II-5 Somali Coastal Current: LME #31

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The Somali Coastal Current LME extends from the Comoro Islands and the northern tip of Madagascar in the south to the Horn of Africa in the north (Alexander 1998, Okemwa 1998). It is bordered by Somalia, Kenya and Tanzania. Early descriptions of the circulation patterns of the system related to the monsoons and oceanography are given by Newell (1957) and Johnson *et al*. (1982). Weather and ocean currents in the Somali Current LME are strongly influenced by the two distinct monsoon seasons. The prevailing winds during the monsoons are a particularly important influencing factor on water circulation (affecting the distribution of nutrients and marine organisms as well as biological processes), changing wave action, and affecting a wide range of human activities (Richmond 2002). From November to March, the prevailing trade wind is from the North-East, but more north-westerly in direction to the South of the Equator. From June to September, the stronger South-West monsoon wind prevails. South of the Equator, this wind is more south-easterly in direction (Newell 1957, Okemwa 1998, Richmond 2002). This LME's unique bathymetry results from major submarine tectonic features of the Indian Ocean, including the mid-Indian Ridge, the Owen Fracture Zone and the Carlsberg Ridge (Okemwa 1998). Covering an area of about 840,710 km^2, of which 0.86% is protected, the LME contains about 0.98% of the world's coral reefs and 0.01% of the world's sea mounts (Sea Around Us 2007). A volume edited by Sherman *et al*. (1998) on the Indian Ocean LMEs contains several articles on this LME.

I. Productivity

The Somali Current LME is a highly productive ecosystem (>300 gCm^{-2}year^{-1}). During the Southwest Monsoon, upwelling off Somalia becomes one of the most intense coastal upwelling systems in the world (Baars *et al*. 1998, Bakun *et al*. 1998). However, the mean phytoplankton density and productivity are lower than expected, possibly due to the dilution of the upwelling effects over a large area because of the strong winds and the high speed of the Somali Current (Baars *et al*. 1998). Productivity has been noted during some SW Monsoon seasons (in 1987, for example) to be highest two hundred kilometres offshore; likely due to the dynamics of the offshore eddy which enhances productivity, rather than any consequence of coastal upwelling (Hitchcock and Olson 1992). Euphausids make up about 25% of total zooplankton biomass while copepods make up most of the remainder (Okemwa 1998). Within the upwelling zone, the dominant zooplankton species include the large copepods *Calanoides carinatus* and *Eucalanus elongatus*, as well as several species of smaller copepods. Most taxa, with the exception of *C*. *carinatus*, persist throughout the Northeast Monsoon, during which primary productivity decreases but without a substantial decrease in the zooplankton stock (Baars *et al*. 1998).

The LME encompasses a rich diversity of coastal habitats including coral reefs, mangroves, seagrass beds and estuaries that play an important role in its overall health and productivity (Okemwa 1998, WWF 2002). Several endangered marine turtle and whale species, as well as the dugong and the CITES-listed coelacanth, *Latimeria chalumnae*, occur in the LME.

Oceanic fronts**:** (after Belkin et al. 2009) The Somali Current (Figure II-5.1) velocity and direction are linked to the monsoon that dominates the meteorological and hydrographic regime of the Indian Ocean. In summer, the prevailing winds from the southwest accelerate the along-shore Somali Current that flows north. North of the Equator, the

Somali Current is deflected eastward, thus resulting in the upwelling of cold, nutrient-rich waters along the Somali coast. These waters are separated by a sharp front from the warm and salty waters carried by the Somali Current. With the advent of the boreal winter monsoon, the wind field reverses and the prevailing winds from the North-East shut down the coastal upwelling, spin down the Somali Gyre and cause downwelling along the Somali coast (Belkin *et al*. 2009).

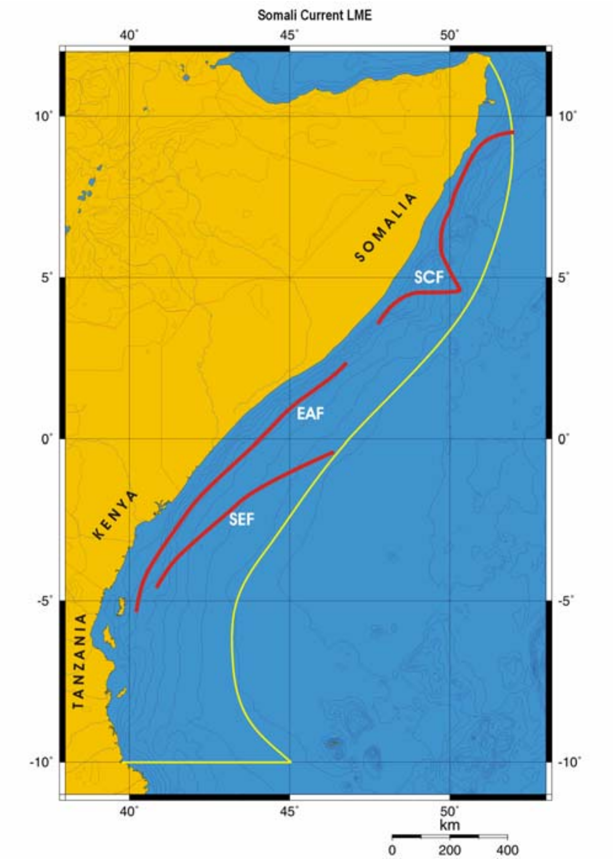

Figure II-5.1. Fronts of the Somali Coastal Current LME. SSF, Shelf-Slope Front. Yellow line, LME boundary. After Belkin et al. 2009).

Somali Coastal Current SST (after Belkin 2009)
Linear SST trend since 1957: 0.46°C
Linear SST trend since 1982: 0.18°C

The Somali Current has warmed slowly and steadily from 1957 to the present. On the southern end, the Somali Current cold/warm events likely affected the Agulhas Current LME through sporadic southbound leakages. On the northern end, the Somali LME has no LME neighbour and its connection to the Arabian Sea LME is tenuous at best. And yet, the all-time maximum of 1998 occurred simultaneously in both LMEs, which could have resulted from large-scale forcing since this maximum has been observed more or less synchronously around the entire Indian Ocean. The two most conspicuous warm events, of 1983 and 1998, are linked to the extremely low values of the Southern Ocean Oscillation (SOI) Index (Annamalai & Murtugudde 2004; Reynolds & Smith 1994).

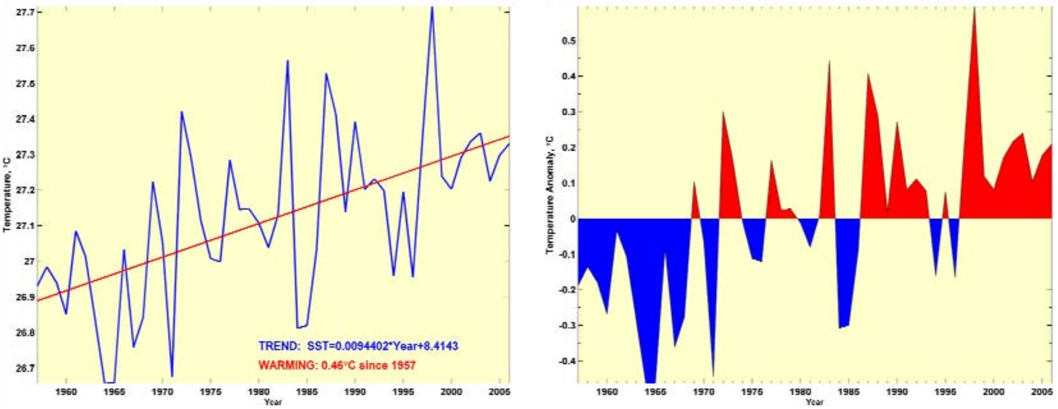

Figure II-4.2. Somali Current LME annual mean SST (left) and annual SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Somali Current LME Trends in Chlorophyll and Primary Productivity: The Somali Current LME is a highly productive ecosystem (>300 $gCm^{-2}year^{-1}$).

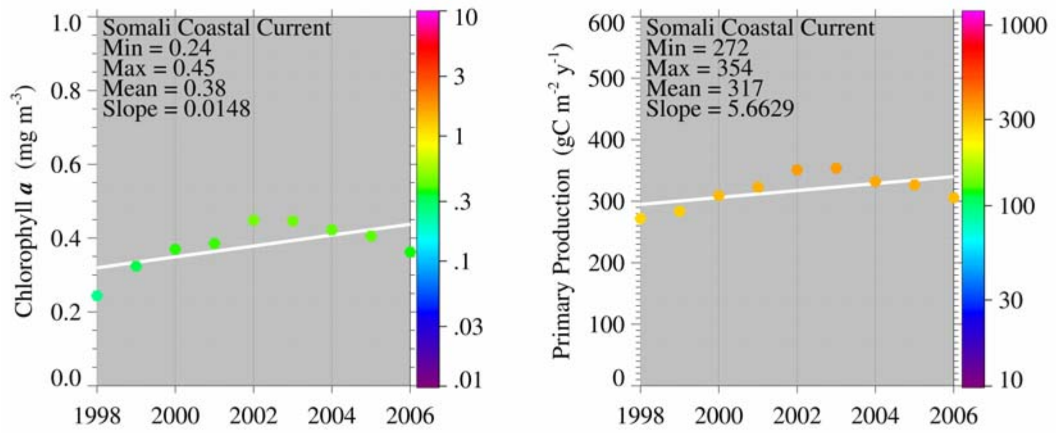

Figure II-4.3 Somali Current LME trends in chlorophyll *a* (left) and primary productivity (right) 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Over half of the reported landings in the Somali Coastal Current LME consists of the 'mixed group.' The LME contains a high level of subsistence and artisanal fisheries which are confined to its inshore areas, due to the ease of access and lack of appropriate expertise and technology to fish in offshore waters. In 1994 in Tanzania, more than 96 % of the total marine production was contributed by small-scale artisanal fishers, while in Kenya the value was 80%. In 1984 in Somalia, it was estimated that 90 000 – 100 000 people were directly or indirectly involved in the artisanal fishing industry. Fishing gears used include gillnets (drift and demersal), long lines, cast nets, traps and handlines (Marshall and Barnett 1997). There is no large fishery for small pelagic fish (Everett 1996) as there is in the Canary Current and Benguela Current LMEs. Oceanic fisheries in the LME are dominated by distant-water fishing fleets from Europe and East Asia.

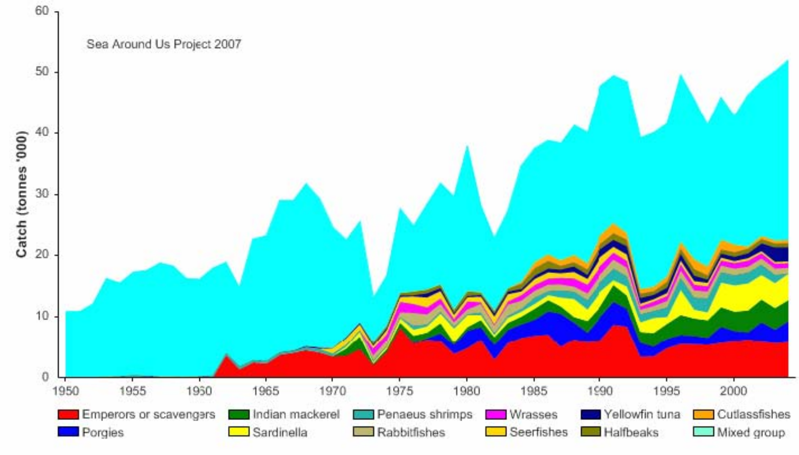

Figure II-5.4. Total reported landings in the Somali Coastal Current LME by species (Sea Around Us 2007).

Due to the poor quality of the available landings statistics in the region, a majority of the landings in the LME can only be classified as 'unidentified marine fish' (included in the 'mixed group in Figure II-5.4), making interpretation of the status of marine fisheries in the LME extremely difficult. Total reported landings in the LME showed a general increase over the reported period, but with marked fluctuations, recording 52,000 tonnes in 2004 (Figure II-5.4). The value of the reported landings peaked in the late 1970s at around 70 million US$ (in 2000 real US$), with recent years between 50-60 million US$ (Figure II-5.5).

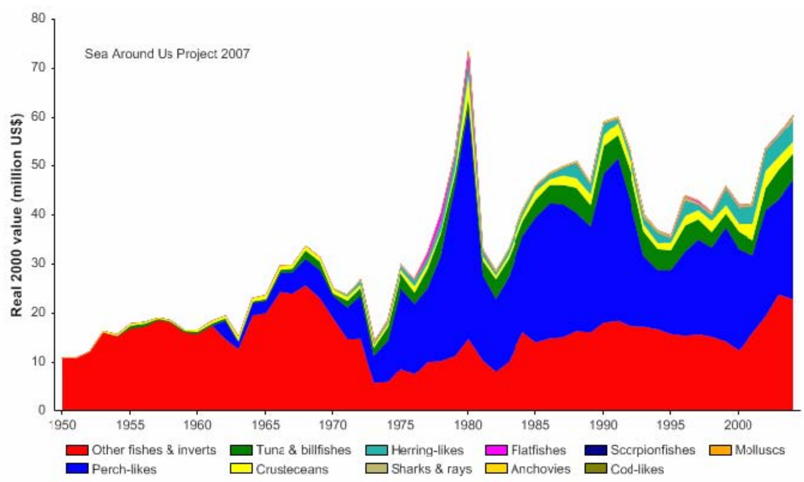

Figure II-5.5. Value of reported landings in the Somali Coastal Current LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in the LME has increased over the years, reaching 2.5% in recent years (Figure II-5.6). Tanzania accounts for the largest ecological footprint in the region, though a number of foreign fleets can also be found to be operating in the LME.

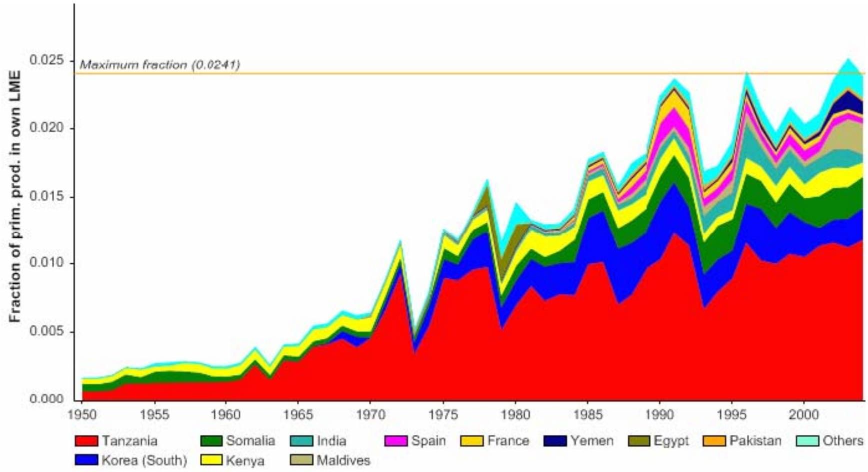

Figure II-5.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Somali Coastal Current LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Due the high proportion of unidentified catches in the underlying statistics, the mean trophic level (i.e., the MTI; Pauly & Watson 2005) and the FiB index of the reported landings estimated for this LME should not be viewed as good indicators of the state of its fisheries. The increase in the MTI from 1950 to the mid 1970 (Figure II-5.6 top) is likely a result of the improvement in the taxonomic details of the reported landings (see Figure II-5.4), while the increase in the FiB index (Figure II-5.6 bottom) seems to be informative, as it suggests the spatial expansion of fisheries in the region.

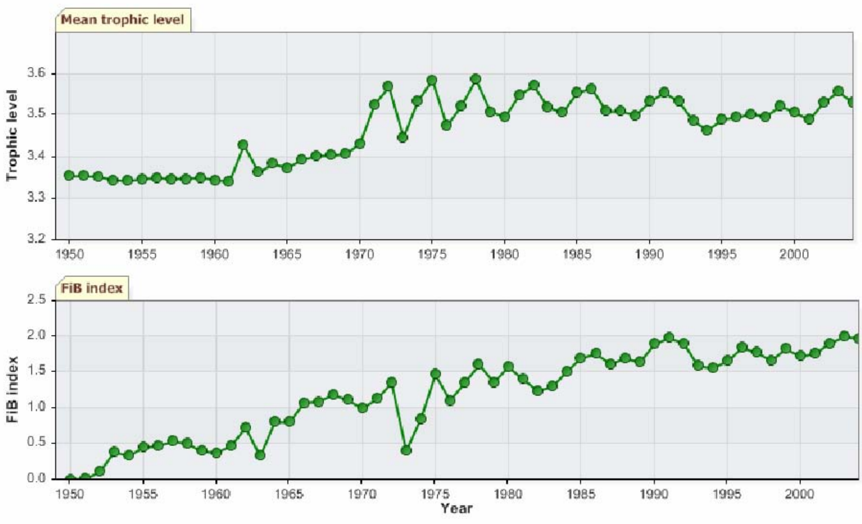

Figure II-5.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Somali Coastal Current LME (Sea Around Us 2007).

The Stock-Catch Status Plots show that local fisheries predominantly target stocks that are classified as 'overexploited' (Figure II-5.8, top) and that fully and overexploited stocks contribute a majority of the reported landings biomass (Figure II-5.8, bottom). Again, we must stress the high level of taxonomic uncertainty in the underlying statistics.

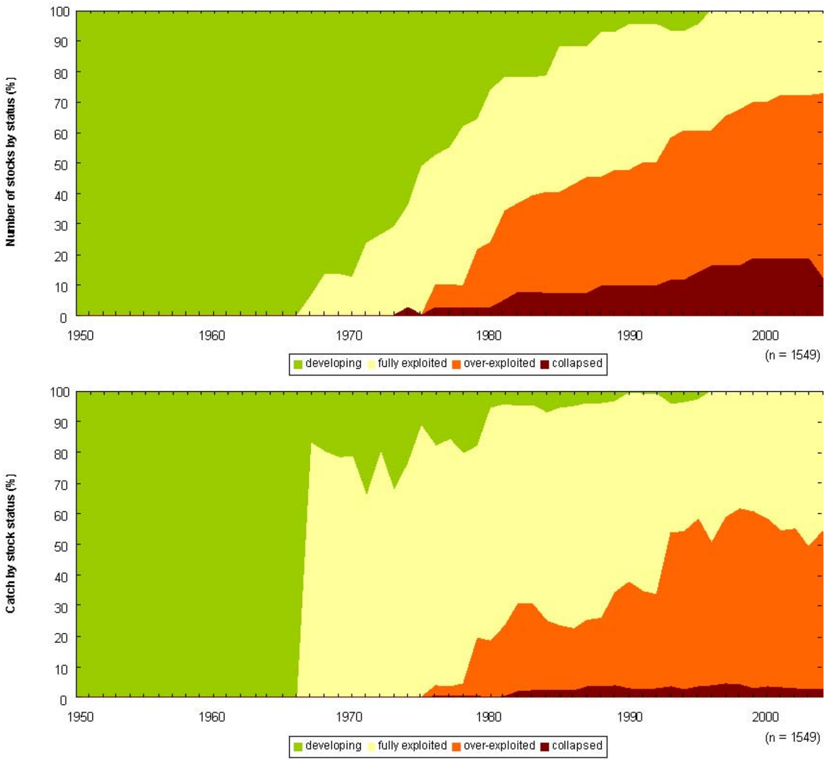

Figure II-5.8. Stock-Catch Status Plots for the Somali Coastal Current LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2003. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

The fisheries of the Somali Coastal Current LME are heavily exploited, contrary to assumptions of huge unrealized potentials (Aden 2007), with indications of unsustainable exploitation documented in several areas (Kelleher & Everett 1997, Fielding & Mann 1999). Harvests of inshore resources are dwindling, including the giant mangrove mud-crab *Scylla serrata*, the mangrove oyster *Saccostrea cucullata*, lobsters (*Panulirus* sp.) and prawns *(Penaeus* sp.). The average size of lobsters caught has diminished, with most of the lobsters now caught before they have reached the age of maturity. Furthermore, berried females are often caught during the breeding season, when the fishery is not strictly managed (Fielding & Mann 1999). Shark populations are also on a rapid decline as a consequence of the harvest of shark fins by fishers from Yemen, Somalia, Djibouti and Sudan, despite such practice being banned in most cases (Pilcher & Alsuhaibany 2000). According to FAO (2000), most tuna stocks are fully exploited in all oceans, including the Western Indian Ocean and some are overexploited or severely depleted.

While there is no evidence to suggest that the offshore stocks of the LME are at risk of collapse, this may well be due to the absence of adequate observations, including the lack of reliable data on fishing effort, total catch, and bycatch. The problem of Illegal, Unregulated and Unreported (IUU) fishing is particularly acute in Somalia, largely as a result of civil wars and the lack of a functioning government for the last decade (Gelchu & Pauly 2007). The status of the LME's fish stocks is not known with any certainty and a need exists for stock assessments and enactment of appropriate management measures.

Destructive fishing practices also pose a threat to coastal fisheries and coral reefs. In areas around coral reefs, unsustainable exploitation is related to increasing fishing effort and the use of destructive gear (McClanahan 1996, Obura et al. 2000). The use of dynamite, pull seine nets, poisons and selective fishing on certain species and juveniles are widespread in the region (UNEP 2002). Offshore trawling grounds, especially those targeting prawns, are showing signs of overexploitation with excessive bycatch and discards. A significant fraction of shrimp bycatch is composed of juvenile fish and on average, only 32% of the bycatch is retained, with a discard rate of up to 1.8 tonnes per trawler per day (KMFRI 2003). Purse seines yield a high bycatch of cetaceans and shark gill nets also catch non-target species such as turtles, dugong, dolphins and whales (Pilcher & Alsuhaibany 2000, Van der Elst & Salm 1998). The bycatch of shark gill nets in Somalia also includes sawfish (Pristis microdon and P. pectinata), which are of global concern as they have been overexploited worldwide (IUCN 1997). Somalia may be one of the last refuges for these vulnerable elasmobranchs (Van der Elst & Salm 1998).

Problems of unsustainable exploitation are expected to persist in the future due to a lack of or inadequate capacity for effective management and surveillance, including failures in addressing illegal fishing and conducting stock assessments, and inadequate knowledge and information. The most important knowledge gaps that currently preclude optimal management of transboundary living resources are identified in the Somali Coastal Current LME TDA (GEF 2003). For the overexploited inshore resources, an approach that reduces fishing pressure, while promoting fisheries restoration and sustainable exploitation practices is indispensable. Sustainable exploitation of the offshore resources in the LME is of great interest for the countries of the region and there is an urgent need for fisheries surveys in order to determine the potential for development of these fisheries. However, efforts are being directed at developing the fisheries for small pelagic and mesopelagic fish (Okemwa 1998).

II. Pollution and Ecosystem Health

Pollution: The coastal areas of the Somali Coastal Current LME are under increasing pressure from land and sea-based sources of pollution, including agrochemical, industrial and municipal wastes as well as sea-based petroleum wastes, which cause varying degrees of localised pollution (Nguta 1998, Okemwa 1998, UNEP 2002, Ruwa 2006). Pollution is generally moderate in this LME (UNEP 2006), although estuaries and urban areas located along the coastline are pollution hot spots (UNEP 2001, Van der Elst & Salm 1998).

Most of the coastal municipalities do not have the capacity to handle the vast quantities of sewage and solid wastes generated daily. Raw sewage containing organic materials, nutrients, suspended solids, parasitic worms and benign and pathogenic bacteria and viruses is discharged into waterways and coastal areas (Okemwa 1998). High microbial levels are observed in areas near to sewage outfalls (Mwaguni 2000). Large quantities of wastes from fish processing plants, slaughterhouses and tanneries also contribute to pollution along the coast (Nguta 1998, Van der Elst & Salm 1998). Because of the lack of purification facilities, industrial pollution is severe and includes solid and liquid industrial wastes such as noxious oils, organic and inorganic chemicals (Nguta 1998, Okemwa 1998). Large volumes of solid wastes are dumped on the shores or disposed of in an unsatisfactory manner and are blown or washed out to sea where they pose a threat to wildlife and human health (UNEP 2002). In addition, seepage and leakages from coastal dump sites pose serious pollution problems, especially during the rainy season (Nguta 1998). These leakages are high in BOD and contain significant amounts of dissolved toxic metals and organic chemicals.

Fertilisers and pesticides are increasingly being manufactured and used in the region, with resulting increase in agricultural-based sources of pollution in coastal areas, from both land run off and direct discharge of wastes from fertiliser factories. The latter is a severe problem in the region (Okemwa 1998). Likewise, poor land use practices such as slash and burn agriculture, overgrazing and nomadic pastoralism as well as farming in river basins contribute to increased suspended solids that are ultimately deposited in the ocean. For example, about 16-21 million tonnes of sediments are deposited into the ocean annually from the two perennial rivers, Tana and Athi Rivers in Kenya (Kitheka 2002). Mining, urban development and dredging also contribute to increased sedimentation in coastal areas (Okemwa 1998). As a consequence, the coastal configuration, accretion and erosion patterns and associated ecosystems are changing. For example, the size of river deltas and estuaries is increasing, and beach as well as seafloor composition has been altered. Eutrophication is not yet a serious issue, although isolated pockets are found in sheltered bays, with threat of occurrence of HABS (Mwaguni 2000).

Maritime activities also contribute to pollution in the Somali Coastal Current LME, especially in harbours and along the coastline during the Southeast Monsoon. Oil and ballast water are the principal contaminants from shipping activities, with ballast waste water, waste oil, as well as sewage released directly into the sea (Okemwa 1998). Longshore currents and winds in the Western Indian Ocean are instrumental in the horizontal distribution of pollutants, particularly in bringing oil slicks and residues of degraded oil from the open sea to coastal waters (UNEP 2002). Beaches in this region are sometimes littered with tar balls, with deleterious effects on marine biota and humans (UNEP 2002). For instance, soluble PCBs from these products are toxic to marine life and also accumulate in the food chain. Plastic litter is a major concern at turtle beaches.

Habitat and community modification: The Somali Coastal Current LME contains a variety of habitats including coral reefs, mangrove forests, estuaries and seagrass beds that serve as shelter, breeding grounds and nurseries for several commercially important fish species as well as endangered species of animals such as marine turtles and dugong. These habitats also have high biodiversity. For example, the coral reefs of Somalia, which are still in good, often pristine condition, especially in Marine Protected Areas (MPA), are among the most biologically diverse in the entire Indian Ocean (Pilcher & Alsuhaibany 2000). Coral cover distribution is more abundant in the area between the Athi/Sabaki river estuary and Ruvuma river estuary, which has been described as the ‘Coral Coast’ by virtue of its rich coral assemblage (WWF 2002). These coastal habitats also protect the adjacent land from erosion and wave damage.

Coral reefs are impacted by several anthropogenic activities such as mining, pollution, exploitation of reef fishes and other organisms for food and ornamental trade, tourism and siltation. Many reefs outside of MPAs are overexploited and severely degraded (Spalding et al. 2001). High fishing effort and destructive fishing methods such as dynamiting not only cause overfishing in coral reefs but also lead to structural damage as well as changes in biodiversity, for instance, population explosions of sea-urchin (McClanahan 1996). Coral bleaching has had a significant impact on many of the LME’s coral reefs, especially during the 1998 El Niño (Muhando 2002). In Kenya, the surviving corals appeared to have recovered one year later, but severely damaged areas had still not been re-colonised. Another major threat to the marine habitats is increased sedimentation (Obura et al. 2000). Conversion of mangrove habitat for agricultural, industrial and residential uses and salt and lime production, as well as over-harvesting of mangrove wood for building, charcoal, firewood and trade purposes have caused deterioration of mangrove forests and their faunal communities. Destruction of mangrove forests is also leading to heavy offshore siltation and reduction in nutrients for offshore species with concomitant reduction in fish catches (Okemwa 1998).

Seagrass meadows are under threat from destructive fishing methods such as drag nets, pollution from various sources and siltation (Okemwa 1998). Estuaries are being modified through pollution, sedimentation and infilling. Damming of rivers for hydropower and irrigation (e.g., Tana River) and abstraction of water for irrigation (e.g., Athi-Sabaki Rivers) have various impacts on the coastal, estuarine and marine habitats through reduced inflow of freshwater and nutrients into the coastal zone (Raal & Barwell 1995). Degradation of beaches in the region by mining, litter, oil pollution, dredging, erosion and coastal development is also a major problem. This has affected endangered sea turtles that use undisturbed beaches as their sole nesting sites (Okemwa 1998). Coastal erosion is a major environmental concern along the East African coast and leads to shifting coastal features such as dunes, beaches and shoreline (UNEP 2002). Mitigation measures for coastal erosion have in some cases exacerbated the problem due to inadequate information and technical support (UNEP/GPA 2004)

Extreme droughts and floods linked with ENSO have been documented in the region in recent years (IPCC 2001, Kitheka & Ongwenyi 2002, UNEP 2001). These events induce strong responses in the LME, and have important effects on the distribution of fish stocks, as well as a potential negative impact on coastal habitats such as estuaries and mangroves in which inflow of freshwater is important for maintaining productivity. Sea level rise is also expected to have significant impacts in the Somali Coastal Current LME, since most of the low-lying coastal plains are only a few meters above the highest spring tide water level and therefore susceptible to sea water intrusion and flooding (Okemwa 1998).

Anthropogenic pressures from increasing human populations and unrestricted coastal development continue to threaten the health of the Somali Coastal Current LME. This is exacerbated by inadequate monitoring as well as insufficient data needed to characterise the impact of these pressures on natural resources. An immediate need towards improving the health of this LME and sustainable use of its coastal and marine resources is to fill the existing gaps in knowledge (GEF 2003).

III. Socioeconomic Conditions

The Somali Coastal Current LME region supports about 15 million people, more than half of whom live in coastal areas (Kelleher & Everett 1997, UNEP 2001). Following an increase in the 1980s, the population growth rate has recently shown a marked decline. There is a high rate of urbanisation in the region, with major coastal cities such as Mombasa and Dar es Salaam growing at a rate of 5% and 6.7% respectively (Hatziolos et al. 1996). Other population movements are conflict-driven, e.g., the movement of refugees. Poverty is particularly acute among various vulnerable groups such as households headed by the elderly and children. Furthermore, there is a general food deficit, particularly of protein, causing a high level of under-nourishment, especially in Somalia.

The main economic sectors are agriculture, fisheries, industry, manufacturing and services (the latter includes tourism and maritime transport). Coastal tourism is a significant industry, especially in Kenya which leads the region with some 940, 000 international arrivals in 1999 (Gossling 2006). Although the contribution of the industrial fisheries to GDP is small (0.04% for Kenya, 2% for Somalia, 2.7% for Tanzania), the artisanal fisheries are regarded as a significant source of employment and food. In Tanzania, more than 25% of the country accrues direct benefit from the coastal zone (Kamukala and Payet 2001), and the artisanal and traditional fisheries play a significant role in food security (Cunningham and Bodiguel 2005). The socioeconomic impact of overexploitation is severe in this LME and includes the loss of employment and reduction in the capacity of local communities to meet basic needs. Furthermore, the increase in the industrial fisheries has further reduced the resources available to artisanal fishers and considerable friction between the two groups has arisen as a result of the destruction of stationary artisanal fishing gear by industrial vessels (Okemwa 1998). Mariculture of seaweed, shrimps, finfish, sea-cucumbers and pearl oysters is a growing sector of the economy (Richmond 2002).

Degradation of the coastal zone poses a threat to economic returns and employment from activities such as fishing and tourism, through the loss of critical habitats and recreational areas. Economic costs of habitat modification and loss are associated with beach replenishment schemes, dredging and coastal protection to prevent beach erosion. Protected species such as marine turtles, dugongs, whales and dolphins are reportedly declining as a result of increasing levels of wastes, notably plastics (UNEP 2002). This could have a negative impact on tourism. Human health is also at risk from pollution through the consumption of contaminated sea food or through direct contact.

V. Governance:

Kenya and Tanzania have extensive legal and institutional frameworks to manage water resources. However, law enforcement is a major problem due to poor monitoring and surveillance systems. Somalia lacks specific laws and regulations to protect and preserve the marine environment, which has further been aggravated by the political situation and conflicts in this country. This LME comes under the UNEP Eastern Africa Regional Seas Programme. All three countries have ratified the Nairobi Convention. GEF is supporting three projects in this LME together with the Agulhas Current LME.

As described in section II-4 for the Agulhas Current LME, The Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project, currently underway, will seek to institutionalize cooperative and adaptive management of the Agulhas and Somali LMEs. A phased approach is planned that progressively builds the knowledge base and strengthens technical and management capabilities at the regional scale to address transboundary environmental concerns within the LMEs, builds political will to undertake threat abatement activities and leverages finances proportionate to management needs. In addition to the ASCLME Project, the Programme includes two parallel projects, one that addresses land-based sources of pollution and coastal degradation (WIO-LaB, implemented by UNEP); and one that builds knowledge for the purposes of managing industrial fisheries (SWIOFP, implemented by the World Bank).

The activities within the ASCLMEs Project are focused on filling the significant coastal and offshore data and information gaps for these LMEs by capturing essential information relating to the dynamic ocean-atmosphere interface and other interactions that define the LMEs, along with critical data on artisanal fisheries, larval transport and nursery areas along the coast. A Transboundary Diagnostic Analyses (TDA), and Strategic Action Programmes (SAP) will be developed for the Somali Current LME. The parallel UNEP and World Bank Projects will also feed pertinent information into the TDAs/SAPs formulation process, and identify policy, legal and institutional reforms and needed investments to address transboundary priorities.

References

Aden, A.M. (2007). The Somali fisheries: potentiality, challenges and needed interventions. InfoSamak, January/February 2007(1): 13-16.

Alexander, L. M. (1998). Somali Current Large Marine Ecosystem and related issues, p 327-331 in: Sherman, K. Okemwa, E.N. and Ntiba, M.J. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Oxford, U.K.

Annamalai, H., and R. Murtugudde (2004) Role of the Indian Ocean in regional climate variability, in: *Earth's Climate: The Ocean-Atmosphere Interaction*, C. Wang, S.-P. Xie, and J.A. Carton (eds.), AGU Geophysical Monograph, **147**, 213-246.

Baars, M. A., Schalk, P. H. and Veldhuis, M. J. W. (1998). Seasonal fluctuations in plankton biomass and productivity in the ecosystems of the Somali Current, Gulf of Aden and Southern Red Sea, p 143-174 in: Sherman, K. Okemwa, E.N. and Ntiba, M.J. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Oxford, U.K.

Bakun, A., Claude, R. and Lluch-Cota, S. (1998). Coastal upwelling and other processes regulating ecosystem productivity and fish production in the western Indian Ocean, p 103-141 in: Sherman, K. Okemwa, E.N. and Ntiba, M.J. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Oxford, U.K.

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M. , Cornillon, P.C. and Sherman K. (2009). Fronts in Large Marine Ecosystems of the world's oceans. Progress in Oceanography, in press.

Cunningham, S. and Bodiguel, C. (2005). Subregional review: Southwest Indian Ocean, p 67-84 in: De Young, C. (ed), Review of the state of the world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper 488. Rome. 458p.

Everett, G. V. (1996). Some observations on fisheries management related to monitoring, control and surveillance issues in the region of the southwest Indian Ocean and the Maldives. Appendix to the Report of a regional workshop on fisheries monitoring, control and surveillance. Albion, Mauritius. FAO field report 97/93.

FAO (2000). Fishery Statistics – Capture Production. FAO Yearbook, Vol.90/1.

Fielding, P.J. and Mann, B. Q. (1999). The Somalia Inshore Lobster Resource – A Survey of the Lobster Fishery of the North Eastern Region (Puntland) between Foar and Eyl during November 1998. IUCN Project No.6/50-82/95+6/50–83/04.

GEF (2003). Somali Coastal Current Transboundary Diagnostic Analysis. Global Environment Facility.

Gelchu, A. and Pauly, D. (2007). Growth and distribution of part-based fishing effort within countries' EEZ from 1970 to 1995. Fisheries Centre Research Reports, 15(4)

Gossling, S. (2006). Towards sustainable tourism in the Western Indian Ocean. Western Indian Ocean Journal of Marine Science. Vol 5. p 55-70.

Hatziolos, M., Lundin, C.G. and Alm, A. (1996). Africa: A Framework for Integrated Coastal Zone Management. The World Bank, Washington D.C., U.S.

Hitchcock, G. L. and Olson, D. B. (1992). NE and SW monsoon conditions along the Somali coast during 1987, p 583-593, in: Desai, B. N. (ed), Oceanography of the Indian Ocean. National Institute of Oceanography, Goa, India.

IPCC (2001). Climate Change 2001: Impacts, Adaptation and Vulnerability, p 487-531 in: McCarthy, J.J., Ganziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (eds), Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K. and New York, U.S.

IUCN (1997). Somali Natural Resources Management Programme: Strategic Framework for Sustainable Natural Resources Management in Somalia. IUCN Eastern Africa Programme Project No.6/SO-82/95+6/SO-83/04.

Johnson, D.R., Mutua Nguli, M. and Kimani, E.J. (1982). Response to annually reversing monsoon winds at the southern boundary of the Somali Current. Deep Sea Research 29 (10A): 1217-1227.

Kamukala, G. and Payet, R. (2001). Regional report, p 152-180, in: Voabil, C. and Engdahl, S. (eds), The Voyage from Seychelles to Maputo. Successes and failures of integrated coastal zone management in Eastern Africa and Island States. Secretariat for Eastern African Coastal Area Management (SEACAM). Maputo, Mozambique.

Kelleher, K. and Everett, G.V. (1997). Approaches to Marine Fisheries Governance in Somalia. UNDP Project No.SOM/97/013/A/08/19 FAO TCP/SOM/6713.

Kitheka, J.U. (2002). Dry season sediment fluxes in the frontwater zone of the mangrove-fringed Mwache Creek, Kenya, p 194-202 in: Arthurton, R.S., Kremer, H.H., Odada, E., Salomons, W. and Crossland, J.I.M. (eds), African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment – Coastal Area Interaction and Human Dimensions. Land-Ocean Interactions in the Coastal Zone. LOICZ Reports and Studies No.25, LOICZ, Texel, The Netherlands.

Kitheka, J.U. and Ongwenyi, G.S. (2002). The Tana River Basin and the opportunity for research on the land-ocean interaction in the Tana Delta, in: Arthurton, R.S., Kremer, H.H., Odada, E., Salomons, W. and Crossland, J.I.M. (eds), African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment – Coastal Area Interaction and Human Dimensions. Land-Ocean Interactions in the Coastal Zone. LOICZ Reports and Studies 25, LOICZ, Texel, The Netherlands.

KMFRI (2003). Current Status of Trawl Fishery of Malindi-Ungwana Bay. Kenya Marine and Fisheries Research Institute, Mombasa, Kenya.

Marshall, N.T. and Barnett, R. (1997). The trade in sharks and shark products in the Western Indian and Southeast Atlantic Oceans. Traffic. East/South Africa.

McClanahan, T.R. (1996). Oceanic Ecosystems and Pelagic Fisheries, p 39-66 in: McClanahan, T.R. and Young, T.P. (eds), East African Ecosystems and their Conservation. Oxford University Press, New York, U.S.

Muhando, C.A. (2002). Seawater temperature on shallow reefs off Zanzibar Town, Tanzania, p 40-46 in: Linden, O., Souter, D., Wilhelmsson, D. and Obura, D. (eds), Coral Reef Degradation in the Indian Ocean. Status Report 2002. Kalmar University, Kalmar, Sweden.

Mwaguni, S.M. (2000). The Cost and Benefits Associated with Addressing the Sewage Problem Affecting the Coastal Marine and Associated Freshwater Environment with Special Focus on the Town of Mombasa on the Kenyan Coast. A Contribution to the Implementation in East Africa of the UNEP/GPA Strategic Action Plan on Sewage.

Newell, B.S. (1957). A Preliminary Survey of the Hydrography of the British East African Coastal Waters. Colonial Office, Fishery Publication 9. Her Majesty's Stationery Office, London, U.K.

Nguta, C. M. (1998). An overview of the status of marine pollution in the East African Region, p 61-71 in: Sherman, K., Okemwa, E.N. and Ntiba, M.J. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Oxford, U.K.

Obura, D.O., Muthiga, N.A. and Watson, M. (2000). Country Profiles of Coral Reefs: Kenya, p 199-230 in: McClanahan, T.R., Sheppard, C.R.C. and Obura, D.O. (eds), Coral Reefs of the Indian Ocean. Oxford University Press, U.K.

Okemwa, E. (1998). Application of the Large Marine Ecosystem concept to the Somali Current, p 73-99 in: Sherman, K. Okemwa, E.N. and Ntiba, M.J. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Oxford, U.K.

Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D. and Watson, R. (2005). Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.

Pilcher and Alsuhaibany (2000). The Status of coral reefs in the Red Sea and Gulf of Aden 2000, p 35-54 in: Wilkinson, C. (ed), Global Status of Coral Reefs: 2000. Australian Institute of Marine Sciences, Townsville, Australia.

Raal, P. and Barwell, L. (1995). Application of Integrated Environmental Management to the Tana River Delta and its Linkage with the Indian Ocean Large Marine Ecosystem, p 19-23 in: Okemwa, E., Ntiba, M.J. and Sherman, K. (eds), Status and Future of Large Marine Ecosystems of the Indian Ocean: A report of the International Symposium and Workshop. A Marine Conservation and Development Report. IUCN, Gland, Switzerland.

Reynolds, R.W., and T.M. Smith (1994) Improved global sea surface temperature analyses using optimal interpolation, *J. Climate,* **7**(6)*,* 929-948.

Richmond, M.D. (2002). (ed) A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands. Sida/SAREC – UDSM. 461p.

Ruwa, R. (2006). Eastern Africa, p 51–74 in UNEP/GPA (2006), The State of the Marine Environment: Regional Assessments. UNEP/GPA, The Hague.

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org /lme/SummaryInfo.aspx?LME=31

Sherman, K., Okemwa, E.N. and Ntiba, M.J., eds. (1998). Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science. Cambridge, Massachusetts, U.S.

Spalding, M.D., Ravilious, C. and Green, E.P. (2001). World Atlas of Coral Reefs. UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, U.S.

UNEP (2001). Eastern Africa Atlas of Coastal Resources: Tanzania. UNEP and BADC, Government of Belgium, Belgium.

UNEP (2002). State of the Environment: Maldives. Regional Resource Centre for Asia and the Pacific. Thailand.

UNEP (2006). Ruwa, R.K., Kulmiye, A.J., Osore, M.K.W., Obura, D., Mutoro, D., Shunula, J.P., Ochiewo, J., Mwaguni, S., S. and Misana, S. Somali Coastal Current, GIWA Regional Assessment 46. University of Kalmar, Kalmar, Sweden.

UNEP/GPA (2004) Shoreline change in the Western Indian Ocean Region: An Overview. Western Indian Ocean Marine Science Association.

Van der Elst, R.P. and Salm, R. (1998). The Protection and Sustainable Development of Somalia Marine and Environment, Seaports and Coastal Areas Project – Overview of the Biodiversity of the Somali Coastal and Marine Environment. IMO-UNDP SOM/97/013/A/08/19, Nairobi, Kenya.

WWF (2002). Proceedings of the Eastern African Marine Ecoregion Visioning Workshop, 21-24 April 2001. Mombasa, Kenya.