climate-change patterns because they are extremely susceptible to rising SST. The IUCN Climate Change Coral Reef Working Group (http://www.iucn.org/cccr/) guages the health of coral reefs against a benchmark of reef resilience (resistance and recovery) (Obura and Grimsditch 2009) to guide future management and interventions. A regional dataset covering the entire WIO shows the resilience scores of coral reefs in various subregions (Figure 3.2) including Nacala and Cabo Delgado Province (northern Mozambique) to Mtwara (Tanzania); Mafia-Songo Songo (central Tanzania); Zanzibar to Malindi (northern

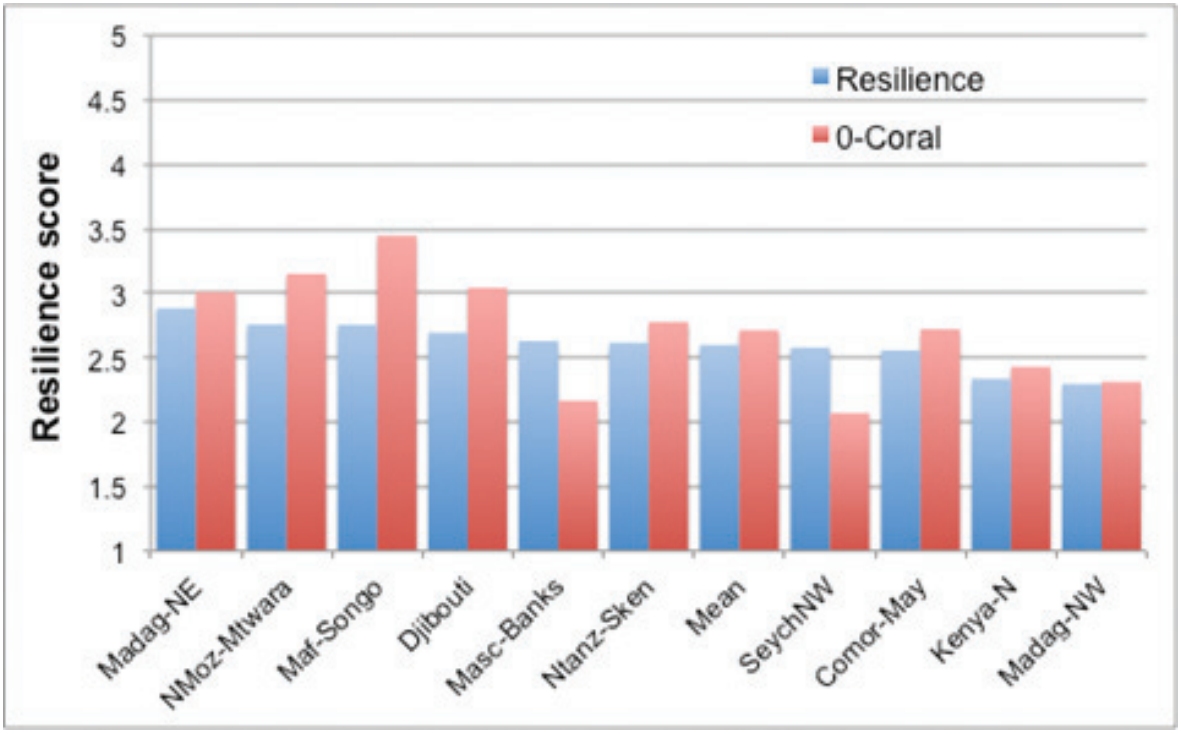


Figure 3.2: Overall resilience and coral community scores for subregions in the WIO. Subregion codes are self-explanatory. (Source: IUCN Coral Reef Climate Change Working Group, unpublished data).

Tanzania and southern Kenya); and northern Kenya. The method is explained by Obura and Grimsditch (2009) and in site reports such as the report on Mafia-Songo Songo (Obura 2011).

The graph shows:

- Reefs in the best condition are in the northern Mozambique Channel (and the northeastern coast of Madagascar); next are those in central Tanzania, with condition decreasing northwards to northern Kenya.
- Reef health aggregated from 14 factors is not equivalent to coral-community cover or health as shown by the different ordering of subregions using the coral-community bars. For example, coral-community cover was highest in central Tanzania due to the absence of bleaching effects during the 1998 El Niño in the Songo Songo region. In contrast Mauritius and remote island banks in the Seychelles (Masc-Banks) have low coral cover, but score well otherwise due to low human impact.
- Overall reef health in the WIO is moderate. All subregions score < 3, which is average to below average. The maximum score in all possible factors is 5.

The vulnerability of coral reefs to thermal stress and coral bleaching has been analysed by Maina et al. (2008, 2012) and Aterwerbehan & McClanahan (2011). Areas of high vulnerability lie off the northwest coast of Madagascar, in northern Seychelles and in northern Kenya. The mainland coast of eastern Africa has intermediate vulnerability. Lower vulnerability occurs in east and southwest Madagascar and the Mascarene Islands. The analysis shows low mortality for corals in northwest Mozambique. This is attributed to the region's experiencing one of the slowest rises in SST and its minimal annual temperature variation. However, other studies report devastating effects on sites around the northern Mozambique Channel (Perreira et al. 2008; Obura et al. in review) and irregular coral mortality in 1998 along the mainland coastline. This indicates that some reefs suffered more than others. Sheppard (2003) shows that the reefs around 10°S (the northern end of the Mozambique Channel) will be the first to experience highly damaging temperatures.

The results indicate that several features are important for the long-term management and maintenance of reef resilience. The hydrodynamic variability in the Mozambique Channel and the complexity of reef structures in Cabo Delgado and Nampula Provinces, as well as Mtwara in southern Tanzania, may be key factors in the variation of bleaching effects and reef health from one location to another. Further north along the Tanzanian and Kenyan coast, the simpler reef structures (fringing reefs on the mainland or large islands) and more uniform linear current (the East African Coastal Current) have resulted in greater vulnerability to bleaching (peaking again in northern Kenya) and less variation in the differences among reefs. While the historically low temperature rise in northern Mozambique might have resulted in less coral bleaching in recent decades, the low variability in temperatures may make the reefs more vulnerable to future temperature increases due to being less adapted. The good

condition of the reefs in the northern Mozambique Channel makes it an important source reef for other regions though its current status may make it more vulnerable to future bleaching events.

Certain trophic groups of reef fish, particularly the herbivores, are critical to boosting coral reefs' resilience to climate change because they control macro-algal communities and prevent coral-algal phase shifts (Bellwood et al. 2004; Hughes et al. 2005; Green and Bellwood 2009). This reinforces the emerging view that if herbivores are protected or, at the least, well managed, coral-reef resilience will be enhanced (Green and Bellwood 2009). The consequences of protecting herbivores could be examined and monitored in no-take zones such as Chumbe Island Coral Park in Zanzibar and Kenya's marine parks to evaluate the relative merits of total protection and partial protection.

The vulnerability of coral reefs to rising SST will have a knock-on effect on fisheries too. Analyses from the WIO show that the harm to reef fish caused by a bleaching event only becomes evident about six years later. The damage varies across different trophic groups of fishes (Graham et al. 2008). Simulation modelling in Kenya has shown that if different artisanal fishing gears are used to selectively control removal of certain species, the negative effects of bleaching on fish can be reduced (McClanahan et al. 2008).

Ocean acidification from CO_2 in the WIO must be minimized as soon as possible or the devastation it causes coral reefs will create serious problems for biodiversity loss, fisheries, tourism and coastline protection. Avenues for maintaining healthy reefs and profitable fisheries for local fishers should be explored further in areas where successes are evident such as Mafia Island and Quirimbas Marine Parks (Samoilys and Obura 2011). Conversely, those reefs that have been decimated by destructive fishing (e.g. Tanga Region, Tanzania) could be considered for mariculture or as sites for establishing artificial reefs.

Coral reefs provide four primary ecosystem services as defined by the Millenium Ecosytem Assessment (2005):

Regulating services:

- coastal shore protection against cyclone, storm and flood damage (projected to increase with global warming)

Provisioning services:

- nursery or grow-out areas for offshore fisheries and for lobster, snapper, grouper, etc.
- artisanal or subsistence fisheries for local communities
- species untapped for human consumption (e.g. medicinal)
- potential tourism revenue (e.g. manta rays, sharks, dolphins, whales, scenic beaches, reefs and diving)

Cultural services:

- aesthetics, recreation, spiritual

Supporting services:

- a productive ecosystem in a 'nutrient desert'
- coral reef ecosystems with mangroves, river estuaries and seagrass beds, contribute to coastal and offshore fisheries

Seagrass beds

Little is known about the effects of climate change on seagrass beds or the interplay between seagrass beds, coral reefs and climate change. It is predicted that ocean acidification will accelerate the growth of seagrasses, fleshy seaweeds and other algae although this is not rooted in research. If true, it presages complex change. More seagrasses would endow this ecosystem with expanded productivity and a larger role in carbon sequestration. It has been suggested (IAEA International Workshop: Ocean Acidification Impacts on Fisheries and Aquaculture, Monaco, October 2012) that carbon sequestration by seagrasses would benefit neighbouring coral reefs by reducing ocean acidification (Andersson and Gledhill 2013). However, at this stage it is only conjecture (Andreas Andersson pers. comm.; Kroeker et al. 2013).

Seagrass beds are exceptionally productive ecosystems that support important coastal fisheries (Waycott et al. 2011). It is possible for this productivity to be sustained and even improved, despite climate change, as long as these ecosystems are protected from dredging, pollution, port development and other harmful activities. The seagrass beds in eastern Africa are in relatively good condition, though a disproportionate number of parrotfish and juvenile fish are taken by beach seines (McClanahan and Mangi 2001). These seines are illegal in Kenya and Tanzania, but enforcement is lax. The important fish in these ecosystems, notably the rabbitfish, appear to have highly productive life-history traits of high turnover (Maina et al. 2013). It is significant that they are at the lower trophic level and therefore are more productive. Fisheries management has made a paradigm shift towards balanced harvesting that focuses on lower trophic groups (see Garcia et al. 2012). This has great potential as an intervention to foster resilience to climate change.

In Kenya there are two large, almost contiguous seagrass beds on the south coast at Diani–Chale (4.5 km^2) and Gazi Bay (8 km^2). There is also a mangrove forest in Gazi Bay. They have been research locations for the Kenya Marine and Fisheries Research Institute (KMFRI) for more than 20 years and Coastal Oceans Research and Development in the Indian Ocean (CORDIO) for more than 10 years, providing a solid base of data and knowledge as well as long experience in community engagement and capacity building. These would be ideal sites for exploring the dynamics and consequences of carbon sequestration (blue carbon) in seagrasses and mangroves (CORDIO 2012). Blue carbon in mangroves is already being investigated by KMFRI in Gazi (James Kairo pers. comm.).

Species of concern and with conservation value

Species of high conservation value or concern are highlighted and described in chapter 2, section 'Species'. They require special consideration in future management and conservation initiatives. Their status, especially where there are healthy populations, has been taken into consideration in the recommendations for potential sites for future Resilient Coasts initiatives (see chapter 4). This section highlights some of the more vulnerable species and gives recommendations for interventions by Resilient Coasts.

Sharks and rays

Sharks and rays in the WIO are highly threatened but little attention is paid to their management. They have a greater earning potential as a tourist attraction than they do as a commodity for the Asian shark-fin trade or for local consumption as meat. Thoughtful conservation measures must be put in place as a matter of urgency before these superb predators are lost forever (see chapter 4 for recommended action). An immediate and vital step is to conduct research on the reproductive and migratory patterns, feeding habitats, and ecosystem dynamics of sharks and rays in the WIO. This should be done at specific locations (see chapter 4) under the auspices of regional initiatives grounded in regional and global instruments.

Marine mammals

Marine mammal research including monitoring and conservation is expanding with the most attention focused on the humpback whale, dugong and Indo-Pacific bottlenose dolphin.

Recommendations for all marine mammals

- Develop a regional marine mammal network, building on the Kenyan marine mammal initiative, to provide a framework for sharing data across the region.
- Develop facilities for watching whales and dolphins aligned to the guidelines for watching marine mammals.
- Support the Bazaruto Archipelago MPA, which has eastern Africa's largest and possibly last viable dugong population and largest visiting humpback whale population. The survival of the dugong ultimately depends on the maintenance of adequate habitat, notably seagrass beds.

Recommendations for humpback whales

- Create a regional database for photo IDs.
- Build on the work of humpback research stations in the region.
- Support the East African Humpback Whale Network

Recommendations for dolphins:

- Dolphin populations in the WIO are threatened. Their status should be investigated as a matter of urgency.
- The Indian Ocean Whale Sanctuary has yet to stimulate adequate levels of research on cetaceans. Research is needed to investigate the abundance and distribution of offshore cetacean species, but also bycatch and the possible overfishing of delphinid prey stocks. In Zanzibar, dolphin research based on fisheries bycatch has yielded information on diet and population structure. There should also be research on the proposed Lamu port to ascertain where whale and dolphin routes would collide with shipping lanes.

Ecosystem goods and services

Placing a monetary value on ecosystems is a challenging exercise, but it is a useful way of assessing the economic merit of preserving coastal and marine ecosystems for future generations. For example, the annual economic value of mangroves (income from the products and services they provide) has been estimated at USD 2,000–9,000 per ha (Spalding et al. 2010). On this basis the annual economic value of Mozambique's mangroves is USD 5.8–26.2 million. For Tanzania it is USD 2.5–11.5 miillion. For Kenya it is USD 1.2–5.5 million.

Putting a price tag on ecosystems is a relatively new concept, which is why WIOMSA has made it a major area of research in its new Marine and Coastal Science for Management programme. The theory is that the cost of damage to ecosystems cannot be assessed accurately if they have not been given a value in the first place. Future research on the economic value of coastal ecosystems could be conducted in partnership with Resilient Coasts.

Small-scale fisheries make an important contribution to food security and poverty alleviation by employing 90% of the world's fishers (FAO 2014). In eastern Africa, where coastal communities depend on fishing, marine ecosystems need to be well managed to ensure sustainable fishing practices and to maximize resilience to climate change.

River basins, estuaries and mangroves

As one of the most productive habitats on earth, mangroves have tremendous social and ecological value (Spalding et al. 2010). They host complex and rich food webs that are dependent on seasonal river discharge for nutrients. Mangroves are photosynthesizing plants that generate their own primary production. Their complex root structures provide sheltered nursery grounds for many fish and invertebrate species that spend their adult

lives in other coastal and pelagic ecosystems. Indirect goods and services include nurseries for prawn and other fisheries, filtering and trapping pollutants, stabilizing coastal land by trapping sediment, and protecting shore lines against storm damage. During the 2004 Asian tsunami the destruction was far greater in the areas where mangroves had been cleared for mariculture (Danielsen et al. 2005; Adger et al. 2005).

People living at the coast find mangrove forests a lucrative source of income. They harvest molluscs, crustaceans and fish, and fell wood for fuel, charcoal, timber, wood chips and boat building (Spalding et al. 2010). Mangrove wood is insect resistant and extremely hard, and its high energy content makes it a cost-effective fuel. Mangrove forests are also efficient at carbon sequestration with an estimated carbon storage of 500–1300 tonnes/ha, of which 70% is trapped below ground in sediment. This is up to three times the amount of carbon stored in primary tropical forests (Nellemann et al. 2009). Consequently, mangroves are attracting interest for their carbon-credit potential (see Blue Ventures' Blue Forest Programme in Madagascar). Forests in Kenya are beginning to be protected through community-based carbon offset projects such as Mikoko Pamoja in Gazi Bay (James Kairo pers. comm.).

Eastern Africa's major river-basin mangrove ecosystems are healthy and productive. In addition, the deltas where they are found enjoy good overall productivity and links with neighbouring seagrass beds and coral reefs. Using these benchmarks for regional and national significance, four river basins are recommended as focal sites for Resilient Coasts (see chapter 4).

Tana, Rufiji, Ruvuma and Zambezi coastal livelihoods and economy

This section looks at the diversity of livelihood strategies and options in coastal communities in Tanzania and Kenya and how they can underpin social resilience to global change[15]. Resilience is linked to the level of dependence on natural resources, diversity in patterns of resource use and access to alternative income-generating activities. This means that resilience is also linked to governance and management frameworks and the politics of resource use (Adger et al. 2005).

Tanzania

Communities on the Tanzanian coast depend largely on agriculture (58.9%) and small business enterprises (21%) for their livelihood (Table 3.1; URT 2006a). More than 75% of the population works in the agriculture sector in Lindi, Mtwara, Pwani and Tanga Regions (Table 3.1). Fishing in contrast is listed as relatively low with an overal average of 4.4% but this may reflect some fishing employment figures have been aggregated under agriculture. The highest rate of employment reported in fishing and related activities is in Zanzibar in North Unguja and Pemba. The profile for employment by gender varies according to sector with the largest number of women employed in agriculture (excluding forestry, fishing and hunting) (URT 2006a). However, these figures do not take into account casual labour and the informal sector.

[15] Information on this is restricted to Kenya and Tanzania due to translation difficulties with information from Mozambique.

Table 3.1: Percentage of employed by sector and region on the Tanzanian coast.

Region	Agriculture	Business operations	Formal employment	Elementary occupations	Fishing	Livestock	Industries
Dar es Salaam	13.0	46.2	19.0	13.0	1.4	1.0	5.2
Lindi	85.8	8.1	2.5	2.0	1.1	—	—
Mtwara	86.6	6.3	2.0	3.3	1.1	—	—
North Pemba	51.7	20.3	4.5	8.4	7.6	6.7	—
North Unguja	64.0	15.2	3.5	2.8	12.5	—	—
Pwani	78.5	10.4	3.5	3.1	2.4	1.2	—
South Pemba	51.9	20.7	6.7	10.4	7.7	1.2	1.1
South Unguja	64.9	16.4	4.8	4.5	6.0	1.0	1.4
Tanga	77.5	12.5	3.8	2.4	1.1	1.7	—
Urban West	14.8	53.4	17.2	6.7	2.8	—	4.2
Overall average	58.9	21.0	6.8	5.7	4.4	2.1	3.0

Source: URT 2006a

Agriculture and animal husbandry

Tanzania's economy depends on agriculture, which accounts for more than 25% of GDP, provides 85% of exports, and employs about 80% of the work force[16].

More than half of those living on the coastline (except Dar es Salaam and Urban West) are employed in the agriculture sector. They are mainly smallholder farmers cultivating food crops. Cash crops are grown in smaller quantities: coconuts, cashew nuts, pineapples, mangoes and tropical fruits. Animal husbandry is not a traditional occupation, but people keep zebu cattle, goats, sheep and chickens in small numbers.

Fisheries

Fishing and associated activities are important sources of income for coastal people although this is not always reflected in national statistics (e.g. Table 3.1). The fishing industry provides employment opportunities and foreign exchange earnings through fishing, boat building and repair, fishing-gear supply, net mending, engine repair and supply, fish transport, fish sales, fish processing and food vending (MLDF 2010). There are five times more people working in fish processing and marketing than as fishers.

Forestry

The coastal forests comprise mangrove and terrestrial forests, both of which have biological and economic significance. The forestry sector (with coastal forests making up a sizeable but unquantified percentage) accounts for about 3% of GDP. Coastal forests are exploited for timber, poles (Rufiji and Mkuranga Districts), honey and wax, wood carving materials, medicinal plants, fuel wood, building materials and food. Rural communities in Tanzania depend on wood and charcoal for cooking. Fuel wood accounts for at least 92% of the country's energy consumption and around 95% of wood products.

[16] CIA WorldFact Book, 2013 data. https://www.cia.gov/library/publications/the-world-factbook.

Direct threats to coastal forests include charcoal production, logging, grazing and land clearing for agriculture. The opening of Mkapa Bridge in Rufiji District will probably accelerate commercial logging in Lindi and Mtwara Regions. Issues affecting the coastal forests of Tanzania are similar to those highlighted in Kenya.

Tourism

Services account for 47% of the country's GDP (2013) with tourism as a leading sector. Wildlife is Tanzania's showcase attraction with up to 90% of all tourists going on game-viewing or hunting safaris (TCMP 2001b). Diversifying away from the national parks to the beaches makes sound economic sense. While a few locations such as Zanzibar are saturated, other locations, as in southern Tanzania, have good development potential. These include Kilwa District, particularly Kilwa Kivinje, Kilwa Masoko, Kilwa Kisiwani, Songo Mnara, Sanje ya Kati and the adjacent mangrove reserves and nearby caves, Saadani Game Reserve, and Mafia District with its cultural heritage sites and excellent diving. However, dynamite fishing is harming coastal tourism through its destruction of coral reefs and safety concerns for tourists (Tanga dynamite monitoring network; Guard & Masaiganah 1997; TCMP 2001b; Wells et al. 2007).

Kenya

The principal livelihoods for communities on the coast are fishing, mangrove harvesting and tourism. Communities living inland subsist on farming and tending livestock. The urban economies are driven by tourism (45%), ports and shipping (15%), agroprocessing (8%), agriculture (5%), fisheries (5%), forestry (4%), mining (2%) and other services (15%) (GoK 2008, 2009) (Figure 3.3). Kenya's GDP is driven by agriculture (29.3%), industry (17.4%) and services (53.3%) (2013 estimate). Unemployment stands at 40%, and 43.4% of the population lives below the poverty line (2012 estimate). Low levels of investment in infrastructure, corruption and reliance on primary goods with low prices have weakened Kenya's longterm position as the largest East African economy. Recent terrorist attacks, particularly those at the coast, have depressed Kenya's important tourism industry.

Table 3.2: Food and cash crops grown in coast counties in Kenya. Source: GoK 2007

County	Food crops	Cash crops
Kilifi	Maize, cowpeas, cassava	Coconut, cashew nuts, mangoes, citrus fruits
Kwale	Maize, cassava, rice	Coconut, cashew nuts, bixa, citrus, mangoes
Lamu	Maize, cowpeas, simsim, cassava, green grams, pigeon peas, bananas	Cotton, bixa, cashew nuts, coconut, mangoes, citrus fruits
Malindi	Maize, cowpeas, cassava	Coconut, cashew nuts, mangoes, citrus fruits
Mombasa	Maize, cowpeas, fruits, vegetables	Coconut, cashew nuts, simsim (sesame), sunflower

Agriculture

The agriculture sector accounts for about one-third of GDP and employs 85% of the rural labour force. Agriculture is important to the wellbeing of coastal communities. Dependence on subsistence agriculture ranges between 90% (Kilifi County) and 60% (Lamu County) (GoK 2007). Coastal agricultural production is a mix of subsistence and commercial food and cash crops (Table 3.2). The coastal region has 3.3 million ha of arable land while another 190,000 ha could be put under irrigation. There is also potential for ranching and alternative livestock production in 80% of the region.

Farms at the coast average 6–8 ha in size and produce maize, cashew nuts, coconuts, citrus and mangoes. Sugar cane is being reintroduced on the south coast following its 1988 collapse. An attempt to plant sugar cane in the Tana Delta has been met with mixed reactions. Cassava, sweet potatoes, maize, coconut, cowpeas and rice are grown under irrigation, in marshes, and on floodplains. Vegetables and citrus, mangoes, bananas, pineapples and watermelons are grown both as food and cash crops for export. Cashew nuts, bixa and sisal are grown mainly for export.

The coastal region could be self-sufficient in food if irrigated cultivation was practised more. The region is a net importer of cereals and other food, and crops such as coconut and cashew nuts are not realizing their potential. Irrigation is practised in the Tana, Umba and Athi-Sabaki River floodplains, mainly for rice.

Nearly 70% of the coastal region is semi-arid and supports livestock but not crops. Only 25 out of the 85 large ranches in the region are operational. Tana River County followed by Kwale and Kilifi Counties have the most livestock (cattle, sheep, poultry, camels) (GoK 2001). Variation in rainfall patterns and vegetation types means that different areas sustain different types of livestock.

Fishing

Most of Kenya's coastal and marine fishing is artisanal for several species for which different types of gear are used (McClanahan and Mangi 2004; Okemwa et al. 2006; Samoilys et al. 2011d). Artisanal fishing is confined to a narrow shoreline strip (2.5–3 nautical miles) from small traditional vessels (Ochiewo 2004; Samoilys et al. 2011d). Fishers use a variety of gear: cast nets, gill nets, beach and reef seines, purse seines, ring nets, hook, handlines and longlines, spear guns, and basket traps (see Samoilys et al 2011d). Illegal fishing gear, particularly the beach seine, is widely used because the ban on these destructive types of gear is poorly enforced.

In the early 1990s there were about 15,000 fishers operating 4,800 boats (80% without motors) (GoK 2009). This number shrank by about half in the late 1990s but has since revived, growing by up to 15% annually between 2004 and 2008 when the fisher population reached 12,000 (Ochiewo 2004; FiD 2008). Artisanal fishers land at least 95% of the marine catch. More than 60,000 coastal people depend on these fisheries for their livelihoods (UNEP 2009; GoK 2009). Artisanal marine fishery production has fluctuated between 4,000 million tonnes and just under 9,000 million tonnes annually over the last two decades (Figure 3.3; Gitonga and Achoki 2003). The production for 2008 was valued at USD 8.7 million. There were declines in marine fishery production in 1991, 1995 and 1998–2000 (Figure 3.4). It has been estimated that some 8,600 fishers caught 7,754 m tonnes of finfish worth USD 7.8 million around Kenya's inshore reefs in 2011 (Samoilys et al. 2011e). Marine fishery products are demersal, pelagic, sharks and rays, crustaceans,

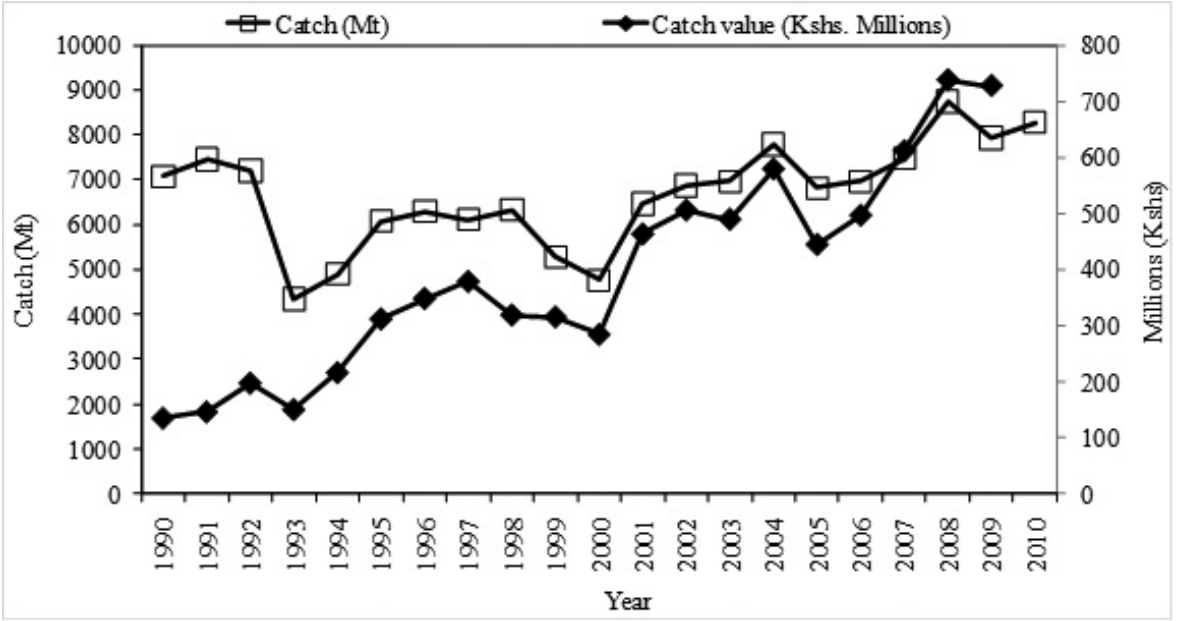


Figure 3.3: Quantity (metric tonnes) and value (KES millions) of artisanal marine production in Kenya, 1990–2010. (Source: FiD 2011).

molluscs, echinoderms and big-game fish. The demersal fish are dominated (> 38%) by emperors, snappers and parrotfish (McClanahan and Mangi 2004; Maina et al. 2013). Pelagic fish make up 27% of the catch.

Current production is low considering that Kenya has a coastline of 600 km and an EEZ of 230,000 km^2. Further, it borders the richest tuna belt in the Indian Ocean. Some of the rich inshore grounds are found around the Lamu Archipelago, Ungwana Bay, the North Kenya Bank, the Malindi Bank, Shimoni, Vanga, Funzi Island and coral reef areas on the border with Tanzania (Nzioka 1984; Fondo 2004). There is not much information on Kenyan marine capture fisheries in its EEZ despite the growth of offshore fisheries since the 1990s. The inshore waters are reported to have the potential to yield ~20,000 metric tonnes per year (Oduor 1984). In 1990 FAO reported that the annual marine catch from reef areas might be closer to 12,000 metric tonnes.

Fishing pressure is greatest in shallow near-shore reefs, particularly for demersal fish stocks. Given that the demand for fish continues to grow, mariculture is a good alternative to near-shore fisheries for subsistence fishers. Aquaculture is becoming more popular and is predicted to overtake wild-capture fisheries. The government has launched an economic stimulus package as an incentive to start-up aquaculture enterprises, but the programme focuses on inland freshwater aquaculture.

Deep-sea commercial fishing is constrained by unreliable fisheries stocks, inadequate institutional support, lack of investment, inefficient traditional vessels and uncertain weather conditions. Industrial fishing occurs within the EEZ and is exploited by other fishing nations. Only six sea-going fishing vessels are listed on the Kenya Ships Register (Kenya Maritime Authority pers.comm. 2011). Deep-sea recreational fishing for big game fish (marlin, sailfish, tuna and others) takes place from the outer reef to about 15 nautical miles offshore during a nine-month season. The good areas for sport fishing are Shimoni, Diani, Mombasa, Mtwapa, Kilifi, Watamu, Malindi and Lamu.

Kenya ranks among the top exporters in the WIO for marine aquarium fish (Okemwa et al. 2006). It is a highly competitive business based on more than 190 species of aquarium fish belonging to 35 families. The fish are exported to Austria, Denmark, France, Germany, Hong Kong, Hungary, Israel, Italy, Japan, Netherlands, Poland, Romania, South Africa, the United Kingdom and the USA.

Tourism

Tourism is an important foreign exchange earner and a pillar of Kenya's Vision 2030 (GoK 2007). Tourism revenues accounted for 45% of the coastal economy in 2009 (GoK 2009). Between 1998 and 2004, coastal tourism accounted for 52–68% of Kenya's tourism earnings (GoK 2005). Nearly half of the tourists who travel to Kenya visit the coast for its climate, sandy beaches, coral reefs, mangroves, river and estuarine systems, marshes and wetlands, marine parks and reserves, terrestrial game parks and reserves, and a cultural setting that blends African, Arab, Portuguese and Western lifestyles (GoK 2001; GoK 2005). There are several five-star hotels.

Coastal tourism is predicated on security, political stability, and the sustainable use of resources. Civil unrest and several security incidents authored by Al-Shabaab, the terrorist organization based in neighbouring Somalia, have dented Kenya's image as a holiday destination. Coastal tourism in general has also been affected by stiff competition from countries offering similar products such as southern Africa, the Caribbean and Southeast Asia (GoK 2001).

Ports and shipping

Kenya serves as an outlet for several landlocked countries in the region. Port and shipping activities are integral to the country's development (Hoyle 2000) and to the economic prosperity of the coastal region. Maritime activities account for 15% of the coastal economy. The port of Mombasa is the largest in East Africa, handling 20 million tonnes in 2011 (see Kenya Port Handbook 2012–2013). Smaller ports along the coastline managed by Kenya Ports Authority are Old Port, Shimoni, Kilifi, Mtwapa, Kipini, Vanga-Funzi area, Lamu and Malindi. Containers (40%) comprise the majority of vessels docking at Mombasa followed by general dry cargo (22%) and bulk oil tankers (18%). Liquid bulk items (mostly petroleum, oil and lubricants) are the lead import item by weight (Kenya Economic Update 2010).

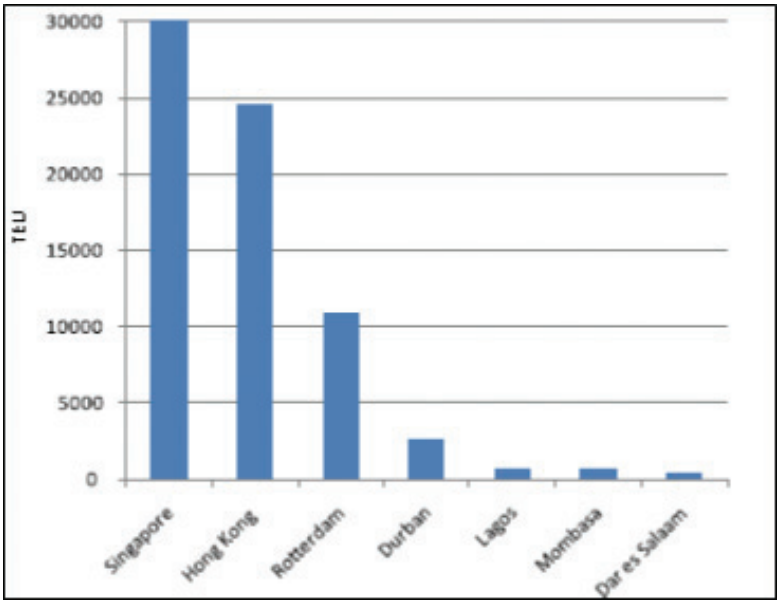


Figure 3.4: Volume in 20-foot equivalent units of cargo handled by selected maritime ports.

Seaweed farmers in Tongoni village, Tanga, Tanzania. *Credit: IUCN TCZCD Programme*

The volumes handled in Mombasa are low by international standards (Figure 3.4). In the wake of oil discoveries in Kenya and neighbouring countries, oil exports could become a significant part of port operations. The volume of transshipment goods handled by the port has steadily declined in recent years due to efficiency and capacity constraints. The government needs to expand the port's physical infrastructure and improve its management. The areas to address include the port's ability to service ships at the quayside, increased yard capacity, and quicker clearance and transfer of cargo.

Mining

Mining currently accounts for a single-digit percentage of the GDP. Mineral deposits that occur at the coast in economic quantities include titanium, niobium, limestone, iron ore, baryte, gypsum and salt (GoK 2009).

Silica sands used for glass manufacture are mined in Arabuko Sokoke in Kilifi District and in the Msambweni area of Kwale District. Ballast used for construction is mined at Kokotoni along the Mombasa–Nairobi road in Kilifi District. Niobium and iron ore in the Mrima Hills of Kwale County have not yet been exploited.

Base Titanium Ltd, a subsidiary of an Australian mining company, has a presence in Kwale County and began exporting ilmenite in 2013. Once its mining operation is fully commissioned, the company will extract 330,000 tonnes of ilmenite, 80,000 tonnes of rutile (14% of global production), and 30,000 tonnes of zircon annually over 13 years. This will yield an estimated $300 million in taxes and royalties to the government.

Forestry

Coastal forests comprise mangrove forests, montane forests and lowland forest patches. Coastal woodland cover is 0.1%, coastal evergreen bushland 0.4% and coastal palm stands <0.1% (Bennun and Njoroge 1999). The two largest coastal forests are Arabuko Sokoke (~370 km^2) and Shimba Hills (~63 km^2) (Burgess and Clarke 2000).

Though fragmented and small, coastal forests contribute 4% to the coastal economy. They serve as water catchment areas and are a tourist attraction. They are also centres of endemism for a wide variety of globally threatened fauna and flora. Some forests are of great cultural and spiritual significance. Some 30 *kaya*[17] forests stretching along 200 km of coastline are sacred to the Mijikenda people. They contain abandoned fortified *kaya* villages, some dating back to the 16th century, that are revered as ancestral abodes. Eleven of these forests have been designated as a World Cultural Heritage Site by UNESCO.

Coastal forests host income-generating activities: fishing, timber, carving, agriculture, apiculture, tourism, mariculture, harvest of medicinal plants, salt production, wood and charcoal for fuel, harvest of mangroves and harvest of wildlife (butterflies, snakes) (Burgess and Muir 1994). The communities around the Arabuko Sokoke Forest earned ~USD 37,000 from guiding, beekeeping and butterfly farming in 2001 (Matiku 2004). Shimba Hills communities in the Mwaluganje Conservancy supplement their incomes through tourism lodges. Women in Gazi and

[17] *Kaya* is a sacred forest of the Mijikenda people at the Kenya coast.

Wasini in Kwale District and at Mida Creek in Kilifi District constructed boardwalks in mangrove forests for ecotourism (Maina et al. 2011). Other communities have attempted apiculture with little success because of economies of scale and lack of processing and marketing knowhow. All these initiatives would benefit from training in governance and management systems (Maina et al. 2011).

Coastal forests are at risk from excision, unsustainable felling, overgrazing and charcoal burning. These threats are a result of human encroachment, poverty, unregulated exploitation, weak district and national institutional frameworks and policy gaps.

Mozambique

Two out of three Mozambicans live in the coastal zone. They depend on fisheries, agriculture and forestry for their livelihood (UNCED 1992). Mozambique's GDP is composed of output from agriculture (29%), industry (25%) and services (46%). In 2010, 55% of the population lived below the poverty line, down from 69% in 1997. The unemployment rate stands at 27% (AfDB 2012). The recent discovery of extensive coal and gas reserves and emerging foreign investor interest in the economy should boost living standards.

Agriculture

Agriculture accounts for 29% of GDP and employs 80% of the labour force (90% of working women and 70% of working men). It is primarily small-scale, rainfed production (90–96% of cropped land). Farms average 2 ha and are cultivated by hand, most often without the benefit of inputs. Shifting cultivation (bush fallow) is the traditional land-use strategy. Yields are below the regional average.

Cassava and maize make up 50% of production and are generally intercropped with legumes such as beans and peanuts. Rice is produced in the alluvial soils and estuarine plains. Mozambique has 240,000 ha suitable for rice. There has been major investment in rice in the coastal zone of Zambezia Province, Chokwe and Xai-Xai Districts in the lower Limpopo Basin (Gaza Province) and Matutuine District (Maputo Province).

Coconuts and cashew nuts are important as cash crops and for food security. Other cash crops are cotton, sugar cane, tobacco, oilseeds (sunflower, sesame, soybean) and spices (ginger, paprika) (Bias et al. 2003). Smallholder farmers also rear livestock. Permanent pastureland accounts for nearly 55% of the total land area in Mozambique.

Forestry

Forests cover 50% of Mozambique. The annual deforestation rate over 20 years (1990–2010) averaged 0.5% (FAO 2014). It was considerably higher in the more densely populated areas and around cities because of shifting cultivation and clear-felling for fuel wood, charcoal and construction poles. Nearly 12 million people use the forests for fuel wood, charcoal and natural fruits.

In recent years, the demand for forest products has led to soil degradation, forest depletion around densely populated areas and a loss of biodiversity. Uncurbed firewood extraction threatens the status quo of the 400,000 ha of coastline mangrove forests (UNEP 2013). The rate of mangrove destruction and degradation is greatest around Maputo, Beira, Quelimane and Pemba where the wood is in demand for firewood, charcoal and timber.

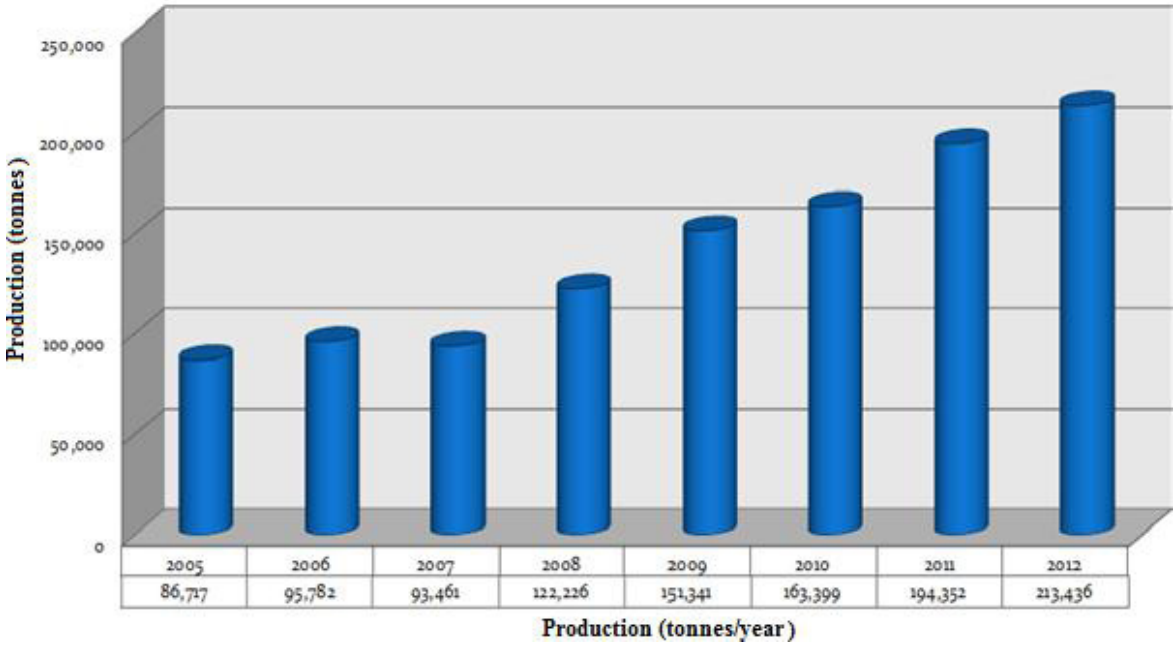


Figure 3.5: Mozambique fisheries annual global production. (Source: MoF 2014).

Fisheries and aquaculture

Fishing is important to coastal communities as it generates jobs and provides food security. The fisheries industry is also a foreign exchange earner (Lopes et al. 1999). Marine fisheries account for more than 90% of total fish production, covering an area of about 100,000 km^2 of marine waters with an EEZ of 200 nautical miles (FAO 2007). The fisheries sector contributes 3% to GDP and makes up 4% of exports. Production in 2012 was 213,400 tonnes valued at USD 526 million (MoF 2014) (Figure 3.5).

The fisheries sector comprises industrial, semi-industrial and artisanal fisheries and is concentrated in two areas. Sofala Bank (Sofala Province) attracts the industrial and semi-industrial fleets for its shallow-water shrimp fishing. Maputo Bay in the south of Mozambique, is the second largest shrimp-fishing ground. It is fished by the semi-industrial fleets. Artisanal fisheries occur along the entire coastline and account for 80% of the marine catch. There are about 343,000 fishers of whom 18% are women.

Artisanal fishers use hand lines, beach seines, gill nets and traps. Beach seines comprise nearly 20% of the 32,500 count of fishing gear (IDPPE 2007) and are used wherever the coastal geography and sea conditions are suitable (Wilson 2012). They catch small fish for local consumption (Chilonda et al. 2011), which are sold fresh, sun-dried or smoked.

The fishing potential is estimated at 332,000 tonnes (FAO 2007), comprising some 1,500 species of fish, 400 of which are of commercial importance (Lopes et al. n.d.). These include shrimp from shallow waters, deep-water crustaceans, horse mackerel, mackerel and demersal fish.

Commercial investment in mariculture is growing due to overfishing and higher operational costs for fisheries. Conditions are excellent for farming prawns, mussels, algae, pearls, tilapia, seaweed, shrimps, bivalves (oysters) and crabs (FAO 2007). There are three industrial prawn farms. Seaweed farming (Eucheuma spinosum and Kappaphycus alvarezii) has started with the support of local NGOs in Cabo Delgado and Nampula Provinces as a component of integrated development programmes for coastal communities. In 2012 aquaculture production was 604 tonnes, 0.3% of total fish production (MoF 2013).

Tourism

There is untapped potential for tourism along Mozambique's 2,700 km coastline, which boasts exceptional beaches, coral reefs and marine life. In addition, 17% of Mozambique's land mass (13 million ha) has been gazetted as a conservation area. Tourism is central to economic growth and the government's development strategy. In 2012 it accounted for 6.7% of GDP and employed 6% of the work force (Makochekanwa 2013). The sector's growth rate has averaged 6% over the last five years, outperforming the global average of 4%. There were 2.2 million visitors in 2009 (HITT 2015). Three out of four visitors come from Africa, the majority from SADC countries (ASCLME 2011).

Tourism development is concentrated in the southern coastal area, particularly the Inhambane coastline and the Bazaruto Archipelago (Inhambane Province); the Chidengele–Chonguene–Xai-Xai–Bilene coastline (Gaza Province); and the Macaneta Peninsula and Ponta do Ouro–Machungulo Peninsula–Inhaca Island coastline (Maputo Province). There has also been investment in Pemba Bay and the Quirimbas Archipelago to the north in Cabo Delgado Province. With its rich marine resources and the ongoing interest in oil and gas deposits, this area has good potential for attracting international visitors.

Mozambique offers some of the best game fishing in the world for pelagic (marlin, king, mackerel, tuna and sharks) and demersal species (groupers). Favoured sports fishing areas are the Bazaruto Archipelago, Inhaca Island, Ponta do Ouro–Machangulo Peninsula, Xai-Xai, and Zavora (Hoguane n.d).

Extractive industries

The extractive industries contribute less than 2% to the GDP, but there has been considerable investment in the sector in recent years: aluminium (Maputo Province), reserves of 23 billion tonnes of coking and thermal coal (Tete Province), natural gas extraction (Inhambane Province) and natural gas exploration (Cabo Delgado Province).

The Dublin-based Kenmare Resources owns the Moma mineral sands mine, which produces 7% of the world's ilmenite, the main source of titanium metal, and 4% of the

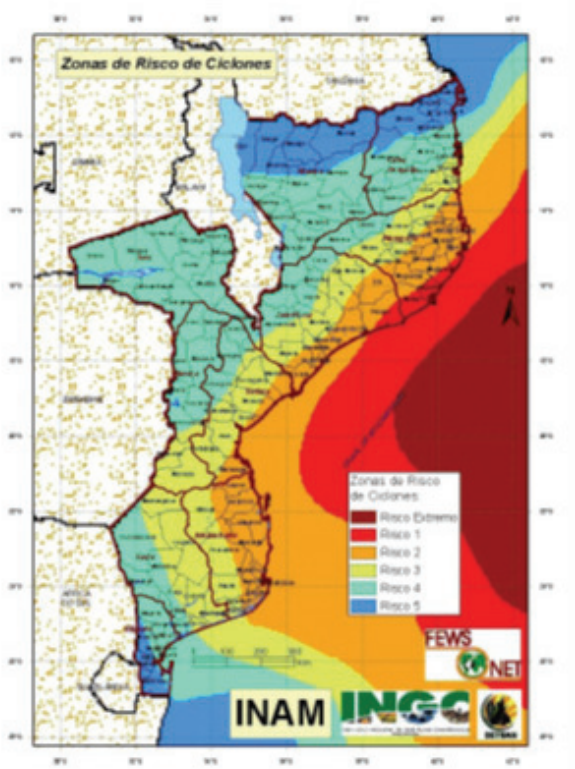
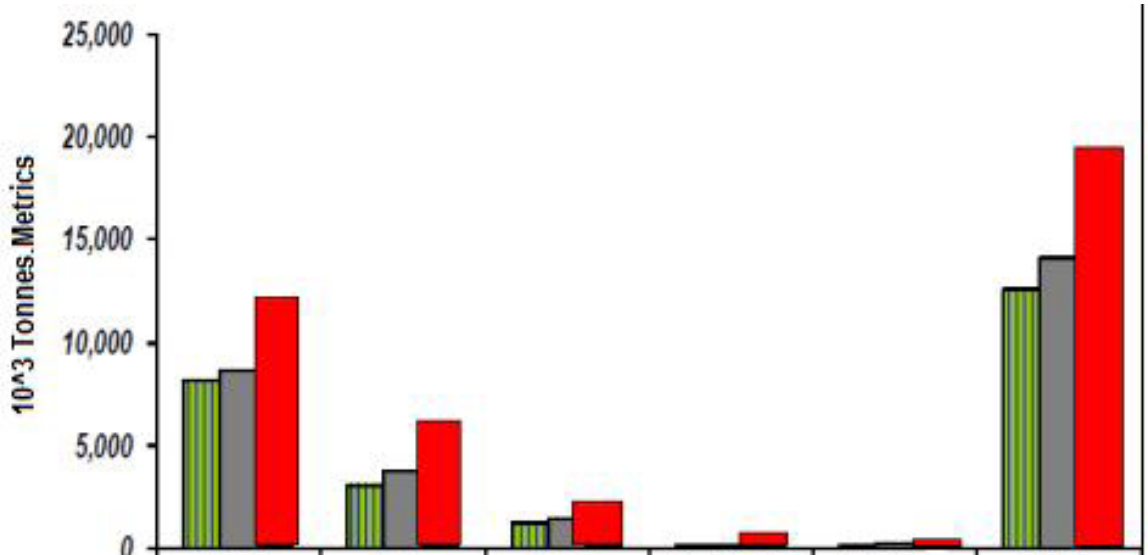


Figure 3.6: Zones prone to cyclones along the coast of Mozambique. (Source: Østergaard 2008).



	Maputo	Beira	Nacala	Quelimane	Pemba	Total
2009	8,167	3,030	1,270	70	115	12,652
2010	8,606	3,805	1,376	131	160	14,079
2011	11,762	5,704	1,629	186	177	19,458

Figure 3.7: Cargo handled by Mozambique's principal ports. (Source: CFM 2013).

world's zircon, a source of zirconium metal. Two smaller operations mine mineral sands in the coastal districts of Angoche (Nampula Province) and Inhassunge (Zambezia Province). There are significant reserves of mineral sands in the coastal districts of Chibuto (Gaza Province), Inharrime and Jangamo (Inhambane Province) and Moma (Nampula Province) (Gove 2011).

The hydrocarbon industry is also expanding with sizeable discoveries of natural gas reserves in the Rovuma Basin both onshore and offshore. Mozambique has the potential to become one of the world's natural gas giants, exporting 150 trillion cubic feet by 2019. Natural gas is already extracted and processed in Inhambane Province with 95% of it exported to South Africa. The remainder is consumed locally.

Ports

Mozambique has exploited its economically strategic position as the gateway for its landlocked neighbours. The ports and railway systems were constructed with a view to meeting the needs of neighbouring countries. Maputo, the largest port, is linked to South Africa and Swaziland by a road and rail system known as the Maputo Corridor. Its cargo-handling capacity exceeds 10 million tonnes. In 2011 the port handled nearly 11.8 million tonnes (Figure 3.6). Zimbabwe has access to Beira's port through the Beira Corridor. The port at Nacala is connected to Zambia and Malawi by the Nacala Corridor. In 2012 about 26 million tonnes (more than 95% of all port cargo) were handled by these three principal ports (CFM 2013). Cargo included coal, aluminium, ferrochrome, cereals, sugar, granite, fuel, clinker and fertilizer.

A small dhow off the Mozambique coast.
Credit: M. Samoilys

4. ADAPTABILITY

This chapter provides a preliminary synthesis of the environmental and socioeconomic chapters of the report to examine environmental and socioeconomic adaptability to climate change and to suggest a framework for planning Resilient Coast initiatives. As highlighted in chapter 1, a full analysis of adaptability is beyond the scope of this report but is recommended as an early exercise in Resilient Coasts through a workshop setting with partners and stakeholders. Such an exercise should be followed with a multisectoral marine spatial planning exercise to determine priority sites and activities using an adapative management approach to address ecological, economic and social objectives (Salafsky et al. 2002; Agardy 2010).

Social resilience and vulnerability

Vulnerability to natural hazards

The effects of rising temperatures and chainging rainfall patterns are becoming clearer. The WIO has suffered prolonged periods of drought, severe floods and devastating cyclones (Table 4.1).

Droughts have affected the largest number of people in Mozambique, Tanzania and Kenya, but floods have been the most disastrous for local economies (Wang et al. 2003; McSweeney et al. 2011). Cyclones happen infrequently compared to drought and floods, but they occur regularly in southern Mozambique (Figure 3.6; Østergaard 2008). Flash floods, river floods and coastal floods are acts of nature but can also be caused by human interference with watersheds, drainage basins and floodplains. In Kenya, Kilifi and Kwale Districts and the Tana River basin are prone to flooding. The worst floods were recorded in 1961/1962 and 1997/1998. The latter one, which affected the entire WIO region, was the most severe and widespread (Obura 2005). This flooding was associated with the El Niño weather phenomenon that spans the Indo-Pacific Oceans, which is predicted to increase in frequency due to global warming. Kenya is prone to cyclical droughts with major ones occurring every 10 years and minor ones every 3 to 4 years (Downing at al. 1989; GoK 2004; GoK 2012; UNEP 2013).

Prolonged droughts in Kenya and Tanzania have forced pastoralist communities to move their herds to coastal areas and into wildlife national parks in search of pasture and water as rivers dry up and grazing is finished. Power cuts are now common when the rains fail and river levels drop because hydroelectric power plants cannot supply their quota to the national grid. Community vulnerability assessments indicate the timing and intensity of the long and short rains are no longer reliable (Østergaard 2008; Wang et al. 2003; CORDIO 2012; Maina et al. 2012; Laizer et al. 2012) which poses problems for rainfed agriculture and food production. Prolonged droughts invariably put sections of populations at risk of malnutrition and starvation. They also increase consumer demand for fish.

Climate change has implications for diseases and their management. Global warming is likely to increase the incidence of vector-borne diseases such as malaria, schistosomiasis and trypanosomiasis. Floods and unseasonal heavy rains are likely to increase the frequency and magnitude of waterborne diseases such as typhoid and cholera (Østergaard 2008; Wang et al. 2003; CORDIO 2012; Maina et al. 2012; Laizer et al. 2012).

Rising sea levels have serious implications for the wellbeing of coastal communities. In Mozambique, the sea level is projected to rise 0.13 m–0.56 m by 2090 (McSweeney et al. 2011). In Tanzania, the National Climate Change Communications Strategy considers scenarios where the sea level rises by 0.5–1 m over the next century. Saltwater intrusion into the water table along the coast has already contaminated fresh water and resulted in the formation of saline soils. Saltwater has inundated wells at Mlingotini village in Bagamoyo District, Tanzania, and public freshwater wells have been lost to saltwater intrusion (Wang et al. 2003). However, it is not clear whether shoreline erosion in Mozambique, Tanzania and Kenya is caused by rising sea levels or the geological dynamics of coastlines. Heavy floods also erode shorelines.

Another phenomenon is that the direction and strength of seasonal prevailing sea winds are no longer predictable. This affects fishing and safety at sea as well as agriculture as seasonal sea winds were predictors for when to plant crops. Factors contributing to severe, prolonged droughts include inadequate water storage capacity, forest destruction for fuel and agriculture, illegal logging, frequent forest fires, poor water catchment management, the cultivation of riparian zones and river banks, and an absence of policies governing water and drought management.

Poverty, economic dependence on natural resources and single livelihoods (e.g. fishing, agriculture), weak district governance, degraded resources, insecure land tenure and inequitable property rights are some of the underlying reasons for community vulnerability to natural hazards (Table 4.1). Some of the damage caused by flooding in Mozambique, Tanzania and Kenya could be averted if precautions are taken, but often communities are unaware of how to do it. Flooding is exacerbated because crops are cultivated on floodplains.The destruction of trees in catchment areas causes erosion. Soils cannot absorb water as they used to, and housing is constructed with materials that cannot withstand floodwater. Many coastal villages have poor adaptive strategies. This can be changed with the introduction of policies and actions that address the root causes of natural hazards (Østergaard 2008; Wang et al. 2003; Maina et al. 2012; CORDIO 2012; Laizer et al. 2012).

Critical habitats and vulnerability

Mangroves are the flagship habitat for Resilient Coasts, and it is therefore recommended that the Initiative's activities prioritize these ecosystems. Analyses in the previous sections have illustrated clearly that vibrant mangrove forests signify productivity and biodiversity. They have ecological links to neighbouring ecosystems such as coral reefs and seagrass beds. These three habitat types function as a meta-ecosystem, conferring even greater biodiversity and productivity, both of which are generally indicators for greater resilience (e.g. Mora et al. 2011). Mangroves play a pivotal role in mitigating the effects of climate change. They have an exceptional ability to sequester carbon that far exceeds that of terrestrial forests. They can adapt to rising sea levels. They provide abundant goods and services to local communities through their fisheries and timber. And they protect coastlines from floods and storm damage (Adger et al. 2005; Danielsen et al. 2005; Spalding et al. 2010).

The preceding chapters describe how eastern Africa's mangrove forests of note are all connected to major river basins. The mangroves of the major river basins—Zambezi (Mozambique), Ruvuma (Mozambique–Tanzania), Rufiji

Table 4.1: Examples of vulnerabilities to natural hazards from the coasts of Mozambique, Tanzania and Kenya.

Hazard and frequency	Impact (implications)	Coping strategies
Floods and heavy rains (frequent) Mozambique: 2000 Tanzania: N/A Kenya: 1997/98, 2002, 2004, 2008, 2006	• Key sectors affected: fishing, water, agriculture, livestock, health, infrastructure • Food scarcity: loss of crops, pasture, wildlife • Increased sedimentation and erosion • Fatalities and displacement of communities • Crocodile infestation in river estuaries • Outbreak of waterborne diseases such as cholera, typhoid, malaria • Groundwater recharge • Increased abundance of estuarine fish species, e.g. catfish; some fish migrate to offshore habitats • Destruction of infrastructure	• Depend on relief aid and supplies • Use alternative routes and other means for transport • Sun dry fish when it cannot be transported to market
Drought (frequent) Mozambique:1974, 1983, 1984, 1992 Tanzania:1997/98, 2000, 2004, 2008, 2009 Kenya: 1883, 1889/90, 1894/95, 1896/1900, 1907-11, 1921, 1938/39, 1941/44, 1960/61, 1972, 1974-76, 1977, 1980, 1983/84, 1991/92, 1995/96, 1999, 2000	• Key sectors affected: fishing, water, agriculture, livestock, health, wildlife • Food sector: loss of livestock, crops, increased fishing pressure, reduced food production as a result of poor harvests and drying up of crops • Water sector: drying up of wells and rivers • Increased temperature including SST affecting habitats, organisms, populations • Rise in conflicts due to competition for resources • Increased incidents of wildfire • Prolonged electricity supply interruptions	• Migrate to safer areas, areas with food supply • Farm drought-resistant crops and farm with methods that retain water • Diversify livelihoods
Storms/strong winds/ waves (frequent)	• Increased water turbidity • Destruction of houses, settlements, crops, fishing gear and vessels, trees	• Use stronger fishing vessels • Avoid fishing during storms or strong winds
Cyclones (in Mozambique) dates not available	• Livelihood activities such as fishing and navigation affected • Loss of lives in the sea • Spread of crop diseases and pests • Beach erosion	• Have extra fishing gear • Rely on alternative sources of income • Turn to agricultural production
Tsunami (*not frequent*) 2004	• Livelihood activities such as fishing affected • Destruction of habitats	• Keep off the sea

Source: Downing et al. 1989; Gathara 1995; GoK 2004; Turley et al. 2011; GOK 2012; UNEP 2013 and Wikipedia, accessed 15 Feb 2013
SST = sea surface temperature

(Tanzania) and Tana (Kenya)—have the largest areas under mangrove cover and the healthiest mangrove forests in eastern Africa (Spalding et al. 2010). In view of the close relationship between mangrove forests, coral reefs and seagrass beds, this report recommends five meta-ecosystem sites for Resilient Coasts activities. They all have the potential for adaptability and resilience to climate change. The criteria for selecting these sites have also drawn on the resilience, vulnerability and adaptability of the coastal communities for whom these marine ecosystems are vital. However, there has been insufficient research on community vulnerability to climate change, and an in-depth analysis is required.

It is strongly recommended that one of the first steps taken by Resilient Coasts is to assess the complex issue of adaptability of eastern Africa's coastal systems. It is suggested that an indicator framework is developed to rank and assess the different sites of interest. The framework should use quantitative, semi-quantitative, qualitative and expert-opinion indicators. Vulnerability and resilience indicators can be developed to assess the potential adaptability of these sites. This would be helpful for strategizing which locations would benefit from specific interventions appropriate to those sites. It is recommended that this analysis is then discussed in a consultative workshop with partners and stakeholders, including government experts. In addition, the knowledge gaps in coastal-system resilience to global change that have not been addressed in this report can be addressed in the analysis.

Significant sites for Resilient Coasts

Five meta-ecosystem sites (mangrove forests, coral reefs and seagrass beds) highlighted for Resilient Coasts activities are further described here. These include four of the river basins mentioned above and three locations in eastern Africa that have been proposed as sites of outstanding universal value to be considered for listing by UNESCO's World Heritage Centre (Obura et al. 2012), using many of the criteria used for Resilent Coasts prioritization. The WH proposed sites are:

- the Quirimbas-Mnazi Bay complex, northern Mozambique and southern Tanzania
- Bazaruto–Tofo in Inhambane Province, southern Mozambique
- the Lamu Archipelago–Tana Delta, northern Kenya

Other sites that provide valuable ecosystems services described here are:

- Rufiji Delta–Mafia Island, southernTanzania
- Funzi Bay and Ramisi River Estuary, southern Kenya

It is also recommended that a socioeconomic (chapters 2 and 3) and institutional assessment of these sites is conducted to gauge their potential for adaptability.

Quirimbas–Mnazi Bay complex, northern coast of Mozambique and southern coast of Tanzania

The Quirimbas–Mnazi Bay complex, in northern Mozambique and southern Tanzania, has been recommended as a site of Outstanding Universal Value. This recognition inspired the crossborder TRANSMAP Project. The complex contains coral reefs with the highest biodiversity in the WIO. They are also some of the healthiest reefs in the region with a unique evolutionary and genetic history. In terms of absolute numbers of species, they are second only to the Coral Triangle in Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor–Leste. The mangrove forests are extensive and in good health too. There is good connectivity and mixing of ocean currents, which provides a node for accumulating and dispersing of marine organisms. This dyamic productivity supports an unusually high density of turtles, whales, seabirds, sharks and large teleost fishes and underscores the importance of the complex as nesting, migration and feeding grounds.

Bazaruto–Tofo in Inhambane Province, southern coast of Mozambique

Bazaruto–Tofo in Inhambane Province, southern Mozambique, has been recommended as a site of outstanding value for its rich diversity of terrestrial and marine habitats. This includes some of the largest dune systems in the WIO as well as lakes, seagrass beds, mangrove forests, coral reefs and an island archipelago. The seagrass beds support the largest and possibly only viable dugong population in the WIO. Up to 250 dugongs have been sighted. It is easy to see why this area is of vital importance for this *Vulnerable* species (IUCN Red List 2012), which is probably the most endangered mammal in Africa (Samoilys et al. 2011a). Significant whale shark and manta ray aggregation sites in Tofu could become unique tourist attractions that protect shark and ray breeding and feeding grounds.

The area around the Save River and further south to the Bazaruto Archipelago has been proposed as an EBSA by the CBD (UNEP/CBD 2012). The seagrass beds and mangroves around the Save River are valued for their inshore fish production. Loggerhead turtles nest in this area, and large pelagic fish breed around the islands. Invertebrate diversity is high around Bazaruto Island, which is a national park[18]. Productivity is a result of turbulent upwellings, eddies and tidal turnover, some associated with the Agulhas Current, and with the water flow and nutrient discharge from the Save River.

[18] It has been rated as having 'high naturalness', one of the CBD criteria for describing EBSAs. Naturalness in this context refers to an area that has minimal human disturbance or degradation.

A fisherman who makes gill nets from northern Kenya, Kiunga, Kenya. *Credit: M. Samoilys*

Lamu Archipelago–Tana River Delta, northern coast of Kenya

The UNESCO World Heritage Centre recommended this site based on an ecosystem assessment of outstanding values (Obura et al. 2012). It is recommended that the Tana Delta is included as it is already a Ramsar site on the basis that it supports one of the most significant mangrove systems and wetlands in Kenya. The Tana is one of the largest rivers in East Africa. It flows into Ungwana Bay, which supports Kenya's only commercial prawn fishery and which is ecologically linked to the productive offshore North Kenya Banks. The Tana Delta is home to two *Critically Endangered* sawfish species (IUCN Red List 2012), and Ungwana Bay is likely to be an important nursery area for threatened sharks. The Tana River region has experienced many socioeconomic problems: minimal development and infrastructure, poor education and healthcare delivery, a dearth of income-generating opportunities and conflict over access to land.

Rufiji Delta–Mafia Island, southern coast of Tanzania

Spanning Rufiji, Mafia Island and Kilwa Districts, this is one of the poorest areas in the country. The delivery of health, education and other services to the population of 250,000 is extremely inadequate. Some of the island communities do not even have access to fresh water. The 25-member Village Government Councils oversee environmental matters (including beach management units (BMUs)) and enforce the Fisheries Act and Fisheries Regulations.

The Mafia Island seascape, which encompasses the Rufiji Delta and the Songo Songo Archipelago, has one of the richest diversities of marine species in the region. Its biological and ecological significance was recognized in the early 2000s when a regional spatial planning and priorities exercise defined the Eastern African Marine Ecoregion (EAME) (WWF 2004a). It was included as an EBSA submission at a recent CBD Conference of the Parties (UNEP/CBD 2012). The seascape arguably contains the finest representative complex of characteristic tropical marine habitats and species in the EAME. The Rufiji Delta hosts the largest area of contiguous mangrove forest in eastern Africa (540 km^2). The trees are in good condition and are relatively well protected. Mafia Island and the Songo Songo Archipelago have extensive and biodiverse coral reefs (Obura 2012; Samoilys et al. 2012) and have demonstrated an exceptional resilience to coral bleaching (Obura 2011).

This area, alongside the high-diversity coral reef systems of the Quirimbas–Mnazi Bay Complex, is one of the recommended sites for World Heritage nomination (Obura et al. 2012). There are also extensive seagrass beds, algal beds and intertidal flats. Some of these are preferred habitats for sharks, rays and turtles. There are numerous seabird species. Coelacanth have been caught here too.

The local communities engage in fishing and tourism (mainly Mafia Island), subsistence agriculture, animal husbandry and trade (mainly Kilwa and Rufiji), and charcoal production. Cashew nuts, simsim and coconuts are grown as cash crops. The food crops are maize, cassava and rice. There are also commercial crustacean

and finfish fisheries. The Rufiji Delta yields around 70% of the national prawn catch. Mafia Island provides up to 60% of finfish for Dar es Salaam markets. More than half the national octopus exports come from Mafia and Kilwa.

The area also has extensive offshore sedimentary basins containing giant natural gas deposits. Careful exploration and extraction is vital if the marine and coastal ecosystems are to be maintained in a healthy state. To safeguard against habitat destruction and industrial pollution, all the stakeholders in the region must continue to consult with each other and mediate conflicting interests.

The Rufiji-Mafia-Kilwa seascape is one of the areas most vulnerable to climate change and climate variability. Because poverty is deeply entrenched, communities have virtually no safety net to help them adapt to change. Infrastructure is almost nonexistent. There is scant access to capital or technology. There are no coping mechanisms to counter changing rainfall patterns; droughts; animal, crop and human diseases; and bad weather.

A paradigm shift in rural and community development priorities has become a matter of urgency. Poverty alleviation and development policies and plans should protect people's livelihoods and rights; enhance access to infrastructure, resources and services; create access to markets; and empower women through education. The priority areas for introducing adaptation strategies are the ocean, fishing, agriculture and health.

Funzi Bay–Ramisi River Estuary, southern coast of Kenya

Diani to the Tanzanian border, in Kwale County, is a popular tourist destination providing good revenues since the 1970s although there have been many points of conflict between the tourism industry and local fishers and the Kenya Wildlife Service (KWS). The poverty rate for Kwale County is 71%. Only 10% of the population have attended secondary school[19]. These communities will not be able to escape poverty until they can enjoy access to water, sanitation, reliable education and health services, security of tenure for agricultural land, and access to markets for fish and cash crops.

[19] In Lamu and Kilifi Counties, one-third of the population has not attended school at all.

The two mangrove bays in Funzi and Gazi host shallow seagrass beds, prawn fisheries and a basket-trap fishery for rabbitfish (Samoilys et al. 2011a; Maina et al. 2013). These bays would be a good focal site for pilot projects as they are easily accessible from Mombasa and have been well researched thereby providing a comprehensive baseline of data on the marine environment, social vulnerability and adapatability, and mangrove goods and services. Its scuba diving, white sandy beaches and whale sharks could also be marketed more agressively to tourists. There is a governance structure in place ranging from government MPAs to community coastal conservation associations. There is the potential to link up with Tanga in Tanzania, where there is a solid culture of institutional support and community awareness of marine resource management and conservation (Wells et al. 2007).

Most people earn a living as fishers and small-scale farmers. Reef and nearshore resources are the main sources of income for many households. The existence of community-based organizations (CBOs), NGOs and some supportive legislation provides entry points for mobilizing interventions.

In summary, there are several healthy ecosytems where Resilient Coasts can be active. The challenges will be in addressing the current social, political and economic context and the adaptability of the coastal people living within these ecosystems. People's wellbeing is constantly being battered by climate-induced catastrophes. Outbreaks of disease are more common when the countryside is flooded or harvests fail. Disaster-related loss of property, assets and food stores takes a heavy toll on people who have no economic safety net. These problems need to be addressed holistically to cover the spectrum of biodiversity, wetlands, fisheries and forest conservation together with agriculture, disaster preparedness, sanitation and building community capacity.

There must be an integrated ecosystem management strategy to restore ecosystems and strengthen BMUs and CBOs. Microfinance programmes would enable communities to invest in their livelihoods, education for their children and better housing. These are all measures to underpin the resilience of people who live at the coast. This in turn generates the ability to adapt to changing external circumstances.

5. POLICY, LEGAL, REGULATORY AND INSTITUTIONAL FRAMEWORKS FOR MANAGING THE MARINE AND COASTAL ENVIRONMENT

This chapter details the institutions and governance frameworks involved in marine and coastal management in Mozambique, Tanzania and Kenya. It looks at international and regional institutions and frameworks involved with coastal and marine issues. These are United Nations (UN) agencies, the African Union (AU), regional economic integration organizations, international and regional civil society organizations, governance frameworks for river basins, and regional management organizations for fisheries. It also looks at national institutions, and legal and policy frameworks and programmes.

International and regional institutions and organizations

Several international institutions in Mozambique, Tanzania and Kenya are involved in the protection of the WIO's marine ecosystem and the region's socioeconomic development. Their mandates, influence and priorities vary.

United Nations Environment Programme

UNEP is based in Nairobi, Kenya. It reports to the UN General Assembly through the UN Secretary-General. It facilitates international environmental cooperation and provides policy guidance for environment programmes within the UN system. It also promotes scientific knowledge and information, contributes to the technical aspects of environment programmes, and reviews the impact of national and international environment policies on developing countries. Its studies and programmes are designed to counter environmental problems. Implementation is often carried out with the collaboration of regional and national government and civil society organizations.

UNEP's Medium-term Strategy (2014–2017) has seven priorities:

- climate change
- disasters and conflicts
- ecosystem management
- environmental governance
- chemicals and waste
- resource efficiency
- environment under review

UNEP's Marine and Coastal Strategy (2011) sets out four objectives:

- Highlighting the links between ocean and land to encourage countries to integrate the management of coastal areas and watersheds and the marine environment to optimize ecosystem services and marine ecosystem resilience
- Creating ecosystems for humanity by evaluating the drivers of change of marine and coastal ecosystems and their link to human wellbeing
- Reconciling use and conservation to ensure that governance frameworks, management tools, capacity and options for sustainable management are available to regions, countries, communities and the private sector
- Strengthening the ecological, economic and social resilience of vulnerable communities and places, and improving the response to natural disasters and climate change

UNEP has played a significant role in developing various instruments of environmental law. For example, it has negotiated 48 multilateral environmental conventions and protocols since 1976, initially at diplomatic conferences convened under its auspices and subsequently through its Montevideo programmes.

UNEP is the secretariat for the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean region. It was signed in 1985 and came into force in 1996 as part of UNEP's Regional Seas Programme. The convention's particular strength is that it has been ratified by all the signatories, as have its two initial protocols. The convention is a regional legally binding agreement covering 10 states, five of which are island states in the Western Indian Ocean. These are the Protocol on Specially Protected Areas and Wildlife and the Protocol on Cooperation in Combating Marine Pollution in Cases of Emergency. The latter protocol is primarily to combat oil pollution from ships.

A subsequent Protocol on Land-based Sources and Activities recognizes that pollution from land-based sources and activities constitutes one of the major threats to the sustainability of the WIO's marine and coastal ecosystems. It is awaiting ratification or accession by the contracting parties.

The ICZM protocol is currently under development. It will provide a framework for regional and national integrated coastal zone management for sustainable development including climate change adaptation and mitigation measures.

The Nairobi Convention is guided by the governments of the region through a network of national focal points and thematic groups of experts (Coral Reef Task Force, Marine Turtle Task Force, Mangrove Network, Legal and Technical Working Group, and Forum for Academic and Research Institutes). Its decision-making organ is the Conference of Parties, a biennial meeting that brings together the ministers for environment and technical experts from all the countries that are party to the convention. The ministers are represented by senior officials known as the Forum of Focal Points. The forum oversees policy and coordination for the programmes implemented by the convention's secretariat.

The secretariat based at the UNEP headquarters in Nairobi, Kenya, works closely with the convention's Regional Coordinating Unit in the Seychelles, which is responsible for intergovernmental political coordination. The Nairobi Convention's partnership (through its secretariat) with Resilient Coasts has been an essential factor in rallying political support from Mozambique, Tanzania and Kenya.

African Ministerial Conference on the Environment

The UNEP Regional Office for Africa is the secretariat for the African Ministerial Conference on the Environment (AMCEN). It meets biennially and champions environmental protection as well as the sustainable provision of basic human needs, equitable social and economic development and an agriculture sector designed for food security.

AMCEN led the development of the Action Plan for the Environment Initiative of the New Partnership for Africa's Development (NEPAD), which was endorsed by the AU in 2002. The 10-year Environment Action Plan is underpinned by the notion of sustainable development through poverty eradication, social equity and good governance. It is organized in programmatic clusters and project activities. AMCEN supports UNEP's Africa Environment Outlook, which provides information for environmental adaptation measures. AMCEN facilitated the revision of the 1968 African Convention on the Conservation of Nature and Natural Resources (Algiers Convention).

The AMCEN Bamako Declaration (2010) includes the following:

- To urge the AU Commission, together with UNEP, the United Nations Economic Commission for Africa and other partners, to develop a marine and coastal environment strategy for Africa, taking into account the detrimental impact of climate change and the need to improve community livelihoods
- To encourage countries to develop national and subregional strategies and action plans for climate change and the marine and coastal environment
- To urge states and organizations to expedite ratification, acceptance or approval and implementation of the Amended Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean and the Protocol for the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-based Sources and Activities, adopted by a Conference of Plenipotentiaries in April 2010
- To urge UNEP and partners to support the implementation of the Strategic Action Programme for the Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities that was endorsed in March 2010
- To urge coastal states to support a project on mangrove ecosystem management being led by the African Mangrove Network and funded by the Global Environment Fund (GEF)

African Ministerial on Water

AMCOW encourages new approaches to the provision, use and management of water resources through political leadership, policy direction and advocacy. It facilitates intergovernmental cooperation in managing shared waters, including surface and groundwater, and secures funding for the water sector. It also monitors the implementation of regional and global water and sanitation initiatives. AMCOW fosters best practices for policy reform, integrated water-resource management, food security, water supply and sanitation. It channels dialogue between UN agencies and other partners and promotes participation in regional studies on climate change and the development of observation networks.

AMCOW's secretariat is in Abuja, Nigeria. Its executive committee is composed of three water ministers from each of the five subregions: West Africa, Eastern Africa, Central Africa, North Africa and Southern Africa. It also has a technical advisory committee.

New Partnership for Africa's Development

NEPAD was constituted by African leaders through the AU in 2001 to accelerate the continent's social, economic and political development. NEPAD has an environment action plan to address priority issues. A 2002 framework proposes four strategic directions.

- capacity building for environmental management
- fostering political will to address environmental issues
- harmonizing international, regional and national resources, conventions and protocols
- supporting best practices and pilot programmes

The action plan is organized in programmatic clusters: land degradation, drought and desertification, wetlands, invasive species, marine and coastal resources, cross-border conservation of natural resources and climate change. It also refers to the related coastal problems of pollution, forests, freshwater, capacity building and technology transfer (UNEP 2009a).

The AU is developing an African climate change strategy, which will include a chapter on the coastal and marine environment. It is also developing a strategy to address climate change issues in the fisheries and aquaculture sectors. Another initiative is NEPAD's Fisheries and Aquaculture Programme, run through its Planning and Coordinating Agency in Pretoria, South Africa. It supports fisheries improvement programmes in collaboration with the Marine Stewardship Council in Mozambique, Tanzania and Kenya and the AU-InterAfrican Bureau for Animal Resources in Nairobi, Kenya. The presence in Nairobi of this arm of the AU and NEPAD's Coastal and Marine Secretariat provides an opportunity for Resilient Coasts to tap into other continental programmes.

The African Process for the Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa

Commonly known as the African Process, this initiative supported by the GEF, delivers results that are incorporated into frameworks such as the NEPAD Action Plan. It had its genesis in two 1998 conferences: the Pan-African Conference on Sustainable Integrated Coastal Management in Maputo, Mozambique; and, in South Africa, the Cape Town Conference on Cooperation Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. These events stimulated a political awareness for the need to develop an integrated approach towards the sustainable development of the coasts and oceans fringing the continent.

The African Process recognizes the need for regional cooperation to address the many social, economic and environmental problems that are either transboundary in nature or common to most countries. The initiative relies on the expertise of WIOMSA and marine scientists from individual countries to identify priority areas for action. It has led to the incorporation of a coastal and marine subcomponent of the environment component of the NEPAD Action Plan. Its secretariat, the NEPAD Coastal and Marine Secretariat, is based in Nairobi, Kenya.

International Maritime Organization

IMO is the UN body that has oversight for the safety and security of international shipping and the prevention of marine pollution from ships. It was established in 1948 by means of a convention and is based in the United Kingdom. IMO has a series of hard and soft law instruments. Many of the responsibilities and obligations defined in these instruments devolve to coastal states, flag states and port states. Mozambique, Tanzania and Kenya fall into at least two of these categories.

An instrument that may be of relevance to Resilient Coasts is the Ballast Water Management Convention (2004), which has provisions on invasive species dispersed through ballast waters. The Port Management Association of Eastern and Southern Africa and the Initiative on Environmental Cooperation for Improved Performance in African Ports are beginning to address the environmental aspects of port operations in the WIO.

Food and Agriculture Organization

FAO is the UN agency charged with helping countries to improve their agriculture, forestry and fisheries practices to achieve good nutrition and food security. It has evolved to embrace environmental concerns, such as sustainable approaches to fishing, aquaculture, water-resource management and agriculture that take into account environmental and conservation needs, habitat protection and the effects of pollution, pesticides and fertilizers. FAO was party to the development of the Convention on Fishing and Conservation of the Living Resources of the High Seas (1958); the Agreement to Promote Compliance with Conservation Measures on the High Seas (1993); the Agreement on Straddling and Highly Migratory Fish Stocks (1995); and in collaboration with UNEP, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998) (Sands 1994; Sands and Klein 2001; Birnie and Boyle 2009).

FAO and Resilient Coasts could collaborate through the NEPAD-FAO Fish Programme, which is establishing baselines for the integration of climate-change adaptation and disaster-risk management in fisheries and aquaculture policy and activities in southern and eastern Africa. In another example, FAO's SmartFish Programme helped WIOMSA organize a regional workshop on managing sea cucumbers.

Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization

UNESCO-IOC offers scientific advice and conducts research on the marine environment to define the probable consequences of action and inaction (www.ioc-unesco.org). It is becoming more involved in joint research programmes with developing countries through intergovernmental commissions dealing with land-based pollution, pollution from dumping and fisheries. It works with the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, whose reports have informed marine policy and management action (Birnie and Boyle 2009).

United Nations Development Programme

UNDP's mandate is primarily socioeconomic development. Unlike UNEP, it has country offices in Mozambique, Tanzania and Kenya and other WIO countries. It channels multilateral, technical and investment assistance to developing countries, including for environmental programmes such as the GEF.

The GEF Small Grants Programme offers financial and technical support to projects that conserve and restore the environment while enhancing people's wellbeing and livelihoods. The projects are implemented through country programme teams comprising a national coordinator, a programme assistant and a national steering committee. These teams are often hosted by UNDP's country offices. The national steering committees consist of voluntary members drawn from civil society organizations, government, UNDP, academia, the private sector and the media. They oversee grant approvals, monitoring and evaluation, and learning processes. Mozambique, Tanzania and Kenya all participate in the Small Grants Programmes.

Regional economic integration organizations

There are four regional economic integration entities relevant to the WIO: the Southern Africa Development Community (SADC), the Common Market for Eastern and Southern Africa (COMESA), the East African Community (EAC) and the Indian Ocean Commission (IOC). Mozambique and Tanzania are members of SADC. Kenya is a member of COMESA. Kenya and Tanzania are members of the EAC. Only the island states of the WIO are members of the IOC.

Southern African Development Community

SADC is a regional economic cooperation agreement constituted under a 1992 treaty. There are 15 members of the SADC Treaty. Six are also members of the Nairobi Convention (UNEP 2009a). Mozambique and Tanzania are SADC members but Kenya is not. The SADC Treaty has its headquarters in Botswana. It is administered by sectoral subcommittees including one on environment and land management and another on fisheries.

The SADC Protocol contains the generic rules for the management of transboundary rivers. Article 5 establishes the institutional framework for the management of shared watercourses through SADC's water-sector organs and Shared Watercourse Institutions (SWCIs). The SADC Protocol on Fisheries (2001) is relevant primarily to inland fisheries rather than marine fisheries. No sector is dedicated to the marine environment but the Fisheries Protocol and the Shared Water Courses Protocol are both relevant to coastal and marine environments by implication.

Similarly, there is no environmental assessment protocol governing potential transboundary pollution. The adoption of a SADC protocol for environmental impact assessment modelled on the European Union (EU) Espoo Convention would allow member States to harmonize national environmental impact assessments. The Espoo Convention obliges signatories to assess the environmental impact of certain activities at an early stage of planning. The challenge is to include at least land-based marine pollution concerns when developing and implementing protocols for SADC and the Nairobi Convention (UNEP 2009a).

The Revised Protocol on Shared Water Courses that follows from the International Water Courses Convention encourages the establishment of regional institutions for river basins to manage shared water resources in a sustainable way. They would be known as permanent river basin water commissions or operating authorities.

SADC has a Climate Change Strategy, but it does not directly address marine and coastal issues.

Common Market for Eastern and Southern Africa

COMESA is a free-trade area established in 1994. Its 19 member States extend from Libya to Swaziland. Five WIO countries are COMESA members and party to the Nairobi Convention: Comoros, Kenya, Madagascar, Mauritius and Seychelles. Tanzania left COMESA in 2000.

East African Community

The EAC has five member States: Burundi, Kenya, Rwanda, Tanzania and Uganda. It is headquartered in Arusha, Tanzania. Originally it was a customs union, but its remit was broadened under the Treaty for the Establishment of the East African Community (1999) to become a regional economic integration organization. With only two members from the WIO and a focus on inland concerns, the EAC has had little involvement with regional marine issues (UNEP 2009a).

However, in 2010 the EAC, COMESA and SADC launched a joint five-year programme, Climate Change Adaptation and Mitigation. The intention was to present a common position for Africa to be incorporated in the post-2012 UN Framework Convention on Climate Change global agreement so as to unlock resources to improve the lives of millions who are vulnerable to climate change. The programme seeks to increase investment in agricultural methods that are carbon efficient and resilient to changing climate patterns by 2016. It is funded by the Norwegian government, the EU and DfID. A workshop planned in the near future for the WIO on coastal and marine issues in the context of the Common African Position on Climate Change will be an opportunity for collaboration with Resilient Coasts.

Indian Ocean Commission

IOC is an instrument of regional cooperation comprising five island states: Comoros, France (by virtue of its sovereignty over Reunion), Madagascar, Mauritius and Seychelles. Its principal concern is marine fisheries, and it has several fisheries partnership agreements (UNEP 2009a). Climate change is also given considerable attention as island nations are particularly vulnerable.

River basin governance frameworks

Numerous commissions govern transboundary waters in the WIO. Arguably the best known is the Zambezi River Basin Commission. It administers the Zambezi River System Agreement to which Botswana, Democratic Republic of the Congo, Mozambique, Tanzania, Zambia and Zimbabwe are signatories. Agreements such as this one provide for two categories of shared watercourse institutions:

- Shared water commissions are essentially advisory bodies providing a forum for notification, consultation and negotiation; for coordinating responses to emergencies; for collecting data; and for setting water-quality targets and standards.
- River basin authorities go further in that they have specific powers granted to them by parties to the shared water agreement.

The International Watercourse Treaty and the SADC Protocol on Shared Watercourses (2000) envisage both these arrangements.

SADC institutions are vested primarily with monitoring functions concerning the application of the SADC Protocol as well as with facilitating the harmonization of the SADC member States' water laws and policies. These water-management institutions are not mandated with the implementation and enforcement of agreements governing river basins. That is done by shared watercourse institutions and the relevant national institution.

A range of organizations have been formed to advise basin states on river management issues (basin commissions), cooperate over technical aspects (technical committees) and implement projects (development authorities) (Malzbender and Earle 2007). The SADC Protocol is non-prescriptive on the types of shared watercourse institutions that may be formed, leaving member States to determine their own mechanisms.

Only five organizations governing WIO rivers have a mandate to develop and execute joint projects. They are the Komati Basin Water Authority (South Africa, Swaziland and Mozambique), Pangani Basin Water Office (Tanzania), Rufiji Basin Development Authority (Tanzania), Tana and Athi River Development Authority (Kenya), and Zambezi River Authority (Mozambique, Zambia and Zimbabwe). They operate according to a clearly defined mandate (Malzbender and Earle 2007) for a specific purpose such as shared dam construction or operation, hydropower generation and irrigation. They do not engage in interstate negotiations or formulate policy.

The two transboundary river basin organizations with an executive mandate are the Zambezi River Authority, which manages Zambia's and Zimbabwe's shared hydroelectric infrastructure on the Zambezi River; and the Komati Basin Water Authority, constituted by South Africa and Swaziland to implement Phase 1 of the Komati River Basin Development Project. Both organizations cover transboundary rivers yet do not include all the basin states. Even so, they are important examples of interstate cooperation that could be emulated by Kenya and Tanzania, as well as Mozambique and Tanzania, for their shared water courses (Malzbender and Earle 2007).

International and regional civil society organizations

International, regional and national CSOs are active in the WIO. Only a few have dedicated programmes for the marine and coastal environment. The organizations listed below are expected to have a role in Resilient Coasts. Other international and regional CSOs in the WIO include Conservation International, the East African Wildlife Society, the Wildlife Conservation Society, BirdLife International and Seacology.

International Union for Conservation of Nature

IUCN, established in 1948, brings together 83 countries, 110 government agencies, more than 800 NGOs, and some 10,000 scientists and expert practitioners from 181 countries in a unique worldwide partnership. It has a presence in 40 countries and is one of the world's largest and most important conservation networks. It assists societies in conserving the integrity and diversity of nature and ensuring that the use of natural resources is equitable and ecologically sustainable. Its headquarters and secretariat are in Switzerland. Its strength lies in the fact that its activities are grounded in science.

IUCN has a Global Marine and Polar Programme (GMPP) that focuses on the use of science and technology for the sustainable management and conservation of marine ecosystems and resources. This includes providing scientific information on the impact of climate change on the marine environment and policy recommendations on ecosystem-based adaptation to international processes such as the UN Framework Convention on Climate Change. GMPP represents IUCN in a number of policy meetings such as FAO's Committee on Fisheries, the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea and meetings on the UN Fish Stocks Agreement.

GMPP works with the World Commission of Protected Areas—Marine to develop best practices and provide guidance for site managers and also as a scientific advisory body for marine World Heritage sites. GMPP has been working extensively in partnership with a variety of corporations from the private sector on themes such as tourism, offshore renewable energy and minimization of the environmental impact of coastal oil and gas exploration and extraction.

IUCN's Environmental Law Centre in Germany is part of its Environmental Law Programme that offers decision-makers information, legal analysis, advisory services, legislative drafting, and mentoring and capacity building at national, regional and global levels. It also provides a networking forum for governments, NGOs and others. Another aspect of the programme is the IUCN Commission on Environmental Law, a global volunteer network of more than 500 environmental law specialists located in more than 130 countries.

IUCN merged its eastern and southern African offices to establish the Eastern and Southern Africa Regional Office (IUCN ESARO) in Nairobi, Kenya, in 2008. ESARO has six country offices: Kenya, Mozambique, South Africa, Tanzania, Uganda and Zimbabwe. The ESARO programme has six thematic areas[20] led by technical experts and technical teams of regional and country programme officers. There are 13 IUCN members in Mozambique, Tanzania and Kenya. Kenya is a State member while government agencies are members in Mozambique and Tanzania. Nine NGOs (three being international) are members.

IUCN ESARO has advocated for rare, threatened and endangered species and habitats in the WIO and implemented education and awareness programmes. It has facilitated the Tanga Coastal Zone Conservation and Development Programme in Tanzania, and the Eastern Africa Marine and Coastal Ecosystems Programme. It partnered with other organizations to initiate the Jakarta Mandate for implementation of the 1992 Biodiversity Convention. It supports Kenya's Kisite Marine Park. It supports Tanzania's newly established Mnazi Bay–Ruvuma Estuary Marine Park and Moheli Marine Park in Comoros. In addition, the organization has been assisting the region to develop MPAs with tool kits for managers and collaborating with the IUCN World Commission on Protected Areas to introduce the concept of assessing management effectiveness.

Currently, IUCN ESARO is implementing the Fair Coasts Initiative on the northeastern Mozambican coast with government ministries and agencies, oil and gas companies, the ecotourism sector and coastal communities to assure equitable and sustainable economic development, biodiversity conservation and community development in the wake of natural gas discoveries. ESARO has also been working with UNEP on a GEF project following the Addressing Land-based Activities in the Western Indian Ocean (WIO-LaB) Project that was executed by the Nairobi Convention secretariat. The first phase of the project produced a Strategic Action Programme, which proposes environmental flow assessment (EFA) as a decision tool to manage rivers in the region. In the second, implementation phase IUCN proposes to mainstream the EFA as a tool for sustainable development for four river basins in Kenya, Mozambique, South Africa and Tanzania. ESARO also supports regional processes and currently chairs the Consortium for the Conservation of Coastal and Marine Ecosystems in the WIO.

[20] The five areas: conservation areas and species diversity; business and biodiversity; landscapes (drylands; forests and climate change); marine and coastal; water and wetlands.

Western Indian Ocean Marine Science Association

WIOMSA was constituted in 1993 as a professional, non-profit, membership organization to develop all aspects of marine sciences that underpin the sustainable use and conservation of marine resources in Comoros, Kenya, Madagascar, Mauritius, Mozambique, Reunion (France), Seychelles, Somalia, South Africa and Tanzania. WIOMSA has a particular interest in using research findings to improve the management and governance of the region's marine and coastal ecosystems. Flagship programmes include the Marine Science for Management Research Grant Programme; the Organization of International and Regional Marine Scientific Symposia and meetings; and joint initiatives to address marine and coastal management issues.

WIOMSA's five-year programme has four key themes: vulnerability, resilience and adaptation; coastal livelihoods; governance for the future; and ecosystem service research. It coordinates research grant programmes from biological to socioeconomic studies; develops regional research agendas; organizes training and professional development initiatives; and feeds science into management, advocacy, networking and the dissemination of technical information.

WIOMSA's membership profile has grown in size and variety with the addition of more social scientists and practitioners to complement its natural scientists. WIOMSA's executive board of trustees comprises eight members of scientific standing who bring regional and international perspective to the governance of the Zanzibar-based association. Membership is open to any professional or institution in the region and beyond with an interest in the coastal and marine environment of the WIO. It works with partners in Mozambique, Tanzania and Kenya and is well placed to support Resilient Coasts, particularly the research component.

Coastal Oceans Research and Development in the Indian Ocean

CORDIO is a regional research-based organization that generates knowledge to counter the problems facing coastal people and marine environments in the WIO. Its genesis was in the 1998 El Niño phenomenon that caused mass bleaching and mortality of Indian Ocean corals. It has offices in Mombasa and Nairobi, Kenya, and a network that extends to Sweden and South Asia.

CORDIO's research and conservation work addresses WIO's rapid population growth in the face of limited resources and threatened habitats. This situation is exacerbated by poor governance and marked divides in education and wealth. CORDIO seeks holistic solutions embracing ecological and social resilience; adaptive capacity; environmental conservation; sustainable resource use; better education, policies and governance; and investment in livelihoods. CORDIO assesses the ecological and socioeconomic impact of climate change and human activity, particularly fishing, and monitors longterm trends

using coastal environmental indicators. Research results and longterm trends are published in its WIO status reports, which also extend to the northern Indian Ocean.

CORDIO's strategic programme (2010–2014) has five objectives.

- Conduct research to sustain and restore healthy and productive coastal and ocean ecosystems.
- Strengthen social and economic assessment and research integrated coastal management, poverty alleviation and sustainable development.
- Foster the integration of science, practice and policy at local, national and regional levels.
- Educate and build the capacity of coastal people to improve their livelihoods and longterm wellbeing.
- Build human and technical capacity and foster networking and partnerships to develop solutions to marine and coastal problems.

CORDIO's education programme targets school teachers, children and adults and facilitates technical training during field-based surveys on coral reefs, fishery monitoring and field identification of corals and fishes. Its partnerships build scientific capacity in the WIO, particularly through supporting postgraduate and intern programmes. CORDIO also encourages alternative and supplementary livelihoods for coastal communities to reduce the fishing offtake of wild stock. Fishers learn how to manage marine resources through adult learning and by using interactive telecommunication tools.

World Wide Fund for Nature

WWF has a mandate to conserve the world's biological diversity through the sustainable use of renewable natural resources and the reduction of pollution and wasteful consumption. Among its 2,000 conservation projects are global marine and coastal initiatives, including a dedicated marine programme, MPAs, sustainable fishing, sustainable resource use and climate change interventions (UNEP 2009a).

The WWF Eastern Africa Regional Programme Office was established in Nairobi, Kenya, in 1986 within the WWF Africa and Madagascar Programme. It has since incorporated southern Africa to become the WWF Eastern and Southern Africa Programme Office (WWF-ESARPO). This office provides project support and local and regional evaluation. WWF-ESARPO's goal is to ensure the conservation of biodiversity is in harmony with the needs and aspirations of local communities through partnerships with different sectors of society.

WWF's East African Marine Ecoregion (EAME) project, based in Dar es Salaam, Tanzania, is concerned with coastal forests in Kenya and Tanzania, threatened marine turtles and climate change. The East African Coastal Forest Programme is likely to be introduced to include all WIO coastal forests.

WWF has partnered with Mozambique, Tanzania and Kenya to create a network of MPAs as part of its WWF Coastal East Africa Initiative. The Rufiji-Mafia-Kilwa (RUMAKI) Seascape Programme in Tanzania is entering its second five-year phase. RUMAKI recognizes the importance of the Rufiji Delta and its mangrove ecosystems, together with the adjacent coast and offshore islands, to the ecology of the entire southern coast of Tanzania. While social resilience and climate change were not the priority in the first phase of the programme, they will be the primary focus of the second phase. Lessons learned will be used in other WWF Seascape Programmes such as Kiunga-Lamu (Kenya), Mtwara-Quirimbas (Tanzania-Mozambique), Primeiras and Segundas Archipelago (Mozambique), and the Zambezi Delta (Mozambique). RUMAKI's integrated approach could provide guidelines for Resilient Coasts.

Consortium for Conservation of Coastal and Marine Ecosystems in the Western Indian Ocean

Since 2006, WIO-C has been fostering synergistic partnerships to advance marine research, conservation and management. It is guided by the Nairobi Convention and is a forum for influencing decision-making that will improve natural resource management. The network shares information and management experiences, mobilizes resources and develops collaborative programmes, particularly those concerning regional and transboundary issues.

The network's founding members are CORDIO, IOC, UNESCO-IOC, IUCN, NEPAD, the Nairobi Convention, Wildlife Conservation Society (WCS), WIOMSA and WWF. It has a revolving secretariat, which is currently with WIOMSA (UNEP 2009a).

Regional fisheries management organizations

RFMOs in the WIO involve Mozambique, Tanzania and Kenya to a greater or lesser degree, depending on the scope of each country's marine fishing activities. Fisheries for tuna and tuna-like fishes are managed by the Indian Ocean Tuna Commission (IOTC). Other shared resources (small pelagics, demersal fish, crustaceans, molluscs) are managed by the Southwest Indian Ocean Fisheries Commission (SWIOFC) or the Southern Indian Ocean Fisheries Agreement. All WIO countries are SWIOFC members, but only Kenya, Madagascar, Mauritius, Seychelles and Tanzania are members of the IOTC. South Africa is a 'cooperating non-contracting party' to the IOTC.

With the adoption of the Ecosystem Approaches to Fisheries, issues are no longer discussed in isolation from the environment. This has opened the way for collaboration with other environmental initiatives. A memorandum of understanding is being developed between SWIOFC and the Nairobi Convention.

Table 5.1: Priority adaptation sectors in national climate change strategies and plans.

Country strategy	Sectors
Mozambique National Adaptation Programme of Action	Early warning system, agriculture, coastal zones, water resources
Tanzania National Climate Change Strategy	Agriculture, water, energy, forestry, health, wildlife, tourism, industry, coastal and marine resources, human settlements, wetlands
Kenya National Climate Change Response Strategy (2010)	Agriculture, horticulture, food security, livestock and pastoralism, water, health, forestry, energy, rangelands, wildlife and tourism, social infrastructure and human settlements, physical infrastructure, fisheries, coastal and marine ecosystems

Regional governance structures have been developed by international institutions such as the World Bank, which implemented the South West Indian Ocean Fisheries Project (SWIOFP), and FAO, which administers RFMOs and commissions such as the SWIOFC. The industrial marine fisheries sector enjoys the best governance because of the formalized fishing activities by the fleets of long-distance fishing nations from the EU and Asia operating in the WIO. Offshore fisheries for large pelagic and other species would probably be beyond the scope of Resilient Coasts, which concentrates more on coastal areas. However, several of the fisheries that come under the regional fisheries programmes and the SWIOFC operate in coastal waters.

Regional and national governance frameworks

Mozambique and Tanzania have a central government while Kenya has a devolved system that is enshrined in a new constitution promulgated in 2010. Legal and policy issues for all three countries revolve around whether there are environmental provisions in the constitution, a framework environmental act, including environmental assessment provisions, and at least a policy promoting the notion of integrated coastal area management.

Recent assessments of national adaptation activities regarding climate change show that the environment has been neglected in favour of agriculture, water resources, health and energy. Although most country strategies and plans include fisheries and coastal zones, there have been relatively few adaptation initiatives specific to these sectors (see Table 5.1).

The region's disparate and diverse capacity to address environmental challenges provides opportunities for further regional collaboration through Resilient Coasts. Two references provide an overview of climate change preparedness in the region (WIOMSA 2011; ABCG 2012).

Several regional initiatives exist that have a governance component and are therefore relevant to Resilient Coasts. Between 2005 and 2013, the countries of the WIO have been implementing three regional GEF/World Bank–funded projects. These were: WIO-LaB, SWIOFP and ASCLME. While WIO-LaB ended in 2010, the other two were completed in 2013. Preparations for follow-up projects for all of these initiatives have been ongoing since 2013.

The follow-up project for the WIO-LaB project is known as Implementation of the Strategic Action Programme for the Protection of the WIO from Land-based Sources and Activities (WIO-SAP) and for the ASCLME project, the WIO Large Marine Ecosystems Strategic Action Programme Policy Harmonization and Institutional Reform (SAPPHIRE). WIO-SAP and SAPPHIRE will be implementing some of the aspects of the Strategic Action Programme for the Protection of the Coastal and Marine Environment of the WIO-SAP and the Strategic Action Programme for Large Marine Ecosystems, respectively. The concepts for these two projects were approved by the GEF Council in 2013. The WIO-SAP is developed under the guidance of the UNEP International Waters Unit and the Nairobi Convention, while UNDP has coordinated the preparation of full proposal for SAPPHIRE.

The third project is the South West Indian Ocean Fisheries Governance and Growth Project (SWIOFish1), whose preparation is being coordinated by the World Bank and the SWIOFC. SWIOFish1 is a proposed six-year regional project supporting regional integration around fisheries management, and aiming at improving the management effectiveness of selected priority fisheries at regional, national and community levels. It is expected that these projects will be implemented towards the end of 2014 or at the beginning of 2015.

Under the auspices of UNESCO-IOC, the IOC Regional Committee for the WIO is facilitating autonomous initiatives to develop management capacity in the region. Under this initiative Kenya, coordinated by the Kenya Meteorological Department, is looking at rising sea levels and flooding in Malindi, and coordinated by KMFRI, at fisheries habitats in Shimoni. Tanzania has a project on Zanzibar coastal erosion, coordinated by the Institute of Marine Sciences. Mozambique has a project on the impacts of dredging and associated sediments run jointly through the Bon Sinais School of Marine and Coastal Sciences at Eduard Mondlane University and the National Institute of Hydrography and Navigation in Beira.

Table 5.2: Pilot projects for priorities defined in Mozambique's National Adaptation Programme of Action.

Project	Type	Focus	Donor	Implementing agency
Disaster risk management and efficient early warning system	Resilience	Capacity building and institutional strengthening	BMZ	INGC
Sustainable management and use of forests	Resilience	Capacity building of local communities	Finland	—
Adaptation to drought and to climate change	Coping	Capacity building, policy formulation and field implementation	SCCF	UNEP
Mainstream adaptation to climate change in disaster risk management of the Buzi River watershed	Resilience	Policy formulation and capacity building including an early warning system for thunderstorms and floods	BMZ	UNDP
Adaptation in coastal areas	Coping and resilience	Capacity building of communities living in coastal zones, to manage the risks associated with climate change	LDCF	UNDP
Support to adaptation to climate change	Coping	Capacity building	USAID	Mozambique government
Mainstream adaptation of the environment and adaptation to climate change	Resilience	Policy formulation and integration, capacity building, diversification of sources of revenues	Spain MDG Achievement Fund	UNDP

Source: ABCG 2012

BMZ Federal Ministry for Economic Cooperation and Development (Germany)
INGC National Institute of Disaster Management
LDCF Least Developed Countries Fund (UN)
MDG Millennium Development Goals
SCCF Special Climate Change Fund
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
USAID United States Agency for International Development

Mozambique

Legal and policy frameworks

Article 90 of the constitution establishes the right to live in a balanced environment and invests the state, local authorities and environmental associations with responsibility for its care and protection (Mazivila 2009).

Colonial-era legal instruments are gradually being replaced, but much has yet to be done.

Mozambique has a number of legal instruments on environmental protection, but enforcement and compliance are weak (UNEP 2009b).

Portugal enacted the Decree Law no. 495 (1973) to protect coastal and marine environments in its then overseas provinces, which included Mozambique. It prohibits, except by special licence, the disposal of pollutants in areas under the jurisdiction of the maritime authority.

The Environment Law (1997) defines the legal basis for sustainable management of the environment by public and private sectors. It does not include specific provisions for coastal and marine environmental protection, but it is an instrument for enacting relevant regulations.

The Sea Law (1996) sanctions conservation of marine areas and species by creating marine national parks, marine nature reserves and marine protected areas. It is consistent with the International Convention on the Law of the Sea (1982), which Mozambique has ratified. It has far greater regulatory competence than the Environment Law to protect and preserve the maritime and coastal environment (Mazivila 2009).

The National Strategy for Sustainable Development derives from the 2002 World Summit for Sustainable Development and integrates recommendations from the Johannesburg Plan of Implementation into the national agenda. It is an important national initiative rooted in local knowledge, local ideas, local expertise and local solutions. The priority areas are biodiversity conservation, land degradation, health, education, agriculture, water, energy and technology transfer. The National Council for Sustainable Development and the Council of Ministers are responsible for its implementation. Once approved, it will be incorporated into all sectoral plans (Mazivila 2009).

The National Environmental Policy is the principal planning instrument for the environment sector. It calls on the state to provide incentives for the sustainable use of natural resources (Mazivila 2009). It integrates

environmental issues into economic planning, recognizes the role of the communities in environmental management and monitoring, and acknowledges a role for the private sector in managing the environment. It also defines the strategy that provides the framework for the Ministry for Coordination of Environmental Affairs (MICOA) and recommends multisectoral coordination (Mazivila 2009).

The Strategic Plan for the Environmental Sector (2005–2015) combines the Action Plan for the Fight against Drought and Desertification, the Strategy for Urban Environment Management, the Coastal Zone Management Strategy, the Strategy and Action Plan Controlling the Fight against Soil Erosion, the Strategy to Combat Deforestation and Burning, the Urban Solid Wastes Integrated Management Strategy, the Hazardous Wastes Management Strategy, the Biodiversity Strategy, and the Action Plan for Biodiversity Conservation (Mazivila 2009). Its priority areas are biodiversity conservation, land degradation, health, education, agriculture, water, energy and technology transfer.

Policy instruments relevant to environmental management (not restricted to coastal areas) are the National Action Plan to Combat Desertification and Drought; the National Forests and Wildlife Policy and Strategy; the National Tourism Policy and Strategy; the National Fisheries Policy; the National Land Policy; the Agrarian Policy; the National Water Policy; and the Strategy and Action Plan for Biodiversity Conservation in Mozambique (Mazivila 2009). Others are the Energy Policy and Strategy (1998); the National Environmental Policy (1995); the Policy for Disaster Management (1999); the National Policy for Land Use Planning (1996); the Policy (1996) and Strategy (2006) for Meteorology Development; the Conservation Policy and Implementation Strategy (2009); and the National Action Programme for Adaption to Climate Change. Activities under the last are illustrated in Table 5.2.

National institutions

A temporary committee was constituted by prime ministerial decree in 1995 to propose a regulatory system to harmonize marine-related legislation. It marked the beginnings of an institutional framework for preserving the marine and coastal environment. Since then other bodies have been established to govern the marine and coastal environment. The principal public bodies constituting the institutional framework are:

- Ministry of Coordination of Environmental Affairs
- National Directorate of Environmental Management
- National Directorate of Environmental Impact Evaluation
- National Directorate of Territorial Planning
- Centre for Sustainable Development of Coastal Zones
- Centre for Sustainable Development of Urban Zones
- Centre for Sustainable Development of Natural Resources
- National Institute of Hydrography and Navigation

A 1995 presidential decree vested MICOA with the authority to oversee national policy, planning and natural resources. MICOA's functions are coordination, advice, control and evaluation. It is the decision-making body for environmental impact studies and the technical quality of environmental impact evaluation; matters relating to environmental auditing; proposals for sustainable development policies; and incentives for best practices. MICOA includes the National Directorate for Environmental Management, the National Directorate for Territorial Planning and the Sustainable Development Centre. This centre coordinates research and offers advisory services and technical training. Its pilot projects inform policy and legislation on coastal management, marine environments and lake shores. The Research Centre for Marine and Coastal Environment, which also comes under MICOA, conducts applied scientific research on marine and coastal ecosystems. MICOA interacts with various sectors (maritime administration, fisheries, mining, agriculture and forests) and the following ministries:

- Ministry of Fisheries
- Ministry of Tourism—National Administration of Conservation Areas
- Ministry of Public Works and Housing—National Directorate of Water and Regional Administration of Water
- Ministry of Mineral Resources
- Ministry of State Affairs—National Institute for Disaster Management

National and international civil society organizations, research institutes and extractive industries

National CSOs involved with the coastal and marine environment include Associacao dos Naturais e Amigos da Ilha da Inhaca (UNEP 2009a); Centro Terra Viva; Christian Council of Mozambique; Community Development Foundation; Kulima; Association for Community Development; Mozambican Association of Women in Legal Careers; National Union of Peasants; Endangered Wildlife Trust; and Rural Organization for Mutual Assistance.

A number of platforms act as national and provincial umbrella organizations for civil society: the Christian Council of Mozambique; Land Forum; Association of Women in Legal Careers; Community Information and Communication Support Centre; Civil Society Platform on Climate Change; and Civil Society Platform for Natural Resources and Extractive Industries. The Civil Society Thematic Group on Natural Resources and Sustainable Development operates in Cabo Delgado Province.

International NGOs with a presence in Mozambique include the Aga Khan Foundation; CARE International; FHI 360; Helvetas Mozambique; Oxfam Belgium; WWF; Save the Children; and SNV.

Academic and research institutes active in the marine and coastal environment include Eduardo Mondlane University School of Marine and Coastal Science; Research Centre for the Marine and Coastal Environment; and the Unilurio Catholic University of Mozambique.

Private companies in the extractive sector, such as the US-based Anadarko Petroleum Corporation and Norway's Statoil, are engaged in oil and natural gas exploration and production and should be included as partners in Resilient Coasts.

Marine and coastal environment projects and programmes

The Management Committee for Natural Resources in Nhangau, Sofala Province, has been restoring mangroves damaged by severe weather since 2004. It is supported by Sofala's Provincial Directorate for Environmental Coordination, the Local Economic Development Agency and the Provincial Directorate of Agriculture and Provincial Services of Forest and Wildlife. The Primeiras and Segundas programme in Nampula and Zambézia Provinces, implemented by the CARE-WWF alliance, works with government and other partners to develop a marine and coastal protected area that furthers biodiversity and social development and assists communities in their role as co-managers. The programme has a rights component that covers the acquisition of land title, civic rights education, and building legal community institutional frameworks. The programme fosters community resilience through agricultural methods to counter climate change and by improving fishing and other livelihoods. WWF has a Reducing Emissions from Deforestation and Forest Degradation programme in Quirimbas National Park, Cabo Delgado Province, and has other initiatives in mangrove and fisheries management elsewhere. Environmental issues have been included in school curricula in Cabo Delgado Province.

The GEF Small Grants Programme is implemented by UNDP for the GEF. In 2012, the GEF implemented 19 programmes in Cabo Delgado, Gaza, Inhambane, Manica, Maputo, Nampula, Sofala and Zambezia Provinces in climate change, land degradation, biodiversity, international waters and persistent organic pollutants (POPs).

A project on adaptation in Mozambique's coastal zones, started in 2012, is being implemented by MICOA's National Directorate of Environmental Management in collaboration with UNDP with government and GEF support. MICOA has also commissioned the Strategic Environmental Assessment for Development along the Coastal Zone of Mozambique. The draft report is available at www.impacto.co.mz/PDFs/Vol1.pdf.

Tanzania

Legal and policy frameworks

Tanzanian environmental legislation is complex. Tanganyika (now mainland Tanzania) and Zanzibar (the islands of Pemba and Unguja) united to become one country in 1964. Tanzania's subsequent constitution distinguishes between union and non-union matters. The environment is a non-union matter resulting in separate legislation and administrative authorities governing environmental issues and marine fisheries for mainland Tanzania and Zanzibar. An exception is the Deep Sea Fishing Authority Act (1998), which is a union matter and is common to both. To further complicate matters, the Tanzanian administration is decentralizing, vesting district councils with greater authority.

The constitution does not have explicit provisions on environmental protection and management. However, there are comprehensive legal and institutional frameworks for coastal and marine environments. Despite this, environmental legislation, which is sector based, tends to overlap and conflict. Neither is it a homogeneous system as it comprises diverse rules of administrative law, constitutional law, law of torts and criminal law. This dilutes the legal protection for coastal and marine environments (UNEP 2009b). Tanzania's customary law is often at odds with its statutory law and is diminishing in importance as the body of written law expands to cover areas hitherto under customary laws and practice (Mgaya and Juma 2001).

The Environmental Management Act (EMA) (2004), which applies to the sustainable management of the environment in mainland Tanzania, overrides other environmental laws.

Zanzibar's Environmental Management for Sustainable Development Act (1996) is an equivalent law governing international obligations, stakeholder participation, institutional arrangements, environmental impact assessments and dispute resolution.

Other laws are scattered across various sectors (Mgaya and Juma 2001). Tourism legislation—the Hotels Ordinance (1963) and the Tourist Agents Licensing Act (1969)—encourages development. This has tended to stress coastal habitats.

Forests are governed by the Forest Ordinance Chapter 389 (1957) as amended variously in 1964, 1979 and 1991, and the Tanzania Forestry Research Institute Act (1980).

Mining and extraction legislation includes the Petroleum (Exploration and Production) Act (1980), the Mining Act (1998), and the Mining (Environmental Management and Protection) Regulations (1999). This last covers sand mining and extraction, a common activity in Tanzania's coastal and marine environment (Mgaya and Juma 2001).

Key legislation governing fisheries includes the Fisheries Act (2003), the Tanzania Fisheries Research Institute Act (1980), the Marine Parks and Reserves Act (1994), and the Deep Sea Fishing Authority Act (1997). Legislation relating to lands and urban development includes the Land Ordinance (1923), the Town and Country Planning Ordinance (1996) Cap 378, the National Land-use Planning Commission Act (1999), and the Village Lands Act (1999).

In the wildlife sector the National Parks Ordinance (1959) and the Wildlife Conservation Act (1974) are important.

The industrial sector has the National Industries Licensing and Registration Act (1967) and the Merchant Shipping Act (1967).

The National Environment Policy (1997) provides the framework for introducing environmental considerations into the mainstream of decision-making. It stresses the importance of formulating legislation for effective and comprehensive environmental management. Its objectives are:

- to achieve sustainability, security and equitable resource use to meet the needs of present and future generations without degrading the environment or risking health and safety
- to prevent and control the degradation of land, water, vegetation and air to conserve and enhance natural and manmade heritage, including the biological diversity of unique ecosystems
- to improve the condition and productivity of degraded areas, including rural and urban settlements
- to raise public understanding and community participation in the connection between environment and development
- to promote international cooperation on the environmental agenda

Other policies and instruments guiding environmental management are the National Forest Policy (1998); the Forest Action Plan (1990/91–2007/08); the Management Plan for the Mangrove Ecosystem in Tanzania (1991); the Agricultural and Livestock Policy (1997); the National Tourism Policy (1991) (reviewed 1996); and the Integrated Tourism Master Plan (1996–2005). Others are the National Fisheries Sector Policy (1997), the Draft Investment and EIA Guidelines for Marine Parks and Reserves in Tanzania and the Draft Mariculture Development Guidelines; the National Land Policy (1995); town and city master plans; district and village land-use plans; the Wildlife Policy of Tanzania (1998); the Sustainable Industrial Development Policy (1996); and the ICZM Policy.

The National Higher Education Policy (1999) emphasizes basic sciences, including environmental science. The national curriculum includes the study and prediction of climatic and global change as a result of human activity on the environment; environmental pollution including water and air pollution with the disposal of toxic and radioactive wastes; disaster management; energy conservation; environmental conservation and enrichment; the effects of chemicals, drugs, pharmaceuticals and fertilizers on the environment; and biodiversity and genetic engineering.

ICZM policy and regulatory instruments include the National Integrated Coastal Environment Management Strategy; the National Steering Committee on Integrated Coastal Management; the Integrated Coastal Management Unit; intersectoral working groups; the development of a climate change adaptation strategy; and several ICZM projects. In Zanzibar, the National Environmental Policy (1992) outlines the conservation and protection of environmental resources and an ICZM plan (even though there is no specific ICZM legislation).

The government has begun to involve communities in the policy, legislation, regulation and management of coastal and marine resources. This is tacit acknowledgement of the limitations of the methods of government managing authorities, which tend to be punitive rather than participatory. Most of the policy initiatives to address management challenges, which are funded by development agencies and international organizations, operate on the principle of co-management and ICZM.

National institutions

National institutions for the mainland and for Zanzibar have been vested with environmental oversight authority by various pieces of legislation. However, the uncoordinated and overlapping jurisdiction of these avenues of enforcement impedes effective management (Mgaya and Juma 2001).

The Division of Environment in the Office of the Vice President is responsible for research[21], policy, planning, monitoring and coordinating broad-based environmental programmes and projects. It also oversees civil society participation in environmental activities. Its location in the Office of the Vice President affords it easy access to interministerial cooperation and goodwill as evidenced in the National Environment Policy and the National Environmental Action Plan.

The National Environmental Advisory Committee advises the Minister for State for Environment. The director of Environment is responsible for the terrestrial environment and pursues the integration of environmental considerations in development policies, plans, programmes, strategies and projects.

The National Environment Management Council (NEMC) serves as an advisory think tank to the government and conducts a number of activities aligned to the UN's Agenda 21. These include pollution prevention and control; environmental education and public awareness; and natural resource conservation and management. NEMC has sponsored the preparation of the national marine contingency plan; the inventory of activities destructive to the aquatic environment; a wetlands inventory and management strategy; an inventory of projects related to natural resources; environmental impact assessment reviews; and an assessment of community participation in natural-resource management.

[21] Includes publishing the National State of Environment Report every four years

Every ministry is required to have an environment section responsible for ensuring EMA compliance. This attempt at an integrated approach is confounded by the fact that the different bodies are subject to different laws and instruments. Local government authorities are subject to the local government legislation. District and urban authorities have been vested with the power to control local pollution in rivers, streams, water courses, wells and other sources of water supply. Yet other regulatory institutions have similar functions under different laws. Fortunately the law provides the opportunity for every institution to perform its functions in cooperation or in conjunction with others, but the law does not put this cooperation as a condition.

The Tanzania Forest Services (TFS) comes under the Ministry of Natural Resources and Tourism. It is responsible for managing and conserving national forest resources, including reserves (natural and plantation), bee reserves and forests on public lands. TFS was established in 2011 to take over from the Forest and Beekeeping Division although this division is still responsible for developing, reviewing and overseeing the implementation of forest policy, laws and regulations.

The TFS mandate extends to coastal forests, including the restoration of degraded mangroves. TSF partners with WWF in the RUMAKI Project that supports village natural resource committees in the Rufiji District. The TFS budget is limited and does not extend to programmes for mangrove management, but the allocation per hectare for mangroves is comparatively higher than for all other forest types. There are mangrove forest officers in every district containing mangroves. This notwithstanding, TFS does not have sufficient human and financial resources to counter the increasing pressure on coastal forests, political apathy and sectoral conflicts (e.g. the Ministry of Housing and Settlements issuing title deeds for land in protected areas).

The Marine Parks and Reserves Authority (MPRA) was constituted under the Marine Parks and Reserves Act (1994). Its board of trustees oversees its administration to safeguard marine resources through sustainable use. MPRA recognizes the significance of coastal habitats, including mangroves, as fish nurseries, bird areas and barriers against flooding. One of its tenets is the importance of creating resilience in threatened habitats by helping local communities to manage their natural resources. MPRA works with TFS mangrove forest officers.

No budgetary resources are allocated to sustainable coastal development and management, but about 5% of the annual MPRA budget is allocated to mangrove forests. MPRA has collaborated on mangrove restoration with WWF and other organizations. Projects have included the development of village environmental management plans, the conservation of sea turtles and mangrove reafforestation in Mtwara. MPRA faces a number of challenges such as capacity gaps within the organization; poor access to technical knowledge on emerging threats (e.g. the effect of pesticides on mangrove habitats); and generally poor awareness of the importance of conserving coastal habitats and ecosystems.

Several institutions in Zanzibar have been constituted under the EMA. The Special Committee of the Revolutionary Council on the Environment, headed by the chief minister, oversees environmental matters. The Department of Environment is the administrative arm and coordinates policy with the EIA–Natural Resource Management section within the ministry, which mobilizes community participation in mangrove restoration. The Climate Change and Environmental Governance Project (2012–2016) also comes under the Department of Environment. It is developing a communications strategy and National Action Plan on Climate Change, which calls for mangrove restoration as a response to sea-related disasters. A Zanzibar steering committee on integrated coastal management is supported by district committees and community groups. The National Environmental Fund for Sustainable Development has been established to support these efforts at a local level.

National civil society organizations

- The Centre for Energy, Environment, Science and Technology in Dar es Salaam conducts research on energy, issues concerning environmental science and technology, and the use and management of natural resources.
- The Economic and Social Research Foundation in Dar es Salaam conducts research on economic, social and development issues.
- Policy Research in Dar es Salaam conducts research on the informal sector, employment trends, poverty alleviation, and environment and development trends.
- The Tanzania Coastal Management Partnership is a group of professionals who work on safeguarding the longterm future of coasts. It has two coastal management projects, both of which came to an end in 2013. The Pwani Project looks at protecting critical marine ecosystems and endangered species, and the human dimensions of coastal ecosystems as in climate change adaptation, economic growth, and HIV and AIDS. It involves women in managing intertidal areas and adapting to climate change and trains them to be decision-makers. The second project integrates cross-sectoral issues into integrated coastal management. The partnership was established in 1997 by NEMC with USAID and the Coastal Resources Center of the University of Rhode Island. Additional funding is currently being sought to continue the work of the partnership.

Marine and coastal environment projects and programmes

Kinondoni Integrated Coastal Area Management Project's comprehensive plan for land-and-water resources management in coastal areas resulted in a ban on sand excavation where beach erosion was critical. Households are educated in the value of mangroves and involved in their protection which has increased mangrove cover.

The Sustainable Coastal Communities and Ecosystems Project, funded by USAID and implemented by Rhode Island and Hawaii Hilo Universities, builds the adaptive capacity and resilience of vulnerable coastal communities. Its 'raft culture' techniques to grow seaweed in deeper water have transformed seaweed cultivation into a year-round income-generating activity.

The government Community Infrastructural Upgrading Programme improves physical infrastructure such as storm water drainage networks and strengthens the capacity of communities, particularly in unplanned settlements.

IUCN had a presence in Rufiji District from 1998 to 2011. It implemented the Rufiji Environment Management Project to safeguard the biodiversity of forests, woodlands and wetlands and to balance renewable natural-resource use against profitable livelihoods. The plan is partly based on component village environmental management plans within four pilot villages, each with unique physiographic characteristics. These plans were drawn up by the villagers with help from the project managers. The project was closed in 2003, but IUCN continued with two other projects in building community capacity to handle resource management: Strengthening Voices for Better Choices (2007–2010); and Livelihood and Landscape Strategy (2008–2011).

In 2013 the Tanzania Coastal Management Partnership with the Coastal Resources Centre and USAID held a workshop on a Coastal Climate Change National Action Plan to discuss how to integrate climate-change activities into coastal planning and management.

Tanzania is a beneficiary of the World Bank–funded SWIOFish1 Project. It is under preparation (scheduled for 2014 to 2018) and is likely to have some important synergies with Resilient Coasts both on the Tanzanian mainland and in Zanzibar.

Kenya

Legal and policy frameworks

The constitution of Kenya 2010 reinforces the importance of natural resources and the environment. Chapter 5, Environment and Natural Resources, contains principles and obligations on the environment; protection and conservation of the environment; enforcement of environmental rights; the use and development of natural resources; agreements relating to natural resources; and environmental legislation. The constitution also provides for the establishment of an environment and land court to address legal disputes related to environmental and land resources and processes.

Kenya's newly devolved system of government calls for collaboration between national and county administrations. The central government has jurisdiction over the use of international waters and water resources, marine navigation, and the protection of the environment and natural resources including fishing and water. The county government is responsible for fisheries and implementing national policies.

Legislation relevant to the marine environment is substantive (nearly 50 pieces of legislation) but confusing. The framework involves at least 14 government ministries and a further 9 authorities. Duplication, omission and poor implementation dilute regulatory effectiveness. Environmental threats to coastal areas are largely a direct result of poor environmental governance caused by:

- failure of government institutions to manage ecosystems for their health rather than maximum yield or production
- management and policy failure to transcend departmental and political boundaries
- sectoral approach to natural resource management
- insufficient legal redress and inconsistencies in historical land tenure systems (Samoilys et al. 2011c).

The National Biodiversity Strategy and Action Plan (2000) harmonizes the fragmented and multiple laws on environment across different sectors. However, its marine and coastal aspects are rarely referred to. It is likely that few coastal people are aware of its existence. Co-management with communities has also become the norm in many of the newer policies and regulations although few communities are aware of their rights (Samoilys et al. 2011c).

The Environmental Management and Coordination Act (EMCA) (1999) provides the legal and institutional framework for managing and protecting Kenya's environment. It is being reviewed to align it to the 2010 constitution. Its effectiveness is impaired by poor judicial understanding of its requirements, weak enforcement, corruption and bureaucracy. Moreover, the Kenya Forest Service (KFS), KWS, and National Museums of Kenya also have jurisdiction over mangroves, which leads to confusion in enforcement and management (Samoilys et al. 2011c).

The EMCA can declare any area of the sea to be a protected coastal zone. The National Environment Council, established by Section 4(1) of the EMCA, undertakes policy formulation and provides direction for the purposes of the EMCA. The National Environment Management Authority (NEMA) was established under the act to implement policy. It became operational in 2002. Section 55 mandates NEMA, in consultation with the relevant agencies, to prepare a survey of the coastal zone and an ICZM policy to encourage effective methods for managing and protecting the marine and coastal environment and its river basins and estuaries. The EMCA imposes stringent penalties for pollution and hazardous-waste dumping. Prosecutions are rare, and regulations envisaged under Section 55(6) for the prevention, reduction and control of pollution have yet to be issued.

The provisions of Section 55(7) relate directly to Kenya's obligations under UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. It mandates the minister to issue regulations to control pollution in rivers and estuaries from pipeline and outfall structures in vessels, aircraft and other engines used in the coastal zones.

The Environmental Impact Assessment and Audit Regulations (2003) require the inclusion of environmental management plans in all EIA reports. NEMA should be more rigorous in monitoring frequently sketchy follow-up. Strict implementation of the provisions of the Physical Planning Act (1996) would help to protect the coast's physical environment and to sustain tourism and other socioeconomic activities.

The County Government Act of 2012 provides for the integration of economic, physical, social, environmental and spatial planning in the county planning framework. The national spatial development framework must also include a strategic assessment of the environmental impact of development, and public service delivery should ensure environmental sustainability.

The Public Health Act (1986, revised 2012) Cap 242 has jurisdiction over public health management.

The Wildlife Conservation and Management Act (2013) broadly provides for the protection of vulnerable ecosystems along the coastal zone through MPAs managed by KWS. This act focuses on terrestrial wildlife resources, and an act for marine living resources is recommended. Legislation regulating seashores and imposing penalties for dumping and pollution is also needed.

The Forest Act (2005) is a substantial improvement on preceding legislation. It established KFS and encourages private-sector and community participation in the management of forests. Mangrove areas and coastal forests, including *kaya* forests, are recognized as areas requiring better management. Community forest associations, enshrined in the act, engage with the government on sustainable management. The act prohibits dumping waste in mangrove forests. Previous studies have shown a severe loss of vegetation and reduced fish populations from sewage sludge, oil spills and other urban waste (UNEP 2009b).

The Kenya Maritime Authority Act (2006) is reinforced by the Merchant Shipping Act (2009) and any other legislation relating to the maritime sector. It established the Kenya Maritime Authority, which advises the government on legislative and other measures for implementing international conventions, protocols and agreements. It also safeguards the marine environment from pollution and responds to marine environment incidents.

The Coast Development Authority Act (1990) established the Coast Development Authority to coordinate development projects in the coastal zone and in the EEZ. It covers most of the upstream areas connected with land-based sources and activities.

The Water Act (2002) gives the minister powers to gazette catchment areas as protected areas. It outlaws actions that degrade the quality of water in rivers. Untreated sewage and wastewater discharged into the sea is one of the principal sources of pollution in the coastal zone. NEMA has recently gazetted wastewater regulations.

The Agriculture Act (1963) Cap 318 oversees degradation of the coastal zone by POPs and fertilizers. The Fertilizers and Animal Foodstuffs (Amendment) Bill (2013) will regulate the use of POPs. The Public Health Act (1986, revised 2012) Cap 242; the Pharmacy and Poisons Act (1957) Cap 244; and the Narcotic Drugs and Psychotropic Substance Control Act (1994) need to be amended to provide for the reduction and elimination of POPs containing dioxins, furans, hexaclorobenzene, and polycyclic aromatic hydrocarbons.

The Mining Act (1940) prohibits the discharge of poisonous substances into waterways and recognizes the effect of mining on the seabed and Kenya's EEZ. The Mining Bill (2012), once enacted, will replace the existing legislation. The EMCA and the EIA and Audit Regulations regulate mining activities along the coast. However, they have not been enforced with sufficient rigor for the mining of salt and limestone, which could cause permanent damage to the physical environment.

The Merchant Shipping Act (2009), which repealed the Lakes and Rivers Act (1930), prohibits marine pollution, ensures security and protects marine environments. Under Section 410, the act regulates marine pollution by drawing from various international maritime conventions and agreements.

The Science, Technology and Innovation Act (2013) established KMFRI to conduct aquatic research in Kenyan waters and riparian areas including the EEZ but does not specify the scope and field of research.

Kenya has enacted land laws aligned with the Constitution of Kenya 2010 to regulate the use of land resources, including tenure, user rights and alienation. Even so, unsustainable coastal development continues, often with impunity, due to corruption and lack of enforcement (Samoilys et al. 2011c).

Policy instruments

The Draft National Environment Policy (2012) aligns sectoral policy with the EMCA. It is a framework for integrating environmental considerations into sectoral policies, development plans and decision-making processes and for regional and international cooperation in environmental management. It calls for sustainable management of terrestrial and aquatic resources to raise the livelihoods and standard of living for coastal communities.

The National Oceans and Fisheries Policy (2008) is rooted in the provisions of the Convention on the Law of the Sea (1982), the Maritime Zones Act (1989) Section 5 and the Presidential Proclamation of June 2005. It affirms Kenya's sovereignty over the exploration, exploitation, conservation and management of ocean resources. It focuses on resource management in territorial waters and the EEZ. It addresses most aspects of fisheries management and development, including environmental conservation, regional cooperation, research, surveillance and monitoring, social responsibility and governance. The preparation of specific fishery management plans is given

high priority, but certain regulations need to be adapted to allow for these plans to be effective (Samoilys et al. 2011c). This policy and the ICZM Action Plan have similar objectives and should be harmonized to avoid duplication.

The Draft Wetland Policy (2009) recognizes the economic importance of coastal, marine and inland wetlands and proposes stringent measures to counter the (primarily human) threat to their longterm sustainability. Its integrated approach complements other sector policies and fulfils Kenya's obligations under the Ramsar Convention and other multilateral environmental agreements and protocols. Education on the importance of wetlands, a greater consultative process with civil society and political good should pave the way for adoption of this policy.

No clear legal framework governs wetland conservation and management. Different aspects are handled by KWS, KFS, NEMA, the Fisheries Department, water sector institutions, regional development authorities and communities (Samoilys et al. 2011c).

The National Land Policy (2009) underpins a system of land administration and management that allows all citizens to gain access to land and to use it. It calls for the equitable and environmentally sustainable use of land resources and requires policies, regulations and laws to be aligned with the EMCA. Its guidelines for formulating land use and management practices take into account the fragile nature of the coastal zone. As land use has major implications for the coastal and marine environment, reform in land tenure is imperative for achieving the ICZM Action Plan's objectives.

The Regional Development Authorities Policy (2007) calls for equitable socioeconomic development through the sustainable use of natural resources by:

- formulating integrated regional development plans in consultation with all those involved
- closing gaps in regional resource mapping
- attracting resource-based investment that benefit communities

The policy is the framework for streamlining and strengthening the Coast Development Authority (CDA) and the Tana and Athi Rivers Development Authority in coastal zone development and management. However, equitable allocation of government funds to socioeconomic development under the Ministry of Regional Development Authorities is questionable, particularly in the case of marine fisheries. An assessment of the immediate development needs of marine fisheries is called for (Samoilys et al. 2011c).

Poverty-reduction policies and strategies

The government acknowledges the role that environment plays in spurring economic growth and reducing poverty in the National Poverty Reduction Plan (1999–2015); the Poverty Reduction Strategy Paper launched in 2001; and Kenya's Vision 2030, which cites environmental degradation as a cause of poverty and argues for environmental protection. The Draft Forest Policy (2012) calls for the sustainable use, conservation and management of forests and trees; sustainable land use through soil, water and biodiversity conservation; the participation of the private sector, communities and others in forest management to conserve water catchment areas and create employment; farm forestry to produce timber, wood fuel and other forest products; and dryland forestry to produce wood fuel, wood and non-wood forest products. It calls for forest extension services for farmers and forest research, training and education as well.

Integrated Coastal Zone Management Policy

The numerous statutes relating to the conservation of the coastal zone can result in duplication, overlap, inconsistency and ineffectual penalties. Although the EMCA prevails in cases where sectoral policies conflict, its effective implementation requires that statutes and substantial financial and technical support be harmonized. There are still no clear government policy guidelines for managing mangroves. Mangrove cutters must be licensed, but their numbers are not controlled.

The ICZM Policy brings together all those involved in the development, management and use of the coastal zone within a framework that facilitates the coordination and integration of activities and decision-making processes. The ICZM Action Plan (2010–2014) is a first for Kenya as it protects fragile ecosystems while pursuing sustainable development. Its thematic areas are integrated planning and coordination; sustainable economic development; conservation of coastal and marine environment; environmental risks and management of shoreline change; capacity building, information and public participation; and implementation through institutional and legal frameworks.

Community legislation

Marine waters are state-owned public property, and private ownership or leasing is not permitted (D. Murage, discussion on MCA projects in East Africa, pers. comm. 27 July 2010). Historically, the government has founded and managed MPAs with scant stakeholder engagement, but the Fisheries (Beach Management Unit) Regulations (2006) support co-management. BMUs allow fishers to manage

their landing sites and in so doing conserve the biodiversity and livelihood of coastal communities. There are presently 33 BMUs along the Kenyan coast (Cinner et al. 2009).

Management plans for community conservation areas are central to the success of the Darwin Initiative Project that the East African Wildlife Society Marine Programme has implemented since 2009. It combines improved livelihoods with the conservation of marine resources to reduce pressure on the ecosystem. Marine and land-based alternative livelihood opportunities have increased in Shimoni, Majoreni and Vanga through a network of six community-conserved areas. This improvement is partly attributable to the BMU regulations, which allow the fish traders, boat owners, fish processors and other beach stakeholders, who traditionally depend on fisheries activities for their livelihoods, to organize sustainable beach management.[22]

Kenya is not well positioned to implement marine conservation agreements due to several sizeable legislative gaps and the lax enforcement of existing legislation. The implications for managing Kenya's marine environment are unclear. Should more favourable legislation be enacted, WWF is well placed to be an implementation partner. It has been running a community project at the Kiunga Marine National Reserve since the mid-1990s (Obura 2001). In the event of BMUs gaining more autonomy as devolution takes hold, the WCS would be another valuable partner.

The Forests Act (2005) legislates for community involvement in forest management. Kenya's 10 forest conservancies have community representation on the forest conservation committees. However, there is no national mangrove harvesting plan, a concept that is still new to coastal communities (Samoilys et al. 2011c).

National institutions

Institutions with a mandate for coastal environment management have evolved over time. The EMCA authorizes NEMA to exercise general supervision and coordination over all environmental matters. It established the National Environment Council, which is charged with policy formulation, setting national goals, objectives and priorities for protecting the environment and fostering stakeholder cooperation. It also established provincial and district environment committees.

Other institutions are specific to sectors or resources. They include KFS for forest management; Kenya Forestry Research Institute for forestry research; Fisheries Department for fisheries management; KMFRI for fishery research; Kenya Maritime Authority for the regulation of maritime goods and services; Kenya Ports Authority for port and harbour management; and KWS for wildlife management including in MPAs. Others are the CDA for coastal regional development; the Water Resources Management Authority; National Museums of Kenya; public universities for capacity building and research; and various local authorities responsible for Mombasa and other municipalities in the coastal region.

National civil society organizations

CSOs come under the Nongovernmental Organization Coordination Act (1990), which is to be replaced by the Public Benefits Organisation Act (2013). The CSOs conducting environmental conservation, education and empowerment activities include Pact Kenya and Kenya Sea Turtle Conservation Committee, Kenya Marine Forum, Nature Kenya, Wildlife Clubs of Kenya, Baobab Trust, Watamu Turtle Watch and Eco-Ethics International.

Marine and coastal environment projects and programmes

The Kenya Coastal and Marine Environment Clearinghouse Mechanism, initiated by the Nairobi Convention, is a partnership between UNEP and KMFRI. It provides a comprehensive information base for decision-makers.

The Marine Ecology and Environment Programme is one of six research programmes at KMFRI generating data and information on coastal and marine ecosystems for sound management and sustainable resource use.

The Kenya Coastal Development Project (2012–2017) is run by KMFRI with World Bank funding. It will improve the livelihoods of coastal communities, specifically through fisheries, but also forestry, biodiversity, agriculture and ecotourism.

The majority of climate adaptation activities currently under way in Kenya are designed to strengthen capacity and influence policy as initial steps toward resilience. They target arid and semi-arid areas, wetlands and coastal zones simultaneously.

[22] Conservation and sustainable management of Kenya's marine and coastal resources, http://www.eawildlife.org/projects/wetlands/marine?format=pdf

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