LMEs and REGIONAL SEAS

I WEST AND CENTRAL AFRICA

1. Benguela Current LME
2. Guinea Current LME
3. Canary Current LME

I-1 Benguela Current LME

S. Heileman and M. J. O'Toole

The boundaries of the Benguela Current LME extend from the Agulhas Current to 27° E longitude, and to the northern boundary of Angola. It encompasses the Exclusive Economic Zones (EEZs) of Angola and Namibia, and part of the EEZ of South Africa, with an area of 1.5 million km^2 of which 0.59% is protected, and contains 0.06% of the world's sea mounts (Sea Around Us 2007). One of its unique features is that it is bounded in the north and south by two warm water systems, the Angola Current and Agulhas Current, respectively. These boundaries are highly dynamic and the neighbouring warmer waters directly influence the ecosystem as a whole as well as its living resources. A strong wind-driven coastal upwelling system, with the principal upwelling centre located off Lüderitz (27°S, southern Namibia), dominates this LME. The system is complex and highly variable, showing seasonal, interannual, and decadal variability as well as periodical regime shifts in local fish populations (Shannon & O'Toole 1998, 1999, 2003). The Benguela Current LME has a temperate climate, and plays an important role in global climate and ocean processes (GEF/UNDP/UNOPS/NOAA 1999). Its major estuaries and river systems include the Kwanza and Cunene Rivers. Books, book chapters, articles and reports on this LME include Crawford *et al*. (1989), Palomares and Pauly (2004), O'Toole et al. (2001), Shannon & O'Toole (2003), Shannon *et al*. (2006) and UNEP (2005).

I. Productivity

The Benguela Current LME is a Class I, highly productive ecosystem (>300 gCm^{-2}y^{-1}). The distinctive bathymetry, hydrography, chemistry and trophodynamics of the Benguela Current LME make it one of the most productive marine areas of the world. The plankton has been generally regarded as a diatom-dominated system, but this perception is to some extent an artefact of past sampling (Shannon & O'Toole 1998). Copepods, which are numerically the most abundant and diverse zooplankton group, play an important role in the trophodynamics of this LME since they are the principal food of sardines, anchovies, and other pelagic fish including the larval and juvenile stages of both fish and squid. The high level of primary productivity supports an important global reservoir of biodiversity and biomass of fish, seabirds, crustaceans, and marine mammals. Favourable conditions exist for a high production of small pelagic fishes such as sardines, anchovies, and round herrings. The LME's estuaries provide nursery areas for a number of fish stocks that are shared among the bordering countries, while both the estuaries and coastal lagoons provide critical feeding grounds for migratory birds.

The LME's considerable climatic and environmental variability is the primary driving force of biomass change in the Benguela Current LME (Sherman 2003, Shannon *et al*. 2006). Harmful Algal Blooms (HABs) regularly occur, and have been associated with fish mortalities as a result of oxygen depletion in the water during and after major blooms (Shannon & O'Toole 1998). Satellite images show frequent and widespread eruptions of toxic hydrogen sulphide off the coast of Namibia (Weeks *et al*. 2004). Eruptions often seem to be coincident with either increased intensity of wind-driven coastal upwelling or the passage of a low-pressure weather cell. In 2001, nine major hydrogen sulphide eruptions occurred, with the largest covering 22,000 km^2 of ocean. Their relevance to the fishery resources, including lobsters, is likely to be high. For example, a widespread depletion of oxygen is blamed for the deaths of two billion young hake in 1993 (Hamukuaya *et al.* 1998, Weeks *et al*. 2004).

Since 1995, efforts have been underway in the BENEFIT and Benguela Current LME project (see Governance) to better understand this highly variable and complex system of physical, chemical, and biological interactions and processes (Shannon *et al*. 2006). Systematic surveys have been conducted to assess oceanographic conditions using both shipboard sensors and satellite remote sensors for temperature, chlorophyll, nutrients, and primary productivity.

Oceanic fronts: The coastal upwelling zone off South Africa extends from Cape of Good Hope (34.5°S) north to 13°S and consists of the two major areas, the northern and southern Benguela upwelling frontal zones (UFZ) separated by the so-called Lüderitz line (LL) at 28°S, where the shelf's width is at a minimum (Shannon 1985, Shillington 1998) (Figure I-1.1). The northern UFZ is year-round, whereas the southern UFZ is seasonal). A peculiar double front is observed within the southern UFZ, between 28°S-32°S, with the inshore front close to the coast (a few tens of km) and the offshore front over the shelf break (150-200 km off the coast). This double-front pattern can be explained by the conceptual model put forth by Barange and Pillar (1992). A vast frontal zone develops seasonally off the Angolan coast. This zone consists of numerous fronts; most fronts extend ESE-WNW; the entire zone seems to protrude seaward from the Angolan coast north of 20°S (Belkin et al. 2008). This zone is likely related to the Angola-Benguela Front (ABF) (Shannon *et al*. 1987, Meeuwis & Lutjeharms 1990).

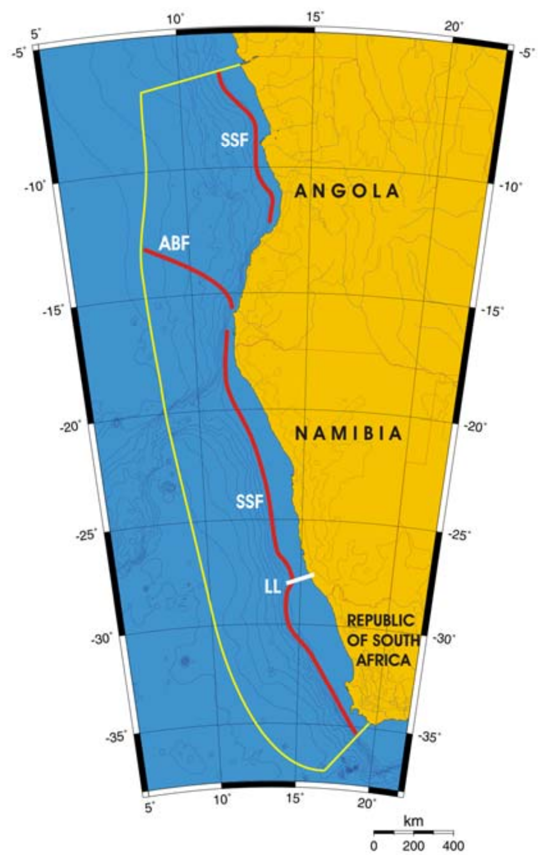

Figure I-1.1. Fronts of the Benguela Current. ABF, Angola-Benguela Front; LL, Lüderitz Line; SSF, Shelf-Slope Front. Yellow line, LME boundary. (Belkin et al. 2008)

Benguela Current SST
Linear SST trend since 1957: 0.26°C.
Linear SST trend since 1982: 0.24°C.

The Benguela Current's thermal history was punctuated by warm and cold events associated with Benguela El Niños and La Niñas, Atlantic counterparts of the Pacific El Niños and La Niñas. Fidel and O'Toole, in a presentation made at the 2nd Global Conference on Large marine Ecosystems in Qingdao, distinguished five major Benguela El Niños over the last 50 years. The most pronounced warming of >1.2°C occurred after the all-time minimum of 1958 and took 5 years to peak in 1963. Other warm events peaked in 1973 and 1984, alternated with cold events of 1982 and 1992. Clearly, decadal variability in the Benguela Current was strong through the last warm event of 1984. After that, the Benguela Current experienced a shift to a new, warm regime, in which decadal variability is subdued. Some researchers also note the 1995 warm event, although this maximum is not conspicuous from Hadley SST data. The post-1982 warming of the Benguela Current LME was spatially non-uniform: whereas SST in some areas of northern Benguela (between 12-26°S) increased by 0.6 to 0.8°C, the inshore shelf area of southern Benguela experienced a slight cooling (Fidel and O'Toole, 2007, after Pierre Florenchie, University of Cape Town, personal communication).

The thermal history of this LME bears limited commonality with either the Guinea Current LME (its northern neighbor) or to the Agulhas Current LME (its southern neighbor). This is not at all surprising since these three LMEs are oceanographically disconnected. Indeed, the Agulhas Current retroflects southwest of Cape Agulhas and therefore does not feed the Benguela Current, save possibly for small occasional alongshore leakages. In the north, the Angola-Benguela Front (ABF) blocks any direct along-shelf connection between two neighbors, the Benguela Current LME and Guinea Current LME.

Correlation analysis suggests different responses to environmental forcing in the northern, central, and southern parts of the Benguela Current region (Jury and Courtney, 1995). For example, the lower correlation in the southern Benguela between SST and local winds suggests that SST variability here is often driven by advection, likely by the Agulhas Current and its extension. The higher correlation in the central Benguela between SST and local winds indicates that SST variability here is largely driven by local upwelling.

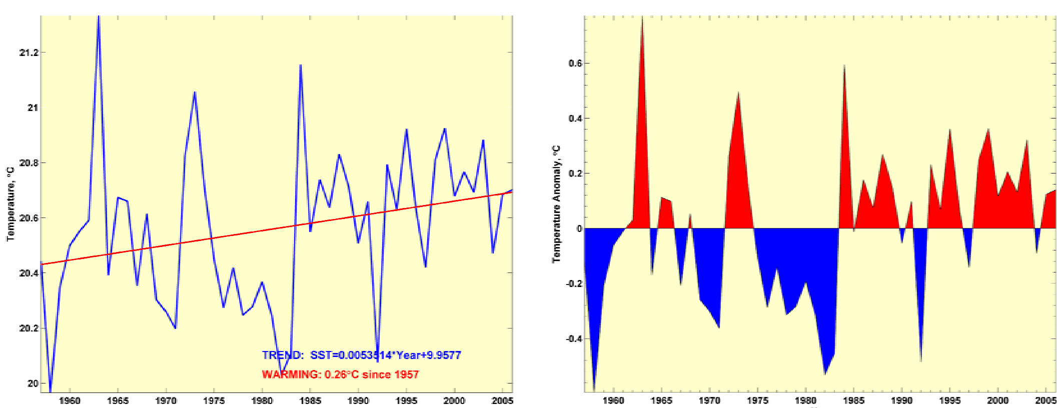

Figure I-1.2. Benguela Current LME mean annual SST (left) and annual SST anomalies (right), 1957 – 2006, based on Hadley climatology (after Belkin 2008).

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

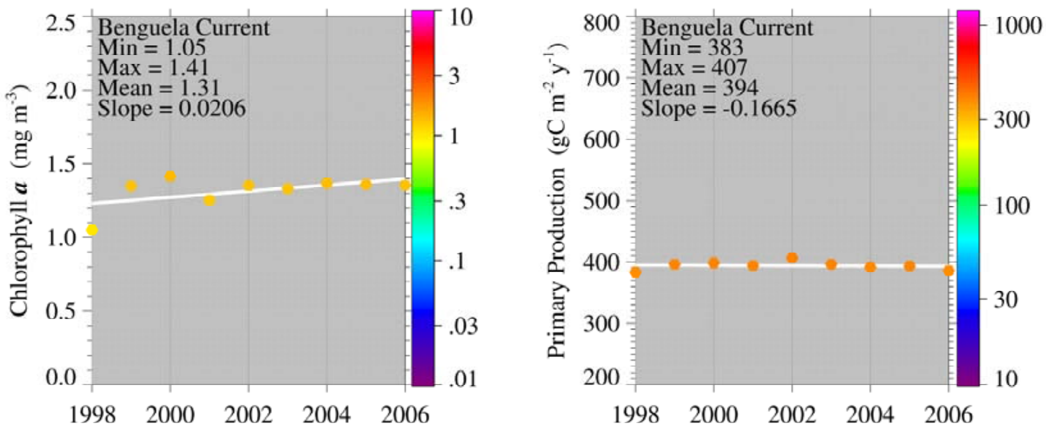

Figure I-1.3. Benguela Current LME trends in chlorophyll *a* (left) and primary productivity (right) 1998-2006; values are color coded to the right hand ordinate. Courtesy of J. O'Reilly and K. Hyde. Sources discussed p.15 this volume.

II. Fish and Fisheries

The Benguela Current LME is very rich in pelagic and demersal fish. Most of the LME's major fisheries resources are shared between the bordering countries or migrate across national jurisdictional zones, and include sardine (*Sardinops sagax*), anchovy (*Engraulis capensis*), hake (*Merluccius capensis* and *M*. *paradoxus*), horse mackerel (*Trachurus trachurus* and *T*. *trecae*), sardinella (*Sardinella* spp.), and rock lobster (*Jasus lalandii*). Artisanal, commercial (industrial) and recreational fisheries are all of significance in the LME, with artisanal fisheries being particularly important for Angola. Total reported landings of the LME increased steadily from 1950 to a peak of about 3 million tonnes in 1978 (Figure I-1.4). In the subsequent years, however, the landings show a general decline, down to about 1.1 million tonnes in 2004. The trend in the value of the reported landings closely resembles that of the reported landings, peaking at just under 3 billion US$ (in 2000 real US$) in 1978 (Figure I-1.5).

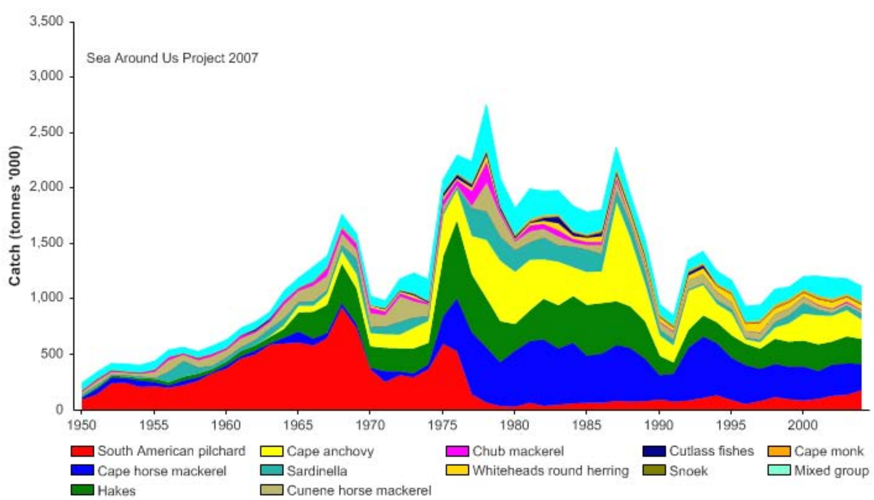

Figure I-1.4. Total reported landings in the Benguela Current LME by species (Sea Around Us 2007).

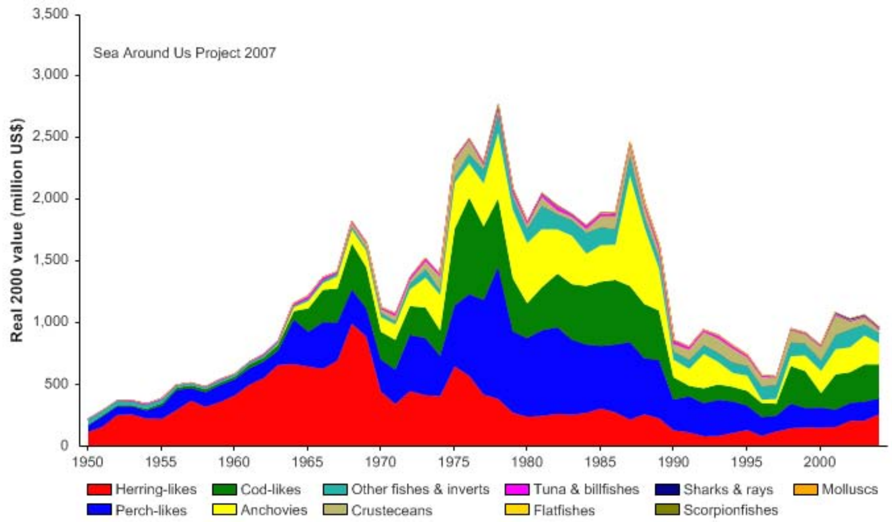

Figure I-1.5. Value of reported landings in the Benguela Current LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in the LME reached one third of the observed primary production by the mid 1970s, but has since declined to half that level (Figure I-1.6). Although there were large numbers of foreign fleets operating in the LME in the 1970s and 1980s, since the early 1990s, Namibia and South Africa have the largest ecological footprints in the region.

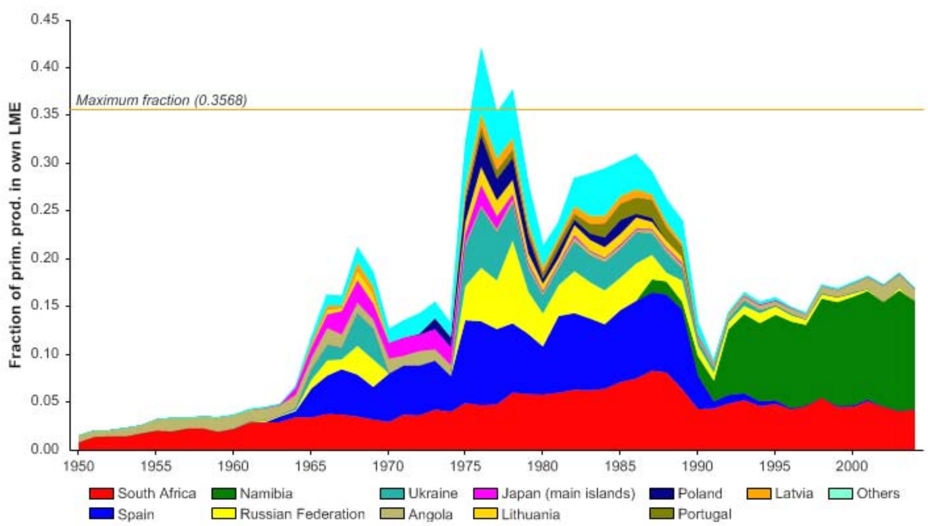

Figure I-1.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Benguela Current LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Since the mid 1970s, the mean trophic level of the reported landings (i.e, the MTI, Pauly & Watson 2005) has been relatively stable in this LME, (Figure I-1.7 top), but as the amount of catch (tonnage) has declined over the same period, the FiB index shows a rapid decline (Figure I-1.7 bottom).

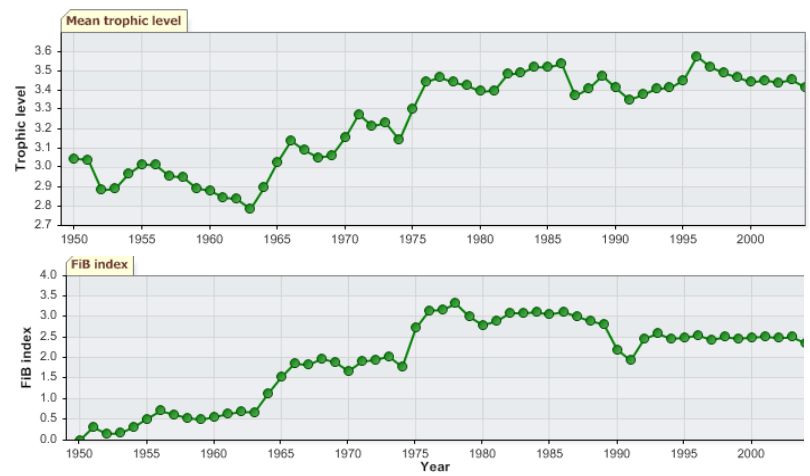

Figure I-1.7. Trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Benguela Current LME (Sea Around Us 2007).

This decline of the FiB index is particularly strong off Namibia (Willemse and Pauly 2004), where the ecosystem has been greatly modified, with jellyfish now dominating the food web (Lynam *et al.* 2006). This is a case of 'fishing down marine food webs' (Pauly *et al.* 1998), but one in which the species that replaced the exploited species are presently not targeted by fisheries.

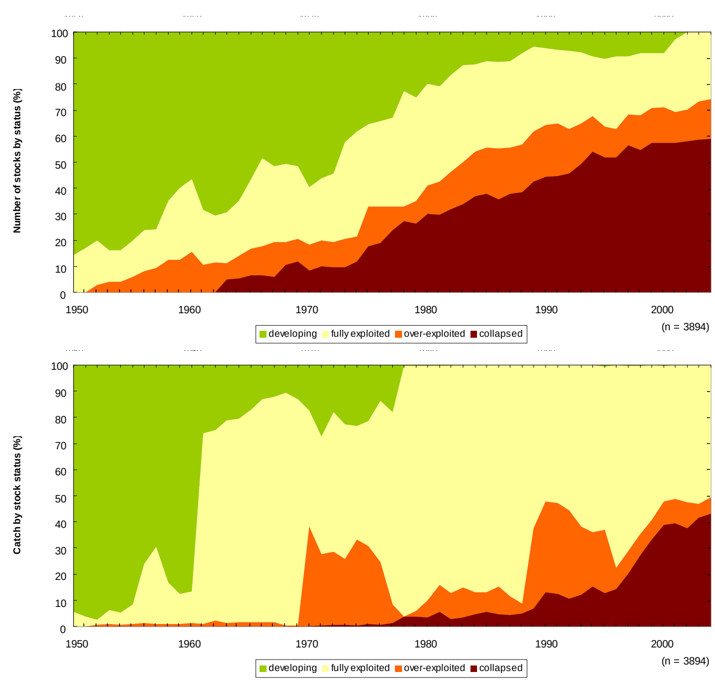

Figure I-1.8. Stock-Catch Status Plots for the Benguela Current LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of '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 Stock-Catch Status Plots indicate that about 60% of commercially exploited stocks in the LME has collapsed, with another 10% overexploited (Figure I-1.8 top), with fully-exploited stocks contributing 50% of the catch (Figure I-1.8, bottom). However, fully exploited stocks, while accounting for less than 30% of the stocks, provide over 50% of the reported landings (Figure I-1.8).

Major changes in the key harvested species have occurred in the last century (Hampton *et al*. 1999, Shannon & O'Toole 2003). While environmental variability has been a contributing factor, some of these changes were undoubtedly the consequence of overexploitation (FAO 2003, Sherman 2003). The decline in these fisheries is caused, in part, by excessive fishing effort and overcapacity of fleets, excess processing capacity, catching of under-sized fish, and inadequate fisheries management (GEF/UNDP/UNOPS/NOAA 1999). As a result, the fisheries in the LME have experienced years of catches well below the maximum or optimal sustainable yields, with dramatic declines in stock sizes and catch per unit effort.

Decline in commercial fish stocks and non-optimal fishing of living resources is now a major transboundary problem in the LME (GEF/UNDP/UNOPS/NOAA 1999). In all three countries bordering the LME, major fisheries resources have undergone significant changes in annual catch (Hampton *et al*. 1999, Tapscott 1999) and this is also true for exploitation of invertebrate resources. For example, rock lobster catches have declined dramatically since the early 1960s, particularly off Namibia, where catches are now well below their 1960s peak. Assessments of the South African rock lobster resource have shown it to be seriously depleted, and estimates of recruitment in recent decades are only about 35% of its pre-exploitation condition (Hampton *et al*. 1999). The abalone stock has also been declining since 1996 (Tarr *et al*. 2000) and the stock is considered to be on the brink of collapse as a result of illegal fishing (Tarr 2000) and an ecological shift in abundance (Tarr *et al*. 1996).

Some of the major stock fluctuations have undoubtedly been influenced by the large-scale environmental perturbations that occur periodically in the system (Shannon & O'Toole 1998, Shannon *et al*. 2006). System-wide changes in abundance of species and species shifts (e.g., sardine and anchovy) are well-documented in this LME (e.g., Hampton *et al*. 1999, Shannon & O'Toole 2003). Fluctuations in abundance of the LME's fish stocks have also been detected through acoustic surveys for pelagic species such as sardines and anchovies (Barange *et al*. 1999, Hampton *et al*. 1999), and trawl surveys for demersal species (Hampton *et al*. 1999). The geographic displacement of stocks (e.g., *Sardinella aurita* and *S*. *maderensis* in Angola into Gabon) is also a common phenomenon with alongshore migration of fish populations across national boundaries in the Benguela Current LME having important implications for resource management. Global warming and associated phenomena are also expected to influence the LME's upwelling system, with potentially significant impact on the local food webs and the entire ecosystem, including fish recruitment and fisheries production.

Fluctuations in fish stocks can also have effects on top predators such as seabirds and seals (Crawford 1999, Crawford *et al*. 1992). For example, the distribution of Cape gannets, Cape cormorants, and African penguins has changed over the past three decades in response to changes in the distribution and relative abundance of sardine and anchovy (Crawford 1998). The high mortality and breeding failure of Cape fur seal colonies in Namibia in 1994 and 1995 can be attributed to low food availability resulting from low sardine abundance, a consequence of the catastrophic environmental variability and anomalous low oxygen events (O'Toole 1996).

Despite the vast scale of the fisheries in the LME, bycatch is not a major problem, and is taken mostly in the large pelagic and demersal fisheries. Discarding is controlled by strict regulations as well as by observers in some fisheries (e.g., Patagonian toothfish) but by self-policing where the bycatch is used as a luxury product. In the demersal trawl fishery of South Africa, 10% of the total catch is discarded (Walmsley-Hart *et al*. 2000). Both South African and Angolan purse seine fisheries yield bycatch rates between 10-20% of the total catch (Crawford *et al*. 1987).

The status of the fisheries is problematic, as the countries develop and implement national and regional fisheries policies and management programmes (GEF/ UNDP/ UNOPS/ NOAA 2002). Furthermore, some stocks show signs of response to environmental variability, e.g., recently correlated with a movement of sardines from Namibian waters to the south and southwest coasts toward the Agulhas Bank (van der Lingen *et al*. 2006). Sardine stocks in South Africa showed signs of recovery from the mid-1990s as a result of careful control of bycatch of juveniles, and the introduction of an operational management procedure which focused on rebuilding sardine stocks while optimally utilising the anchovy. However, recent stock assessment surveys of sardines around the Cape indicate a decline to very low levels compared with the mid 1990s.

III. Pollution and Ecosystem Health

Pollution: Virtually the entire coastline of the Benguela Current LME is exposed to the open ocean and experiences a relatively high degree of wave action. Strong wave action and currents tend to rapidly dissipate any pollution reaching the marine environment. Pollution is not a serious problem in the open marine areas of most of the LME, and is mostly evident in localised areas or hotspots such as ports and enclosed lagoons in all three countries. Poorly planned coastal developments, inadequate waste management, chronic oil pollution, inappropriate agricultural practices, contaminated stormwater run-off, as well as industrial and sewage wastewater discharges are among the factors that contribute to the deterioration of coastal and marine environments in the LME (UNEP 2005, Taljaard et al. 2006). Levels of pollution, with the exception of hotspots, are considered moderate (UNEP 2005). With poor urban infrastructure, there is a very real danger that a rapidly expanding urban population will pose a serious pollution threat, as untreated sewage is discharged into the sea in increasing volumes. HABs have been identified as a major transboundary problem, and their frequency of occurrence, spatial extent, and duration appear to be increasing (GEF/UNDP/UNOPS/NOAA 1999). Although HABs occur naturally in all three bordering countries (Tapscott 1999), several factors, including nutrient loading from anthropogenic activities (e.g., discharge of untreated sewage), can promote their incidence and spread. Toxins produced by HABs have led to mortalities of fish, shellfish, and humans, as well as anoxia in inshore waters that can cause mass mortality of marine organisms (GEF/UNDP/UNOPS/NOAA 1999).

Diamond mining operations impact negatively on the marine environment. Certain mining activities are conducted close to national boundaries (e.g., diamond mining near the Orange River mouth on both sides of the border between South Africa and Namibia), across which negative consequences may be transmitted. Diamond mining is also thought to affect marine living resources. For instance, although the dramatic decrease in Namibian rock lobster catches in the 1990s may be attributed to large scale environmental perturbations, it is evident that stock abundance might have also been influenced by marine diamond mining (Tapscott 1999). While mining is the primary cause of increased suspended solids in the marine areas, poor agricultural practices also contribute to this problem, particularly in estuaries, lagoons, and sheltered bays. Marine litter from land and shipping poses a serious growing problem throughout the LME, with significant transboundary consequences (GEF/UNDP/UNOPS/NOAA 1999). Oil and gas exploration and production are considered to pose a major threat, particularly off Angola, with oil spills sometimes causing severe local pollution which impacts artisanal fisheries. A substantial volume of oil is transported through the region, and poses a significant risk of contamination to coastal environments, damage to shared and straddling fish stocks, and to coastal infrastructure (GEF/UNDP/UNOPS/NOAA 1999).

Habitat and community modification: Four estuaries and five coastal lagoons in the Benguela Current LME are considered to be of transboundary significance. Several lagoons have been designated as Ramsar sites. Species that are endemic to only one or two estuarine systems within the LME are also present. The rare estuaries represent the only sheltered marine habitat in the LME, and are important both for biodiversity and as a focus of coastal development.

Habitat and community modification was assessed as severe in the Benguela Current LME (UNEP 2005). The TDA produced by the GEF-supported Benguela Current Large Marine Ecosystem (BCLME) Project has identified habitat destruction and alteration, including modification of the seabed and coastal zone, and degradation of coastscapes, as a transboundary problem in this LME (GEF/UNDP/UNOPS/NOAA 1999). Nevertheless, compared to other parts of the world, these effects are minor in the Benguela Current LME.

Modification of the few estuarine systems was found to be severe in the Benguela Current LME (UNEP 2005). There is some loss of rocky and sandy foreshores in the region due to port construction, seawalls, resort development, and coastal diamond mining particularly in South Africa and Namibia, and some sand mining in Angola. The invasion of a significant stretch of coastline by the alien mussel (*Mytilus galloprovincialis*) has drastically altered community structure and functional group composition on the shore. Exploitation of some species in the kelp beds and mangroves has led to changes in community structure within these habitats.

The potential impacts of sea level rise on the coastal areas of the Benguela Current LME include increased coastal erosion and inundation of coastal areas. Available evidence suggests that variability and extremes in rainfall pattern are increasing in the south, particularly in the drier western parts (Tyson 1986, Mason *et al*. 1999). The resulting projected changes in stream flow are likely to have serious consequences for the estuaries.

Pollution, particularly microbiological, chemical and solid waste as well as eutrophication, is expected to become worse in the future, if poorly planned urbanization and economic development in the coastal areas of this LME continue (UNEP 2005). Habitat modification and loss are also expected to become worse if current practices continue, increasing the concern over the cumulative future effects on the health of this ecosystem.

IV. Socioeconomic Conditions

A large part of the population of the countries bordering the Benguela Current LME lives in urban areas, many of which are situated near the coast. The LME and its resources are of considerable socioeconomic importance to the bordering countries. For example, the production of oil and gas off the coast is the most important economic activity in Angola, contributing 90% of the total Gross Domestic Product (GDP). The fisheries sector is an important source of revenue, food, and employment in the three countries. Traditionally, fisheries have contributed significantly to the livelihoods of coastal communities. In Angola, this sector currently rates third after oil and diamond mining, and is estimated to provide half of the animal protein consumed in the country. Fishing contributes 9% to Namibia's GDP (SADC 2003), with annual fisheries exports worth over 225 million US$. Although the fisheries sector plays a small part in South Africa's economy, contributing about 1% to GDP (FAO 2006), it makes a significant contribution to the regional economy of the Western Cape, which is the centre for the industrial fisheries. In some coastal areas of South Africa, this sector is the dominant employer.

Fisheries constitute an important contribution to national revenue, employment, and food security in the bordering countries. These include a variable and uncertain job market, loss of national revenue, loss of food security, erosion of sustainable livelihoods, missed opportunities through underutilisation and wastage, and loss of competitive edge on global markets (GEF/UNDP/UNOPS/NOAA 1999). Unpredictable fisheries yields have sometimes resulted in closure of fish processing plants. Conflicts between subsistence, artisanal, commercial, and recreational fisheries also arise when resources become scarce. Subsistence fisheries depletion may adversely affect the diet and consequently the health of those dependent on fisheries. In many coastal settlements fishing is the only source of livelihood for the poorer segments of the population. Reduced fisheries resources also lead to migration of human populations from rural coastal areas to cities, resulting in expansion of urban poverty. Regime shifts as well as factors possibly related to climate change may displace fish stocks, contributing to socio-economic difficulties and threats to breeding populations of endemic species, e.g. African penguin.

V. Governance

The Benguela Current LME is located within the UNEP Regional Seas for the West and Central Africa Region, which was forged in the early 1980s. The West and Central African Action Plan for the Protection and Development of the Marine Environment and Coastal Areas of the West and Central African Region, the Abidjan Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (Abidjan Convention) and associated Protocol Concerning Co-operation in Combating Pollution in Cases of Emergency were adopted by the Governments of the region in 1981. Projects on contingency planning, pollution, coastal erosion, environmental impact assessment, environmental legislation and marine mammals soon followed. A Conference of Plenipotentiaries, which met in Dakar, Senegal, in 1991, adopted the Regional Convention on Fisheries Cooperation among African States bordering the Atlantic Ocean (Dakar Convention), to which Angola has acceded.

There is a strong need for harmonising legal and policy objectives and for developing common strategies for resource surveys, as well as investment in sustainable ecosystem management in the Benguela Current LME. In 1997 a major regional cooperative initiative (BENEFIT: BENguela-Environment-Fisheries-Interaction and Training Programme) was launched jointly by Angola, Namibia, and South Africa, together with foreign partners (Norway and Germany) to enhance science capacity required for the optimal and sustainable utilization of living resources of the Benguela Current LME. This programme has been remarkably successful in developing cooperation among the three countries and in helping to strengthen marine scientific capacity in the region. A GEF grant and in-kind support of 38 million US$ to Angola, Namibia and South Africa, the three countries participating in the Benguela Current LME assessment and management project, will allow for significant additional support for initiating time-series measurement of selected indicators of the ecosystem’s productivity, fish and fisheries, pollution and ecosystem health, and socioeconomics.

In March 2000, this regional cooperation was further enhanced with the initiation of the implementation phase of the Benguela Current LME Programme (www.bclme.org), to assist Angola, Namibia, and South Africa to assess and manage the marine resources of the LME in an integrated and sustainable manner. This programme, which is funded in part by the GEF and the 3 participating countries, chiefly addresses transboundary problems in three key areas of activity: the sustainable management and utilisation of living resources; the assessment of environmental variability, ecosystem impacts and improvement of predictability; and maintenance of ecosystem health and management of pollution. Through this project, the Transboundary Diagnostic Analysis (TDA) and Strategic Action Plan (SAP) were used to review the existing knowledge on the status of, and to identify the threats to the Benguela Current LME. One of the main goals of the BCLME Programme was the creation of the Benguela Current Commission. This process was formalised through the signing of an Interim Agreement by the three countries on 29 August 2006 in Cape Town. This transitional management entity, which will last for four years, will be the precursor of the fully-fledged Benguela Current Commission whose function and responsibilities will be to implement an ecosystem approach to ocean governance in the Benguela region. This will include annual stock assessments of key economic species, annual ecosystem reports, the provision of advice on harvesting resource levels and other matters related to sustainable resource use, particularly fisheries and the management of the Benguela Current LME as a whole.

References

Barange, M., Hampton, I. and Roel, B.A. (1999). Trends in the abundance and distribution of anchovy and sardine on the South African continental shelf in the 1990s, deduced from acoustic surveys. South African Journal of Marine Science 21: 367-391.

Barange, M. and Pillar, S.C. (1992). Cross-shelf circulation, zonation and maintenance mechanisms of *Nyctiphanes capensis* and *Euphausia hanseni* (Euphausiacea) in the northern Benguela upwelling system. Continental Shelf Research 12(9): 1027-1042.

Belkin, I.M. (2008) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M. , Cornillon, P.C., and Sherman, K. (2008) Fronts in Large Marine Ecosystems of the world;s oceans. Progress in Oceanography, in press.

Crawford, R.J.M., Shannon, L.V. and Shelton, P.A. (1989). Characteristics and management of the Benguela as a Large Marine Ecosystem, p 169-219 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press. Boulder, Colorado.

Crawford, R.J.M. (1998). Responses of African penguins to regime changes of sardine and anchovy in the Benguela System, p 355-364 in: Pillar, S.C., Moloney, C.L. Payne, A.I.L. and Shillington, F.A. (eds), Benguela Dynamics: Impacts of Variability on Shelf - Sea Environments and their Living Resources. South African Journal of Marine Science 19.

Crawford, R.J.M. (1999). Seabird responses to long-term changes in prey resources off Southern Africa, p 688-705 in: Adams, N. and Slotow, R. (eds), Proceedings of 22nd International Ornithological Congress, Durban. Birdlife South Africa, Johannesburg, South Africa.

Crawford, R.J.M., Shannon, L.V. and Pollock, D.E. (1987). The Benguela Ecosystem. Part VI. The major fish and invertebrate resources. Oceanography and Marine Biology 25:353-505.

Crawford, R.J.M., Underhill, L.G., Raubenheimer, C.M., Dyer, B.M. and Martin, J. (1992). Top predators in the Benguela ecosystem – implications of their trophic position, p 95-99 in: Payne, A.I.L., Brink, K.J., Mann, K.J. and Hilborn, R. (eds), Benguela Trophic Functioning. South African Journal of Marine Science 12.

FAO (2003). Trends in Oceanic Captures and Clustering of Large Marine Ecosystems – Two Studies Based on the FAO Capture Database. FAO Fisheries Technical Paper 435.

FAO *(*2006). Fisheries country profiles. www.fao.org/fi/fcp/fcp.asp

Fidel, Q. and O'Toole, M.J. (2007). Changing State of the Benguela LME: Forcing, Climate Variability and Ecosystem Impacts. Presentation to the 2nd Global Conference on Large Marine Ecosystems,11-13 September 2007,Qingdao, PR China. Available online at www.ysfri.ac.cn/GLME-Conference2-Qingdao/ppt/18.1.ppt.

GEF/UNDP/UNOPS/NOAA (1999). Benguela Current Large Marine Ecosystem Transboundary Diagnostic Analysis.

GEF/UNDP/UNOPS/NOAA (2002). Benguela Current Large Marine Ecosystem Strategic Action Programme.

Hampton, I., Boyer, D.C., Penney, A.J., Pereira, A.F. and Sardinha, M. (1999). Integrated Overview of Fisheries of the Benguela Current Region: A Synthesis Commissioned by the United Nations Development Programme (UNDP) as an Information Source for the Benguela Current Large Marine Ecosystem (BCLME) Programme. Thematic Report 1: Synthesis and Assessment of Information on the BCLME. UNDP, Windhoek, Namibia.

Hamukuaya, H., M.J. O'Toole and P.M.J. Woodhead (1998). Observations of severe hypoxia and offshore displacement of Cape hake over the Namibian shelf in 1994. S. Afr. J. Mar. Sci. 19:57-59.

Lynam, C.P., Gibbon, M.J., Axelsen, B.E., Sparks, C.A.J., Coetzee, J., Heywood, B.G. and Brierley, A.S. (2006). Jellyfish overtake fish in a heavily fished ecosystem. Current Biology 16 (13): R492-R493.

Mason, S.J., Waylen, P.R., Mimmack, G.M., Rajaratnam, B. and Harrison, M.J. (1999). Changes in extreme rainfall events in South Africa. Climate Change 41:249-257.

Meeuwis, J.M. and Lutjeharms, J.R.E. (1990). Surface thermal characteristics of the Angola-Benguela front. South African Journal of Marine Science 9: 261-279.

O'Toole, M.J., Shannon L.V. de Barros Neto, and Malan, D.E. (2001). Integrated Management of the Benguela Current Region – A Framework for Future Development. P.228-251 In: B. von Bodungen and R.K. Turner (eds): Science and Integrated Coastal Management, Dahlem University Press, Berlin.

O'Toole, M.J. (1996). Namibia's marine environment. Namibia Environment 1:51-55.

Palomares, M.D. and Pauly, D. (2004). Biodiversity of the Namibian Exclusive Economic Zone: a brief review with emphasis on online databases. p. 53-74 in: U.R. Sumaila, Boyer, D., Skogen, M.D. and Steinshamm, S.I. (eds.) Namibia's fisheries: ecological, economic and social aspects. Eburon Academic Publishers, Amsterdam.

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

Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing down marine food webs. Science 279: 860-863.

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.

SADC (2003). Official SADC Trade Industry and Investment Review 2003. www.sadcreview.com/

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=29

Shannon, L.V., ed. (1985). South African ocean colour and upwelling experiment. Sea Fisheries Research Institute, Cape Town.

Shannon, L.V., Agenbag, J.J. and Buys, M.E.L. (1987). Large- and mesoscale features of the Angola-Benguela Front. South African Journal of Marine Science 5: 11-34.

Shannon, L.V. and O'Toole, M.J. (1998). An Overview of the Benguela Ecosystem. Collected papers, First Regional Workshop, Benguela Current Large Marine Ecosystem (BCLME) Programme, UNDP. 22-24 July 1998, Cape Town, South Africa.

Shannon, L.V. and O'Toole, M.J. (1999). Integrated Overview of the Oceanography and Environmental Variability of the Benguela Current Region: Thematic Report 2, Synthesis and Assessment of Information on BCLME: October 1998, UNDP, Windhoek, Namibia.

Shannon, L.V. and O'Toole, M.J. (2003). Sustainability of the Benguela: Ex Africa semper aliquid novi, p 227-253 in: Hempel, G. and Sherman, K. (eds), Large Marine Ecosystems of the World – Trends in Exploitation, Protection and Research. Elsevier, Amsterdam, The Netherlands.

Shannon, V., Hempel, G., Melanotte-Rizzoli, P., Moloney, C. and Woods, J. eds. (2006). Benguela: Predicting a Large Marine Ecosystem. Elsevier Science

Sherman, K. (2003). Physical, biological, and human forcing of biomass yields in Large Marine Ecosystems. ICES CM2003/P: 12.

Shillington, F.A. (1998). The Benguela upwelling system off southwestern Africa, p 583-604 in: Robinson, A.R. and Brink, K.H. (eds), The Sea, Vol. 11: The Global Coastal Ocean, Regional Studies and Syntheses. John Wiley and Sons, New York.

Taljaard, S., Morant, P.D., van Niekerki, L. and Lita, A. (2006). Southern Africa, p 29 - 49 in: UNEP/GPA (2006), The State of the Marine Environment: Regional Assessments. UNEP/GPA, The Hague.

Tapscott, C. (1999). An Overview of the Socioeconomics of some Key Maritime Industries in the Benguela Current Region (Draft): A Synthesis Commissioned by the United Nations Development Programme (UNDP) as an Information Source for the Benguela Current Large

Marine Ecosystem (BCLME) Programme. Thematic Report 6: Synthesis and Assessment of Information on theBCLME. UNDP, Windhoek, Namibia.
Tarr, R.J.Q. (2000). The South African abalone (*Haliotis midae*) fishery: A decade of challenges and change. Journal of Shellfish Research 19(1):537.
Tarr, R.J.Q., Williams, P.V.G. and Mackenzie, A.J. (1996). Abalone, sea urchins and rock lobster: a possible ecological shift may affect traditional fisheries. South African Journal of Marine Science 17:319-324.
Tarr, R.J.Q., Williams, P.V.G., Mackenzie, A.J., Plaganyi, E. and Moloney, C. (2000). South African fishery independent abalone surveys. Journal of Shellfish Research 19(1):537.
Tyson, P.D. (1986). Climate Change and Variability in Southern Africa. Oxford University Press, Cape Town, South Africa.
UNEP (2005). Prochazka, K., Davies, B., Griffiths, C., Hara, M., Luyeye, N., O'Toole, M., Bodenstein, J., Probyn, T., Clark, B., Earle, A., Tapscott, C. and Hasler, R. Benguela Current, GIWA Regional assessment 44. University of Kalmar, Kalmar, Sweden. http://www.giwa.net/publications/r44.phtml
van der Lingen, C.D., Shannon, L.J., Cury, P., Kreiner, A., Moloney, C.L., Roux, J-P, Vaz-Velho, F. (2006). Resource and ecosystem variability, including regime shifts, in the Benguela Current system. P.156 in Shannon, V., Hempel, G., Malanotte-Rizzoli, Paola, Moloney, C., Woods, J., eds. Benguela: Predicting a Large marine Ecosystem. Elsevier, Amsterdam, p.156.
Walmsley-Hart, S.A., Sauer, W.H.H. and Leslie, R.W. (2000). The quantification of by-catch and discards in the South African demersal trawling industry. 10th Southern African Marine Science Symposium (SAMSS 2000): Land, Sea and People in the New Millennium.
Weeks, S.J., Currie, B., Bakun, A. and Peard, K.R. (2004). Hydrogen sulphide eruptions in the Atlantic Ocean off Southern Africa: Implications of a new view based on SeaWiFS satellite imagery. Deep Sea Research Part I: Oceanographic Research Papers 51(2):153-172.
Willemse, N.E. and Pauly, D. (2004). Reconstruction and interpretation of marine fisheries catches from Namibian waters, 1950 to 2000. p. 99-112 in*:* U.R. Sumaila, Boyer, D., Skogen, M.D. and Steinshamm, S.I. (eds.) Namibia's fisheries: ecological, economic and social aspects. Eburon Academic Publishers, Amsterdam.

I-2 Guinea Current LME

S. Heileman

The geographical boundaries of the Guinea Current LME extend from the intense upwelling area of the Guinea Current in the north, to the northern seasonal limit of the Benguela Current in the south. While the northern border of the Guinea Current is distinct, but with seasonal fluctuations, its southern boundary is less well-defined, and is formed by the South Equatorial Current (Binet & Marchal 1993). Sixteen countries border the LME - Angola, Benin, Cameroon, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Gabon, Ghana, Equatorial Guinea, Guinea, Guinea-Bissau, Liberia, Nigeria, São Tomé and Principe, Sierra Leone and Togo. The tropical climate of the region is influenced by the northward and southward movements of the Inter-Tropical Convergence Zone (ITCZ) associated with the southwest monsoon and the Northeast Trade Winds. This LME covers an area of about 2 million km^2, of which 0.33% is protected, and includes 0.15% of the world's sea mounts and 0.20% of the world's coral reefs (Sea Around Us 2007). Twelve major estuaries and river systems (including the Cameroon, Lagos Lagoon, Volta, Niger-Benoue, Sanaga, Ogooue, and Congo rivers) form an extensive network of catchment basins enter this LME, which has the largest continental shelf in West Africa, although it should be noted that the West Africa's shelf is relatively narrow compared with many other shelves of the World Ocean. A volume on this LME was edited by McGlade *et al*. (2002), while another (Chavance *et al*. 2004) contains numerous accounts on this system. Other articles and reports include Binet & Marchal (1993), UNEP (2004) and Ukwe & Ibe (2006).

I. Productivity

The Guinea Current LME is a Class I, highly productive ecosystem (>300 gCm^{-2}y^{-1}). The Guinea Current LME is characterised by seasonal upwelling off the coasts of Ghana and Côte d'Ivoire, with intense upwelling from July to September weakening from about January to March (Roy 1995). Seasonal upwelling drives the biological productivity of this LME, which includes some of the most productive coastal and offshore waters in the world. The cold, nutrient-rich water of the upwelling system is subject to strong seasonal and inter-annual changes (Demarcq & Aman 2002, Hardman-Mountford & McGlade 2002), linked to the migration of the ITCZ. The LME is subject to long-term variability induced by climatic changes (Binet & Marchal 1993). Changes in meteorological and oceanographic conditions such as a reduction of rainfall, an acceleration of winds, an alteration of current patterns, and changes in nearshore biophysical processes might have significant consequences for biological productivity (Koranteng 2001). The coastal habitats and marine catchment basins also play an important role in maintaining the LME's productivity (Entsua-Mensah 2002).

Oceanic fronts (Belkin et al. 2008): Fronts in the Guinea Current occur mainly off its northern coast, in winter and summer (Figure I-2.1). The winter front appears to be the easternmost extension of the coastal Guinea Current that penetrates the Gulf; the front fully develops in January-February, reaching 5°E by March. The summer front emerges largely off Cape Three Points (2°W), usually in July-September, the upwelling season in the Gulf, and sometimes extends up to 200 km from the coast. Wind-induced upwelling develops east of Cape Palmas (7.5°W) and Cape Three Points owing to the coast's orientation relative to the prevailing winds. Current-induced upwelling and wave propagation also contribute to the observed variability in the Gulf (Ajao & Houghton 1998).

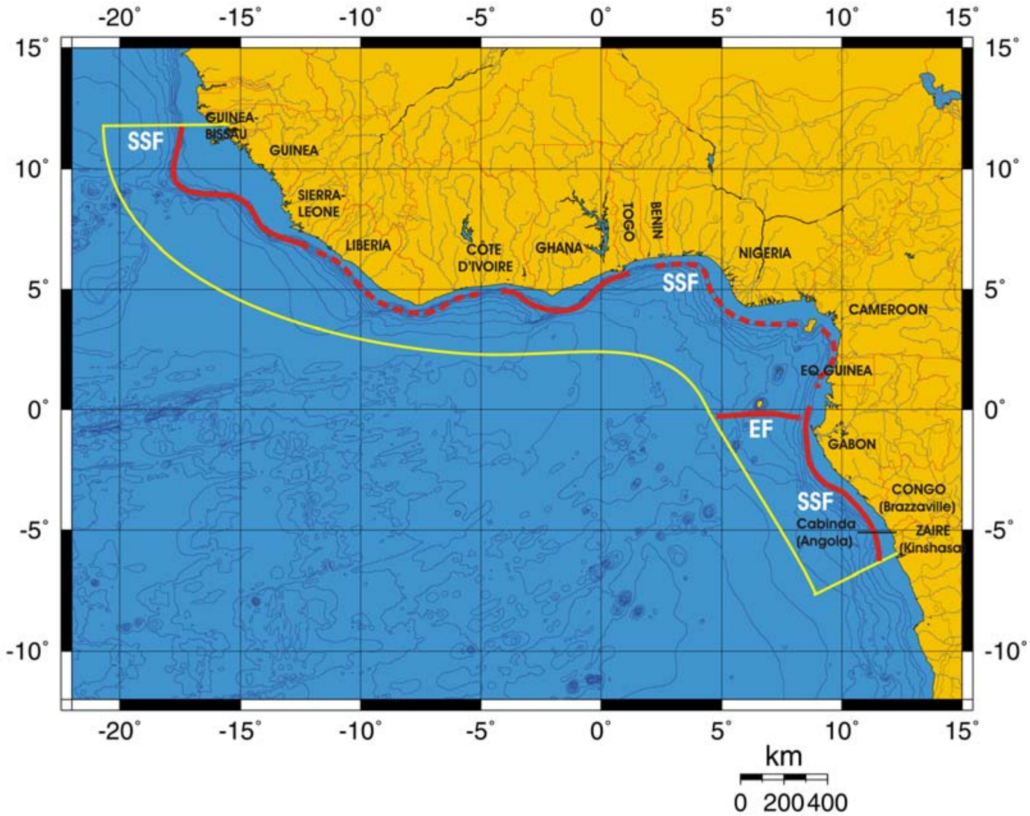

Figure I-2.1. Fronts of the Guinea Current LME. EF, Equatorial Front; SSF, Shelf-Slope Front (solid line, well-defined path; dashed line, most probable location). Yellow line, LME boundary. After Belkin (2008).

Guinea Current LME SST (after Belkin 2008)
Linear SST trend since 1957: 0.58°C.
Linear SST trend since 1982: 0.46°C.

The thermal history of the Guinea Current (Figure 1-2.2) included (1) a relatively stable period until the all-time minimum of 1976; (2) warming until the present at a rate of ~1°C in 30 years. Interannual variability of this LME is rather small, with year-to-year variations of about 0.5°C. The only conspicuous event, the minimum of 1976, cannot be linked to a similar cold event of 1972 in the two adjacent LMEs (Canary Current, Benguela Current) because of the 4-year time lag between the two events, which seems too long for oceanic advective transport of cold anomalies from one LME to another. The only plausible explanation invokes a cold offshore anomaly, probably localized within the equatorial band. Indeed, the North Brazil Shelf LME located on the western end of the equatorial zone saw the all-time SST minimum in 1976, the same year as the all-time minimum in the Guinea Current LME. Since the equatorial zone offers a fast-track conduit for oceanic anomalies, it remains to be seen from high-resolution data if both minima were truly synchronous – hence caused by large-scale (ocean-wide) forcing – or whether this cold anomaly propagated along the equator from one LME to another across the Atlantic Ocean.

The above results are consistent with an analysis of AVHRR SST data from 1982-1991 (Hardman and McGlade, 2002). The latter study has found 1982-1986 and 1987-1990 to be cool and warm periods respectively, with 1984 being exceptionally warm. As can be seen from Hadley data, 1984 was exceeded first by 1988 and then by 1998, when SST reached the all-time maximum probably linked to El-Niño. The SST variability mirrors the upwelling intensity, with strong upwelling in 1982-83, and weak upwelling in 1984 and 1987-1990 (Hardman and McGlade, 2002).

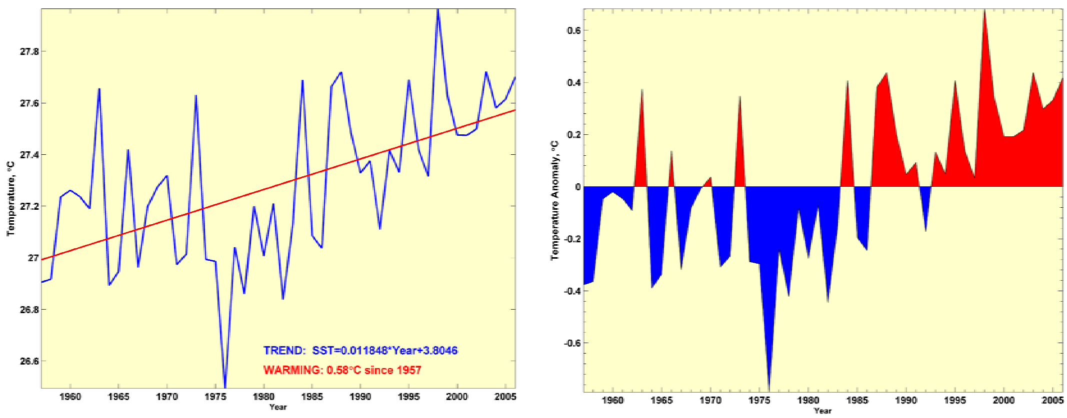

Figure I-2.2 Guinea Current LME mean annual SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

Guinea Current Trends in Chlorophyll and Primary Productivity: The Guinea Current LME is a Class I, highly productive ecosystem (>300 gCm^{-2}y^{-1}).

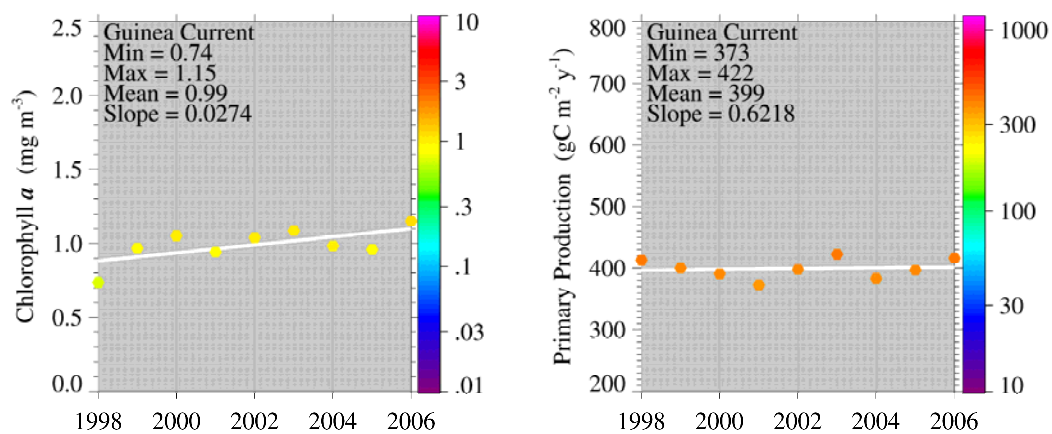

Figure I-2.3 Guinea Current LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The Guinea Current LME is rich in living marine resources. These include locally important resident stocks supporting artisanal fisheries, as well as transboundary straddling and migratory stocks that have attracted large commercial offshore foreign fishing fleets. Exploited species include small pelagic fishes (e.g., *Sardinella aurita*, *Engraulis encrasicolus*, *Caranx* spp.), large migratory pelagic fishes such as tuna (*Katsuwonus pelamis*, *Thunnus albacares* and *T*. *obesus*) and billfishes (e.g., *Istiophorus albicans*, *Xiphias gladius*), crustaceans (e.g., *Penaeus notialis*, *Panulirus regius*), molluscs (e.g., *Sepia officinalis hierredda*), and demersal fish (e.g., *Pseudotolithus senegalensis*, *P*. *typus*, *Lutjanus fulgens*) (Mensah & Quaatey 2002). Several fishery resource surveys have been conducted in the LME (Koranteng 1998, Mensah & Quaatey 2002), with the Guinean Trawling Survey conducted in 1963-1964 having been the first large-scale survey in West African waters (Williams 1968). Data from this survey have recently been recovered (Zeller *et al.* 2005).

Total reported landings show a series of peaks and troughs, although there has been an overall trend of a steady increase from 1950 to the early 1990, followed by fluctuations with a peak at just over 900,000 tonnes (Figure I-2.4). Due to the poor species breakdown in the official landings statistics, a large proportion of the landings falls in the category named 'mixed groups'. The trend in the value of the reported landings increased to a peak of around US$ 1 billion (in 2000 US dollars) in 1991 and thereafter declined considerably until the mid 1990s, before recovering to just over US $800 million (Figure I-2.5). Nigeria and Ghana account for about half of the reported landings in this LME, while European Union countries such as Spain and France, as well as Japan, are among the foreign countries fishing in the LME in recent times. Since the 1960s, high fishing pressure by foreign and local industrial fleets has placed the fisheries in the LME at risk (Bonfil *et al.*1998; Kacynski & Fluharty 2002).

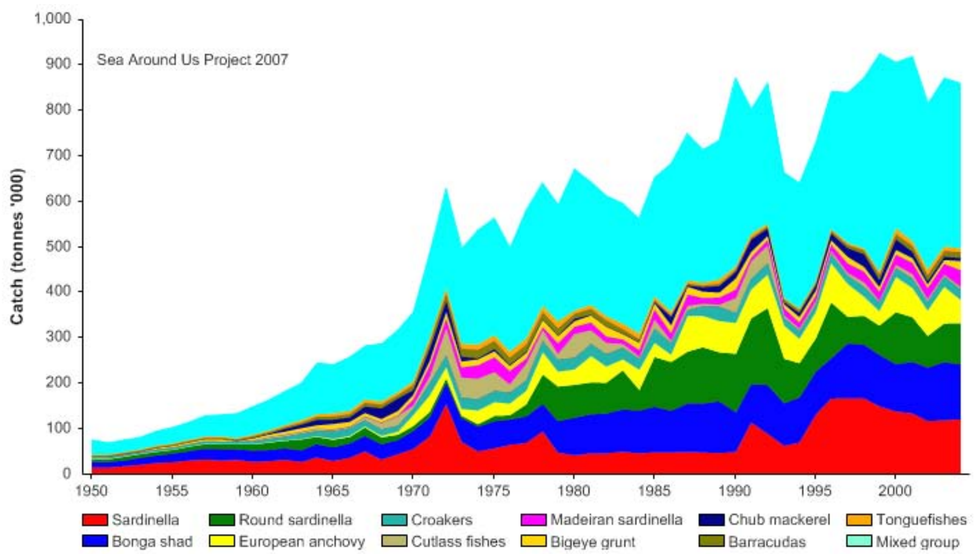

Figure I-2.4. Total reported landings in the Guinea Current LME by species (Sea Around Us 2007).

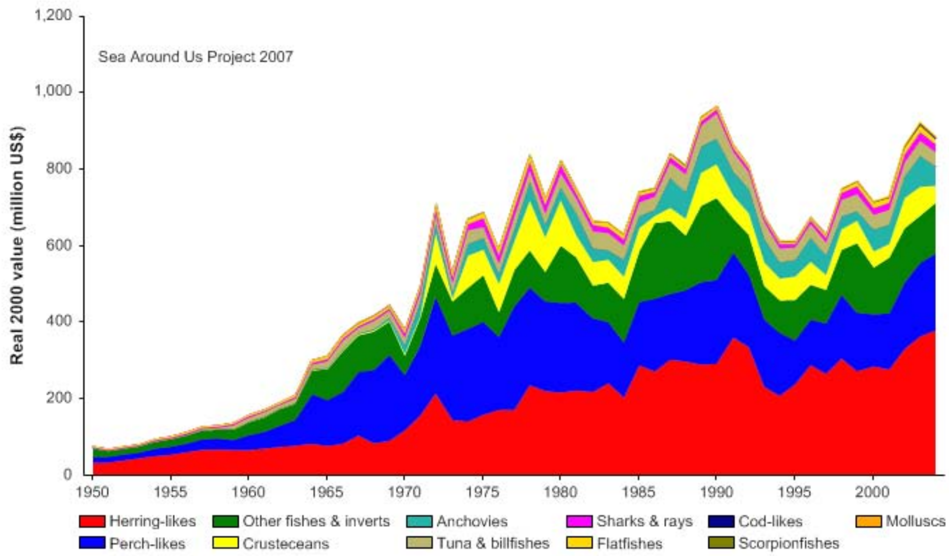

Figure I-2.5. Value of reported landings in the Guinea Current LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in the LME reached 9% of the observed primary production in the early 1990s and has fluctuated between 6 to 9% (Figure I-2.6). Nigeria and Ghana account for the two largest ecological footprints in the LME.

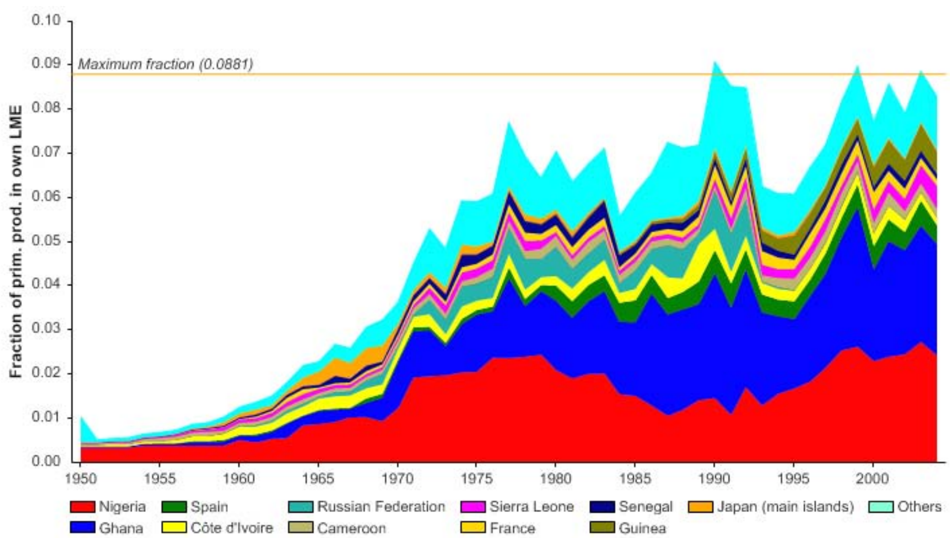

Figure I-2.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Guinea Current LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Since the mid 1970s, the mean trophic level of the reported landings (i.e., MTI; Pauly & Watson 2005) has declined (Figure I-2.7 top), an indication of a 'fishing down' of the local food webs (Pauly *et al*. 1998). The FiB index, on the other hand, has remained stable

(Figure I-2.7 bottom), suggesting that the increase in the reported landings over this period has compensated for the decline in the MTI (Pauly & Watson 2005).

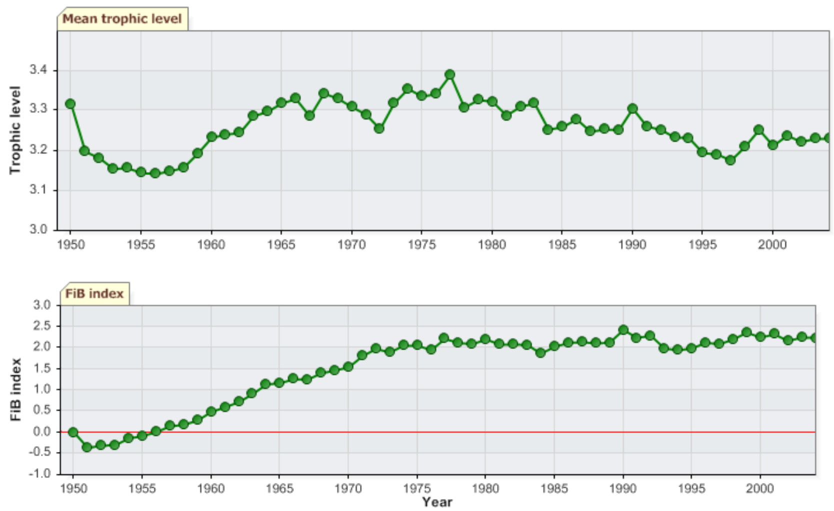

Figure I-2.7. Trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Guinea Current LME (Sea Around Us 2007).

The Stock-Catch Status Plots show that fisheries on collapsed stocks are rapidly increasing in numbers (Figure I-2.8, top). However, the catch is still overwhelmingly supplied by stocks in the fully exploited category (Figure I-2.8, bottom), which account for just under 30% of the stocks.

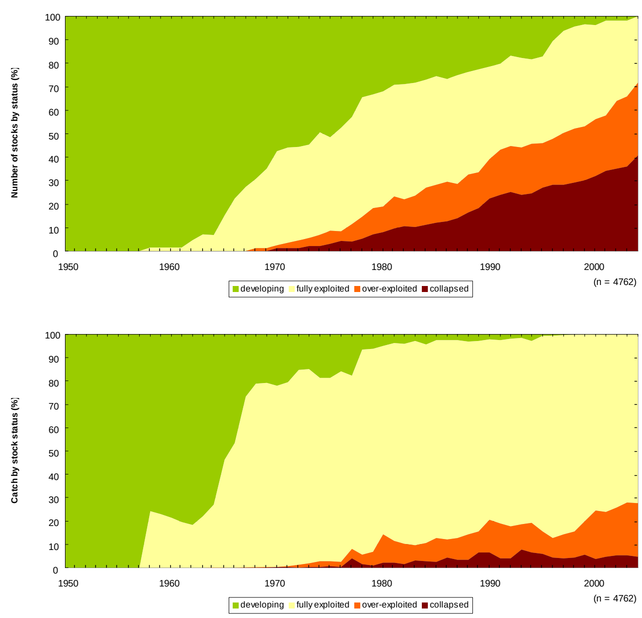

Figure I-2.8. Stock-Catch Status Plots for the Guinea Current LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', 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).

While some fish stocks such as skipjack tuna, small pelagic fish in the northern areas of the Gulf of Guinea, and offshore demersal fish and cephalopods are underexploited (Mensah & Quaatey 2002), the level of exploitation was found to be significant in this LME (UNEP 2004). The Guinea Current LME TDA (see Governance) has identified the decline in fish stocks and unsustainable fishing as a major transboundary problem (UNIDO/ UNDP/ UNEP/ GEF/ NOAA 2003) and reviews of the status of the LME's fisheries resources indicate that several fish stocks are either overexploited or close to being fully exploited (Ajayi 1994, Mensah & Quaatey 2002). These include small pelagics and shrimps in the western and central Gulf of Guinea and coastal demersal resources throughout the LME. There is also evidence of depletion of straddling and highly migratory fisheries stocks, with heavy exploitation of yellow-fin and big-eye tunas (Mensah & Quaatey 2002). Overexploitation has resulted in declining stock biomass and catch per unit effort (CPUE), particularly for inshore demersal species, and this decline has been attributed to trawlers operating in inshore areas (Koranteng 2002, Koranteng & Pauly 2004).

The use of small-sized mesh, especially in trawl, purse and beach seine nets is a widespread problem, especially in the central part of the region. This practice leads to excessive bycatch, but because these catches, mainly of juvenile fishes, are generally utilised, they are discarded only in a few fisheries (e.g., the shrimp fishery). Other destructive fishing practices such as the use of explosives and chemicals are also common in the inshore areas (e.g., see Vakily 1993).

There are indications that overexploitation has altered the ecosystem as a whole, with impacts at all levels, including top predators. Species diversity and average size of the most important fish species have declined as a result of overexploitation (Koranteng 2002, FAO 2003). Strong patterns of fish variability in the LME are thought to be related to strong interactions between species or communities, as well as to environmental forcing (Cury & Roy 2002). The influence of environmental variability on fish stock abundance and distribution in the LME has been demonstrated, for example, by Williams (1968), Koranteng *et al*. (1996), and Roy *et al*. (2002). Several oceanographic features that influence fish recruitment have also been identified (Hardman-Mountford & McGlade 2002). For instance, the abundance and distribution of small pelagic fish species are controlled mainly by the intensity of the seasonal coastal upwelling, which also determines the period of the main fishing season (Bard & Koranteng 1995).

The most significant changes in species abundance are reflected in sardinella (*Sardinella aurita*) and triggerfish (*Balistes capriscus*). The sardinella fishery experienced a collapse in 1973, and was followed by a vast increase in the abundance of triggerfish between 1973 and 1988. The decline of the triggerfish after 1989 was followed by an increase of the sardinella to unprecedented levels during the 1990s (Binet & Marchal 1993, Cury & Roy 2002). Koranteng & McGlade (2002) attributed the almost complete disappearance of the triggerfish after the late 1980s to environmental changes and an upwelling intensification off Ghana and Côte d'Ivoire. The highly variable environment of the Guinea Current LME contributes to uncertainty regarding the status of fisheries stocks and yields which is likely to increase considering the impact of global climate change (UNIDO/UNDP/ UNEP/ GEF/ NOAA 2003). Therefore, environmental variability must be considered in the sustainable use and management of the region's fisheries resources. Cooperation among the countries bordering this LME in the management of the fisheries resources would help to improve the fisheries situation in the future.

III. Pollution and Ecosystem Health

Pollution: LMEs have experienced various stresses as a result of the intensification of human activities. The coastal and marine environments of the Guinea Current are seriously polluted in the vicinity of large cities (Scheren & Ibe 2002). An assessment of the state of the environment with respect to the GPA land-based sources of pollution in this region is given by Gordon & Ibe (2006). More than 60% of existing industries are concentrated in the coastal areas and an estimated 47% of the population lives within 200 km of the coast. Pollution from land-based sources is particularly important, and together with sea-based sources, has contributed to a deterioration of water quality in the bordering countries. The TDA has identified the deterioration of water quality from land and sea-based activities as one of the four broad environmental problems in the LME (UNIDO/UNDP/UNEP/GEF/NOAA 2003). Overall, pollution was assessed as moderate, but more serious in coastal hotspots associated with the larger coastal cities (UNEP 2004). Despite being mainly localised, pollution also has transboundary impacts in this LME through the transport of contaminants by wind and water currents along the coast.

Sewage is one of the main sources of coastal pollution in the LME (UNEP 1999) and arises from generally poor treatment facilities and widespread release of untreated sewage into coastal areas (Scheren & Ibe 2002). Microbiological pollution is localised around coastal cities and remains a problem in terms of human health. Organic pollution from domestic, industrial and agricultural wastes has resulted in eutrophication and oxygen depletion in some coastal areas (Awosika & Ibe 1998, Scheren & Ibe 2002). While the incidence of eutrophication is not widespread and tends to be episodic, there are instances of continuous and persistent causes of eutrophication in large coastal water bodies (e.g., the Ebrié Lagoon in Abidjan). The increasing occurrence of HABs is of concern to the bordering countries (Ibe & Sherman 2002). Pollution from solid waste originating from domestic and industrial sources and offshore activities is severe across the entire region, with the enormous bulk of solid waste produced daily being a serious threat. Pollution from suspended solids is moderate along the coast, and arises mainly from soil loss from farms and deforested areas. Although much of the silt is trapped in dams and reservoirs, this has caused extensive siltation of coastal water bodies.

Chemical pollution is serious in coastal hotspots. Some chemical contaminants enter the aquatic environment through the use of pesticides, agro-chemicals including persistent organic pollutants (POPs) and as industrial effluents. Large quantities of residues (e.g., phosphate, mercury, zinc) from mining operations are discharged into coastal waters. Oil production is an important activity in some of the countries, especially Nigeria, and most of these countries have important refineries on the coast, only a few of which have proper effluent treatment plants. Moreover, the LME's coastline lies to the east and downwind of the main oil transport route from the Middle East to Europe. Pollution from spills is significant, and arises mainly from oil spills from production points, loading and discharge points and from shipping lanes. Significant point sources of marine pollution have been detected around coastal petroleum mining and processing areas, releasing large quantities of oil, grease and other hydrocarbon compounds into the coastal waters of the Niger delta and off Angola, Cameroon, Congo and Gabon. It is estimated that about 4 million tonnes of waste oil are discharged annually into the LME from the Niger Delta sub-region (UNIDO/ UNDP/ UNEP/ GEF/ NOAA 2003). Much of the oil found on beaches originates from spills or tank washing discharged from tankers in the region's ports (Portmann *et al*.1989). Because of the wind and ocean current patterns in the Guinea Current LME, any oil spill from the offshore or shore-based petroleum activities could easily become a regional problem.

Habitat and community modification: The Guinea Current LME is interspersed with diverse coastal habitats such as lagoons, bays, estuaries and mangrove swamps.

Besides being important reservoirs of biological diversity, these habitats provide spawning and breeding grounds for many fish, including transboundary species and shellfish in the region, and therefore are the basis for the regenerative capacity of the region's fisheries (Ukwe *et al*. 2001). Both anthropogenic activities and natural processes threaten these habitats. Although this is mainly localised, there are transboundary impacts related to migratory and straddling fish stocks that may use these habitats as spawning and nursery grounds.

It is estimated that 30% of habitat modification has been caused by natural processes, including erosion and sedimentation due to wave action and strong littoral transport. Coastal erosion is the most prevalent coastal hazard in the LME. Human activities, on the other hand, are thought to be largely responsible for habitat modification in this LME (UNEP 1999). Habitat and biodiversity loss due to hydrocarbon exploration and exploitation is significant. Many coastal wetlands have been reclaimed for residential and commercial purposes, with accompanying loss of wetland flora and fauna. The introduction of exotic species is also recognised as a transboundary problem (UNIDO/UNDP/UNEP/GEF/NOAA 2003).

Mangroves and estuaries have suffered the most losses, followed by sandy foreshores and lagoons. The LME has large expanses of mangrove forests (the mangrove system of the Niger Delta is the third largest in the world). However, these mangrove forests are under pressure from over-cutting, conversion into agricultural farms or saltpans, erosion, salinity changes, and other anthropogenic impacts (e.g., pollution). About 60% of Guinea's original mangroves and nearly 70% of the original mangrove vegetation of Liberia is estimated to be lost (Macintosh & Ashton 2002). The grass *Paspalum vaginatum* is replacing the original mangrove vegetation in these countries. In other areas the extent of mangrove destruction is: 45% in the Lake Nokoue area (Benin), 33% in the Niger delta (Nigeria), 28% in the Warri Estuary (Cameroon) and 60% in Côte d'Ivoire. Dam construction has led to reduction of freshwater and sediment discharge in the lower estuarine reaches of the rivers and altered the extent of intrusion of the estuarine salt wedge inland. This has important ecological effects on the flora and fauna of the coastal habitats.

Climate change is expected to also lead to habitat modification and loss. The IPCC (2001) has reported that Africa is highly vulnerable to climate change and sea level rise. Studies conducted in Nigeria estimated that over 1,800 km^2, or 2% of Nigeria's coastal zone, and about 3.68 million people would be at risk from a 1 m rise in sea level (Awosika *et al*. 1992). Moreover, Nigeria could lose over 3,000 km^2 of coastal land from floods and coastal erosion by the end of the 21st Century. Sea level rise would result in modification or loss of flora, fauna and biodiversity in flooded lands and coastal habitats, particularly in brackish waters (Ibe & Ojo 1994).

The LME is an important reservoir of marine biological biodiversity and has natural resources of global significance. Green, leatherback, hawksbill, loggerhead and olive ridley turtles are found in the LME. The LME is also inhabited by marine mammals (whales, dolphins, and manatees), among which are the Atlantic humpback dolphin and the African manatee, both of which appear on the IUCN Red List of endangered species (IUCN 2002). The humpbacked dolphin is classified as highly endangered and the African manatee as vulnerable under the Convention on International Trade of Endangered Species (CITES).

IV. Socioeconomic Conditions

The 16 countries bordering the Guinea Current LME have an estimated total population of 300 million. At the present rate of population growth, this is expected to double in 20-

25 years. Approximately 47% of the people live within 200 km of the coast (GIS analysis based on ORNL 2003). Rapid expansion of coastal populations with areas of high population densities has resulted from high population growth rates and movements between rural and urban areas (UNEP 1999). In addition, many of the region's poor are crowded in the coastal areas for subsistence activities such as fishing, farming, sand and salt mining and production of charcoal.

The Guinea Current LME and its natural resources represent a source of economic and food security for the bordering countries. In addition to being of major importance for food security in this region, fisheries also provide employment for thousands of people and are a substantial source of foreign exchange for countries such as Angola, Côte d'Ivoire, Ghana, and Guinea. A large proportion of the population could potentially be affected by overexploitation of fisheries (UNEP 2004). A reduction in the size and quality of the fish catch has widespread socioeconomic impacts, since more than 500,000 men and women along the coast from Mauritania to Cameroon are employed in the artisanal fishery (Bortei-Doku Aryeetey 2002). In Ghana, the national fish requirement has been estimated at 794,000 tonnes for a population of about 17.9 million, but fisheries production in 1998 achieved only 57% of the required volume (Akrofi 2002).

Over the past three decades, there has been evidence of reduced economic returns, loss of employment and user conflicts between artisanal and large commercial trawlers for access to the fishery resources (ACOPS/UNEP 1998). Côte d'Ivoire reported losses of about US$80 million in 1998 due to decreased fishing activities. This loss was attributed to the degradation of the coastal zone and its resources (GEFMSP/ACOPS/UNESCO 2001). The overexploitation of transboundary and migratory fish by offshore foreign fleets is having a detrimental effect on artisanal fishermen as well as on those coastal communities that depend on the near-shore fisheries resource for food. Local communities are at risk if artisanal fishing cannot proceed. This becomes particularly serious in the context of exploding demographics in the coastal areas and the fact that most of the fish catch is exported out of the region where all the countries, except Gabon, were classified by the FAO as Low Income Food Deficit Countries in 1998 (FAO 2002).

The socioeconomic impacts of pollution and habitat degradation include loss of recreational resources, pollution of food sources, decline in living coastal resources, and subsequent loss of subsistence livelihoods and reduction in food security and economic activity. In addition, increased pressure on governments to produce alternative livelihoods, and political instability at local or national levels may also arise. Coastline erosion also causes some concern because of the threat to coastal settlements, tourist infrastructure, agricultural and recreational areas, harbour and navigation structures, and oil producing and export handling facilities. The costs of coastal protection and habitat restoration can be high. For example, the restoration of the Korle Lagoon in Ghana has cost the government nearly US$65 million (Government of Ghana 2000). Public health risks from the presence of sewage pathogens and HABs are of concern. The cost of treatment of water-borne diseases is significant. For example, the Korle Lagoon Ecological Restoration Project (Government of Ghana 2000) estimated the cost of treatment to range from US$10 to US$50 per person, depending on the duration and intensity of the disease.

V. Governance

The countries bordering the Guinea Current LME participate in numerous bodies that work together on various aspects of coastal degradation and protection of living marine resources. The LME comes under the UNEP Regional Seas Programme for the West and Central Africa Region (see the Benguela Current LME for more information). They have adopted several international environmental conventions and agreements, among which is the Abidjan Convention and the Dakar Convention.

Mechanisms to provide regional collaboration on transboundary issues in the form of a regional coordination unit, and regionally agreed environmental quality standards and monitoring protocols and methods have been limited. These and other environmental issues are being addressed through joint projects. The GEF-supported Guinea Current Large Marine Ecosystem Project (Ibe & Sherman 2002, Ukwe *et al*. 2006) is an ecosystem-based effort to assist countries adjacent to the Guinea Current LME to achieve environmental and resource sustainability by shifting from short-term sector-driven management objectives to a longer-term perspective and from managing commodities to sustaining the production potential for ecosystem-wide goods and services (www.chez.com/gefgclme/). The pilot phase of this project (Water Pollution Control and Biodiversity Conservation in the Gulf of Guinea Large Marine Ecosystem) involved Côte d'Ivoire, Ghana, Togo, Benin, Nigeria and Cameroon, and ended in November, 1999. In 1998, the Ministerial Committee of this pilot project signed the Accra Declaration on Environmentally Sustainable Development of the Guinea Current LME, as an expression of their common political will for the sustainable development of marine and coastal areas of the Gulf of Guinea.

The second phase of this project 'Combating Living Resource Depletion and Coastal Area Degradation in the Guinea Current LME through Ecosystem-based Regional Actions', has extended the pilot phase to include 10 additional countries (Angola, Congo Brazzaville, Congo-Kinshasa, Equatorial Guinea, Gabon, Guinea, Guinea-Bissau, Liberia, São Tomé and Príncipe, and Sierra Leone). This phase includes the preparation of a TDA and a SAP. A project goal is to build capacity of the countries to work jointly and in concert with other nations, regions and with GEF projects in West Africa to define and address priority transboundary environmental issues within the framework of their existing responsibilities under the Abidjan Convention and the UNEP Regional Seas Programme. The Ministers of Environment of Angola, Benin, Cameroon, Congo, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea Bissau, Liberia, Nigeria, Sao Tome and Principe, Sierra Leone and Togo, gathered in Abuja, Nigeria, 21 – 22 September, 2006 on the occasion of the First Meeting of Ministers responsible for the implementation of the Guinea Current Large Marine Ecosystem (GCLME) Project; the Ministers signed the Abuja Declaration on 22 September, establishing the framework for an Interim Guinea Current Commission. The Interim Commission was brought into force on 22 September 2006 in Abuja, Nigeria, and is presently operating from Accra, Ghana. The focus of the Interim Commission is on achieving sustainable development through integration of environmental concerns in planning,accounting and budgeting, building capacity through multi-sector participation, management of transboundary water bodies and living resources of land, forests and biodiversity conservation, and development of information and data exchanges.

References

ACOPS/UNEP (1998). Background Papers to the Conference on Cooperation for the Development and protection of the Coastal and Marine Environment in Sub-Saharan Africa, 30 November-4 December 1998, Cape Town, South Africa.

Ajao, E. A. and Houghton, R.W. (1998). Coastal ocean of Equatorial West Africa from 10°N to 10°S. p 605-630 in: Robinson, A.R. and Brink, K.H. (eds). The Sea, Vol. II: The Global Coastal Ocean, Regional Studies and Syntheses. John Wiley and Sons, New York, U.S.

Ajayi, T.O. (1994). The Status of Marine Fishery Resources of the Gulf of Guinea, in: Proceedings of the 10th Session Food and Agricultural Organisation of the United Nations, CECAF, 10-13 October 1994, Accra, Ghana.

Akrofi, J.D. (2002). Fish utilisation and marketing in Ghana: State of the art and future perspective, p 345-354 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Awosika, L.F. and Ibe, C.A. (1998). Geomorphic features of the Gulf of Guinea shelf and littoral drift dynamics, p 21-27 in: Ibe, A.C., Awosika, L.F. and Aka, K. (eds). Nearshore Dynamics and Sedimentology of the Gulf of Guinea. IOC/UNIDO. CEDA Press, Cotonou, Benin.

Awosika, L.F., French, G.T. Nicholls, R.J. and Ibe, C.A. (1992). The impacts of sea level rise on the coastline of Nigeria, in: O'Callahan, J. (ed). Global Climate Change and the Rising Challenge of the Sea. Proceedings of the IPCC Workshop at Margarita Island, Venezuela, 9–13 March 1992. National Oceanographic and Atmospheric Administration, Silver Spring, U.S.

Bard, F. and Koranteng, K.A. eds. (1995). Dynamique et Usage des Ressources en Sardinelles de l'Upwelling Cotier du Ghana et de la Cote d'Ivoire. ORSTOM Edition, Paris.

Belkin, I.M. (2008) Rapid warming of Large Marine Ecosystems. Progress in Oceanography, in press.

Belkin, I.M., Cornillon, P.C. and Sherman K. (2008). Fronts in Large Marine Ecosystems of the world's oceans. Progress in Oceanography, in press.

Binet, D. and Marchal, E. (1993). The large marine ecosystem of shelf areas in the Gulf of Guinea: Long-term variability induced by climatic changes, p 104-118 in: Sherman, K., Alexander, L.M. and Gold, B. (eds), Large Marine Ecosystems: Stress, Mitigation, and Sustainability. AAAS, Washington D.C., U.S.

Bonfil, R., Munro, G., Sumaila, U.R., Valtysson, H., Wright, M., Pitcher, T., Preikshot, D., Haggan, N. and Pauly, D. (1998). Impacts of distant water fleets: an ecological, economic and social assessment. Fisheries Centre Research Reports 6(6).

Bortei-Doku Aryeetey, E. (2002). Socioeconomic aspects of artisanal marine fisheries management in West Africa, p 323-344 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Chavance, P., Ba, M., Gascuel, D., Vakily, M. and Pauly, D. (eds). (2004). Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement. Actes du symposium international, Dakar - Sénégal, 24-28 juin 2002. Office des publications officielles des communautés Européennes, XXXVI, collection des rapports de recherche halieutique ACP-UE 15, 532 p. + Appendices.

Cury, P. and Roy, C. (2002). Environmental forcing and fisheries resources in Cote d'Ivoire and Ghana: Did something happen? p 241-260 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Demarcq, H. and Aman, A. (2002). A multi-data approach for assessing the spatio-temporal variability of the Ivorian-Ghanaian coastal upwelling – Understanding pelagic fish stock dynamics, p 83-92 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Entsua-Mensah, M. (2002). The Contribution of Coastal Lagoons to the Continental Shelf Ecosystem of Ghana, p 161-169 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

FAO (2002). Low Income Food Deficit Countries. www.fao.org/ NEWS/FACTFILE/FF9607-e.htm

FAO (2003). Trends in Oceanic Captures and Clustering of Large Marine Ecosystems—2 Studies Based on the FAO Capture Database. FAO Fisheries Technical Paper 435.

GEFMSP/ACOPS/UNESCO (2001). Sub-Saharan Africa Project, National Report of Côte d'Ivoire.

Gordon, C. and Ibe, C. (2006). West and Central Africa, p 5-28 in: UNEP/GPA (2006), The State of the Marine Environment: Regional Assessments. UNEP/GPA, The Hague.

Government of Ghana (2000). Korle Lagoon Ecological Restoration Project, EIA (2000). Ministry of Works and Housing, Ghana.

Hardman-Mountford, N.J. and McGlade, J.M. (2002). Variability of physical environmental processes in the Gulf of Guinea and implications for fisheries recruitment: An investigation using remotely sensed sea surface temperature, p 49-66 in: McGlade, J., Cury, P., Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Ibe, A.C. and Ojo, S.O. (1994). Implications of Expected Climate Change in the West and Central African Region: An Overview. UNEP Regional Seas Report and Studies 148.
Ibe, C. and Sherman, K. (2002). The Gulf of Guinea Large Marine Ecosystem Project: Turning challenges into achievements. 27-39 in: McGlade J., P. Cury P., Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.
IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K. and New York, U.S.
IUCN (2002). The World Conservation Union Red List. www.redlist.org/
Kaczynski, V.M, and Fluharty, D.L. (2002) European policies in West Africa: who benefits from fisheries agreements? Marine Policy 26: 75–93.
Koranteng, K.A. and D. Pauly. (2004). Long term trends in demersal fishery resources of Ghana in response to fishing pressure. p. 243-252. In: P. Chavance, M. Ba, D. Gascuel, M. Vakily et D. Pauly (Editors). Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement. Actes du symposium international, Dakar - Sénégal, 24-28 juin 2002. Office des publications officielles des communautés Européennes, XXXVI, collection des rapports de recherche halieutique ACP-UE 15.
Koranteng, K.A. (2002). Status of demersal fishery resources on the inner continental shelf off Ghana. 261- 274 in: McGlade, J., P. Cury, K. Koranteng and N.J. Hardman-Mountford,eds. The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.
Koranteng, K.A. and McGlade, J.M. (2002). Physico-chemical changes in continental shelf waters of the Gulf of Guinea and possible impacts on resource variability. 93-102 in: McGlade, J., Cury, P., Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.
Koranteng, K.A. (2001). Structure and dynamics of demersal assemblages on the continental shelf and upper slope off Ghana, West Africa. Marine Ecology Progress Series 220:1-12.
Koranteng, K.A. (1998). The Impacts of Environmental Forcing on the Dynamics of Demersal Fishery Resources of Ghana. Ph.D. Thesis, University of Warwick, Warwick, U.K.
Koranteng, K.A., McGlade, J.M. and Samb, B. (1996). A Review of the Canary Current and Guinea Current Large Marine Ecosystems, p 61-83 in: ACP-EU Fisheries Research Report 2.
Macintosh, D.J. and Ashton, E.C. (2002). A Review of Mangrove Biodiversity Conservation and Management. Final Report, Centre for Tropical Ecosystem Research. University of Aarhus, Denmark.
McGlade, J., Cury, P., Koranteng, K. and Hardman-Mountford, N.J., eds. (2002). The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.
Mensah, M.A. and Quaatey, S.N.K. (2002). An overview of fishery resources and fishery research in the Gulf of Guinea. 227-239 in: J. McGlade, Cury, P., Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.
ORNL (2003). Landscan 2002. Oak Ridge National Laboratory. http://www.ornl.gov/gist/
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.
Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing down marine food webs. Science 279: 860-863.
Portmann, J.E., Biney, C., Ibe, A.C. and Zabi, S. (1989). State of the Marine Environment: West and Central African Region. UNEP Regional Seas Reports and Studies 108.
Roy, C. (1995). The Côte d'Ivoire and Ghana coastal upwellings: Dynamics and changes. In: Bard, F. and K.A. Koranteng, eds. Dynamique et Usage des Ren sardinelles de l'Upwelling Cotier du Ghana et de la Côte d'Ivoire. ORSTOM edition, Paris, France.
Roy, C., Cury, P., Fréon, P. and Demarcq, H. (2002). Environmental and resource variability off northwest Africa and in the Gulf of Guinea: A review. 121-139 in: McGlade, J., Cury, P., Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

Scheren, P.A.G.M. and Ibe, A.C. (2002). Environmental pollution in the Gulf of Guinea: A regional approach. 299-320 in: McGlade, J., Cury, P. Koranteng, K. and Hardman-Mountford, N.J. (eds), The Gulf of Guinea Large Marine Ecosystem: Environmental Forcing and Sustainable Development of Marine Resources. Elsevier, The Netherlands.

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=28

Ukwe, C.N., Ibe, C. A. and Sherman, K. (2006). A sixteen-country mobilization for sustainable fisheries in the Guinea Current Large Marine Ecosystem. Ocean and Coastal Management 49: 389-412..

Ukwe, C.N., Isebor, C.E. and Alo, B.I. (2001). Improving the Quality of Coastal Waters in the Gulf of Guinea Large Marine Ecosystem through Mangrove Restoration. Proceedings of the 12th Biennial Coastal Zone Conference, July 15–19, 2001. NOAA/CSC/20120-CD, Cleveland, Ohio, U.S.

UNEP (1999). Overview of Land-based Sources of and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the West and Central African Region UNEP Regional Seas Reports and Studies 171, UNEP, Nairobi, Kenya.

UNEP (2004). Abe, J., Wellens-Mensah, J., Diallo, O.S. and Mbuyil Wa Mpoyi, C. Guinea Current, GIWA Regional Assessment 42. University of Kalmar, Kalmar, Sweden. http://www.giwa.net/publications/r42.phtml

UNIDO/UNDP/UNEP/GEF/NOAA. (2003). Guinea Current Large Marine Ecosystem Transboundary Diagnostic Analysis. Regional Project Coordinating Centre, Abidjan, Côte d'Ivore.

Vakily, M. (1993). Dynamite fishing in Sierra Leone. NAGA, the. ICLARM Quarterly 16(4):7-9.

Williams, F. (1968). Report on the Guinean Trawling Survey. Organisation of African Unity Scientific and Technical Research Commission 99.

Zeller, D., Froese, R. and Pauly, D. (2005). On losing and recovering fisheries and marine science data. Marine Policy 29: 69-73.

I-3 Canary Current LME

S. Heileman and M. Tandstad

The Canary Current LME is a major upwelling region off the coast of northwest Africa, bordered by Morocco, Mauritania, Senegal, Guinea-Bissau, the Canary Islands (Spain), Gambia, Cape Verde and Western Sahara (a disputed, non-self governing territory). It is strongly influenced by the Canary Current, which flows along the African coast from north to south between 30° N – 10° N and offshore to 20° W (Barton 1998). The surface waters of the Canary Current are relatively cool as a result of the entrainment of upwelled water from the coast as it flows southwards (Mittelstaedt 1991). Several drainage systems in this region flow only seasonally because of the high seasonal variation in rainfall, e.g., the Senegal and Gambia Rivers. The LME has an area of about 1.1 million km^2, of which 0.77% is protected, and contains 0.12% of the world's sea mounts and 0.01% of the world's coral reefs (Sea Around Us 2007). There are 7 major estuaries and river systems draining into the LME including the Casamance, Senegal and Gambia. Books, book chapters and reports pertaining to the LME include Bas (1993), Prescott (1993), Roy & Cury (2003), Chavance *et al.* (2004) and UNEP (2005).

I. Productivity

The Canary Current LME is a Class I, highly productive ecosystem (>300 gCm^{-2}y^{-1}). Hydrographic and climatic conditions play a major role in driving the dynamics of this LME, which shows seasonal and longer-term variations (Bas 1993, Roy & Cury 2003). Climatic variability is the primary driving force, with intensive fishing being the secondary driving force, of biomass changes in the LME (FAO 2003, Sherman 2003). The biomass of small pelagic fish species is clearly influenced by the LME's oceanographic conditions (Bas 1993). A cyclonic gyre in the west acts to accumulate plankton from the north. The massive nutrient-rich upwelling stimulates, although with fluctuating intensity, seasonal bursts of primary productivity, then progressively of zooplankton and small pelagic fishes, other opportunistic feeders and predators, including mackerel, tuna and marine mammals in the pelagic zones. The normal community of zooplankton is composed of copepods, but mysid shrimps are also very important in this LME (Bas 1993). Inhabited by a large number of endemic and migrant species, the Canary Current LME is a unique ecosystem of global significance.

Oceanic fronts (after Belkin (2008): Persistent northerly winds along the coast of Northwest Africa cause a year-round coastal upwelling. The upwelled water is drawn offshore by the Canary Current and also by current jets formed farther south, protruding transversally several hundred km offshore (Barton 1998, Barton *et al*. 1998). These processes create a large number of surface-intensified fronts that develop seasonally, synchronised with coastal upwelling (Figure I-3.1). The upwelling zone expands in winter and shrinks in summer and fall. It also migrates meridionally as the season progresses. The zone begins its southern advance in October and reaches its maximum southward extent (5°N) in January-March, then retreats northward, reaching 15°N in late summer.

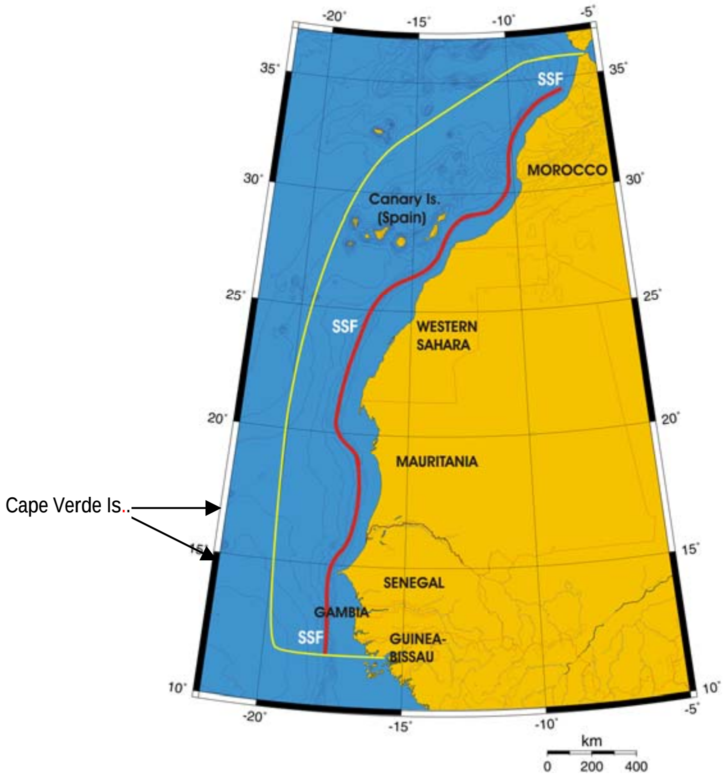

Figure I-3.1 Fronts of the Canary Current LME. SSF, Shelf-Slope Front. Yellow line, LME boundary. After Belkin (2008).

Canary Current SST (after Belkin, 2008)
Linear SST trend since 1957: 0.48°C.
Linear SST trend since 1982: 0.52°C.

The moderate-rate warming since 1957 was interrupted by reversals (Figure 1-3.2). The most significant cold spell occurred after the warm event of 1969 and lasted a decade. The near-all-time maximum of 1969 was concurrent with the all-time maximum in the Caribbean Sea LME. This simultaneity likely was not coincidental since both LMEs are strongly affected – and connected – by trade winds blowing westward across the North Atlantic. The synchronism of both maxima across the North Atlantic, over a 5,000-km distance, strongly suggests a dominant role of atmospheric teleconnection, albeit westward advection by trade wind currents could also have played a role.

The Canary Current is one of four major areas of coastal upwelling in the World Ocean. Global warming is thought to increase the strength of equatorward winds, and hence to increase the upwelling intensity, leading to cooling in major upwelling areas. While the California Current LME and Humboldt Current LME indeed cooled over the last 25 years, the Canary Current actually warmed, as did the Benguela Current LME. This result is especially striking since the 20th century intensification of coastal upwelling off Northwest Africa is well documented (McGregor et al., 2007). The ongoing warming in the Mauritanian waters area is shown to have been beneficial for round sardinella (*Sardinella aurita*), which thrives after upwelling intensification in spring followed by retention of upwelled water – and primary production enhancement - over shelf in summer (Zeeberg et al., 2008).

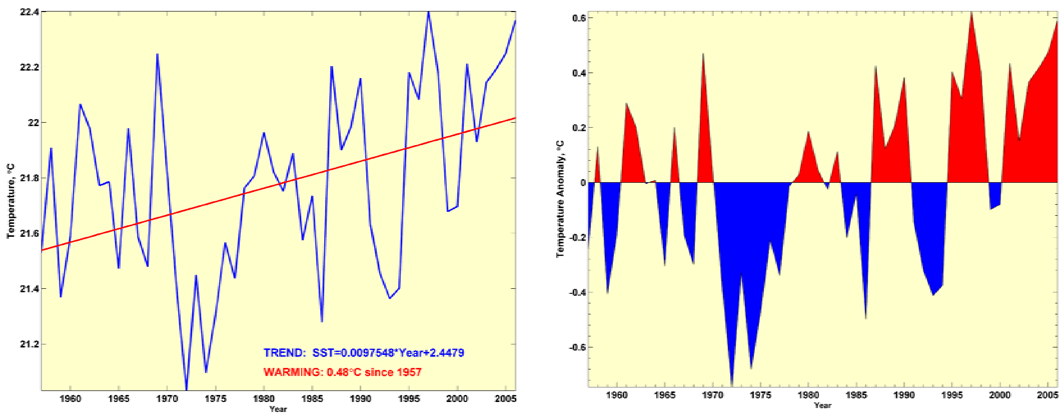

Figure 1-3.2 Canary Current LME mean annual SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology, (after Belkin, 2008).

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

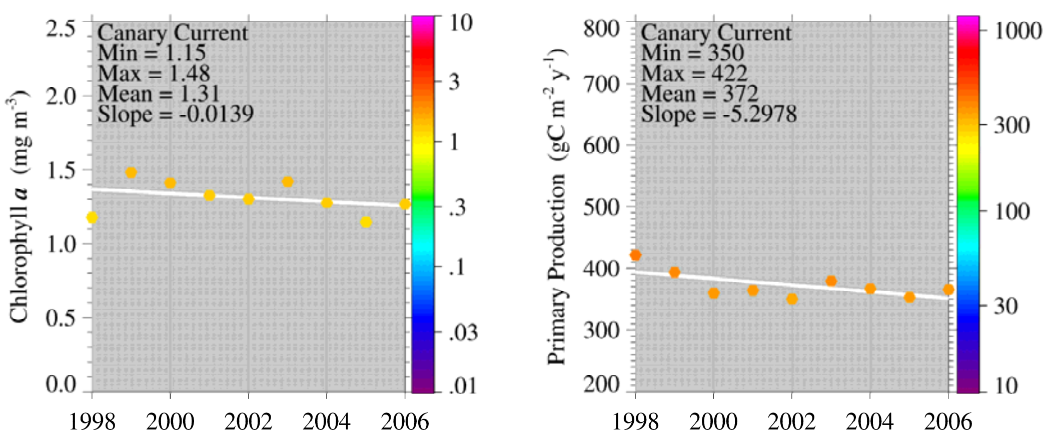

Figure I-3.3. Canary Current LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The Canary Current LME is rich in fisheries resources among which are the small pelagic fish such as sardine (*Sardina pilchardus*), sardinella (*Sardinella aurita*, *S. maderensis*), anchovy (*Engraulis encrasicolus*), chub mackerel (*Scomber japonicus*) and horse mackerel (Trachurus spp.) constitute more than 60% of the catch in the LME. Other species caught in the LME include tuna (e.g., *Katsuwonus pelamis*), coastal migratory pelagic finfish, hakes (*Merluccius merluccius*, *M. senegalensis* and *M. poli*), a wide range of demersal finfish including *Pagellus bellotti*, Pseudotolithus sp., *Dentex canariensis*, *Galeoides decadactylus* and *Brachydeuterus auritus*, cephalpods (*Octopus vulgaris*, Sepia spp., and *Loligo vulgaris*) and shrimps (*Parapenaeus longirostris* and *Penaeus notialis*). Most of these species are transboundary or migratory, with the distribution of tunas often extending beyond the bordering countries' EEZs into international waters. Fishing activities in the LME have increased over the last three decades. In addition to small national fleets, the EEZs of Mauritania, Senegal, Gambia and Guinea Bissau all accommodate large distant water fleets from the European Union and Asia (FAO 2005a).

Total reported landings in the LME increased steadily to about 2.4 million tonnes in 1976, followed by a series of large fluctuations between 1.5 and 2.5 million tonnes (Figure I-3.4). The fluctuations in the total landings are also reflected in their value, which varies between US$1.5 billion and just under US$3 billion (in 2000 US dollars; Figure I-3.5). In recent years, however, both total reported landings and especially their value have undergone a noticeable decline.

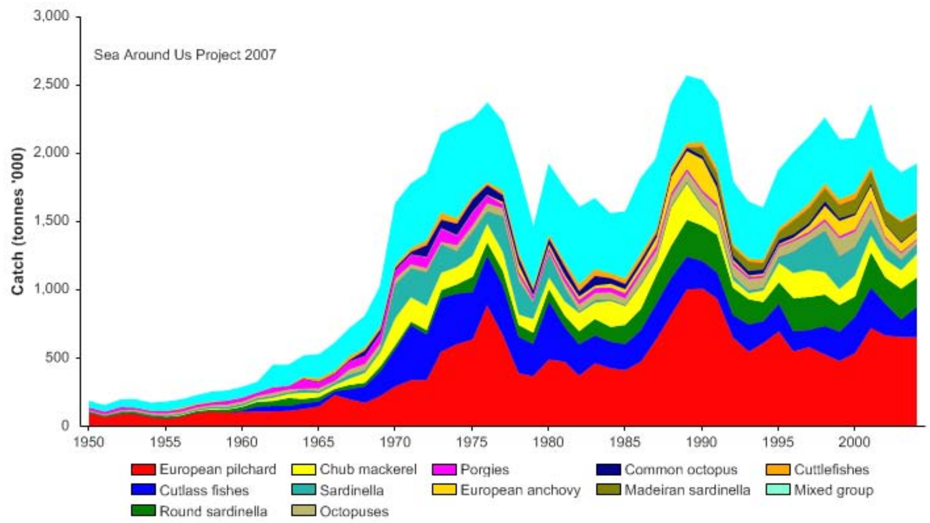

Figure I-3.4. Total reported landings in the Canary Current LME by species (Sea Around Us 2007).

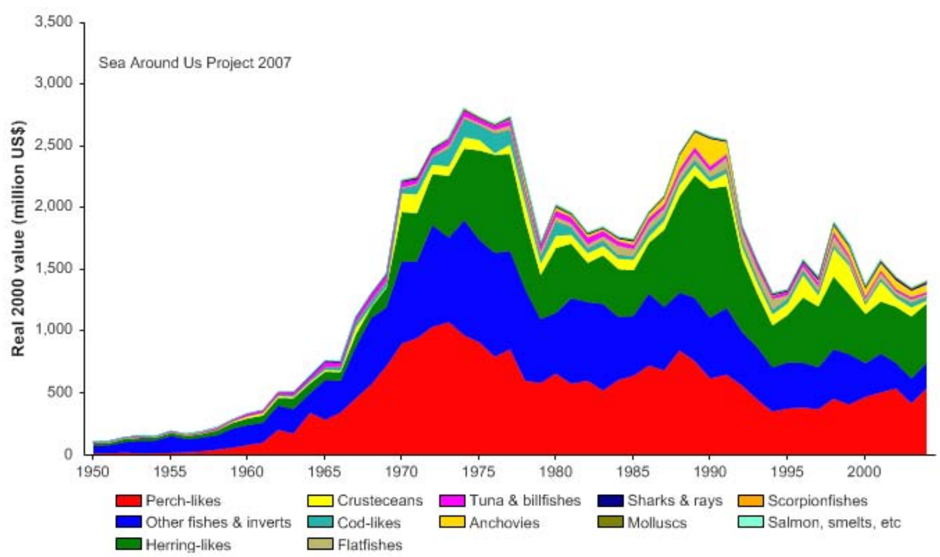

Figure I-3.5. Value of reported landings in the Canary Current LME by commercial groups (Sea Around Us 2007)

From the late 1960s to early 1990s, distant-water fleets from members of the former USSR, Spain and others countries accounted for most of the landings from the LME (Bonfil *et al.* 1998). In 1992, reported landings from the former USSR ceased, and the bulk of the landings were reported by the now independent countries of the former USSR. Substantial foreign fishing continues, notably off Mauritania (Gascuel 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landing in the LME reached 25% of the observed primary production in the early 1970s, but has since fluctuated to about 15% (Figure I-3.6). Spain, Morocco and Senegal are currently the countries with the largest ecological footprints in this LME, although the Soviet Union's republics (Russian Federation, Ukraine, Lithuania, Latvia, and Estonia) also accounted for large footprints in the 1970s and 1980s.

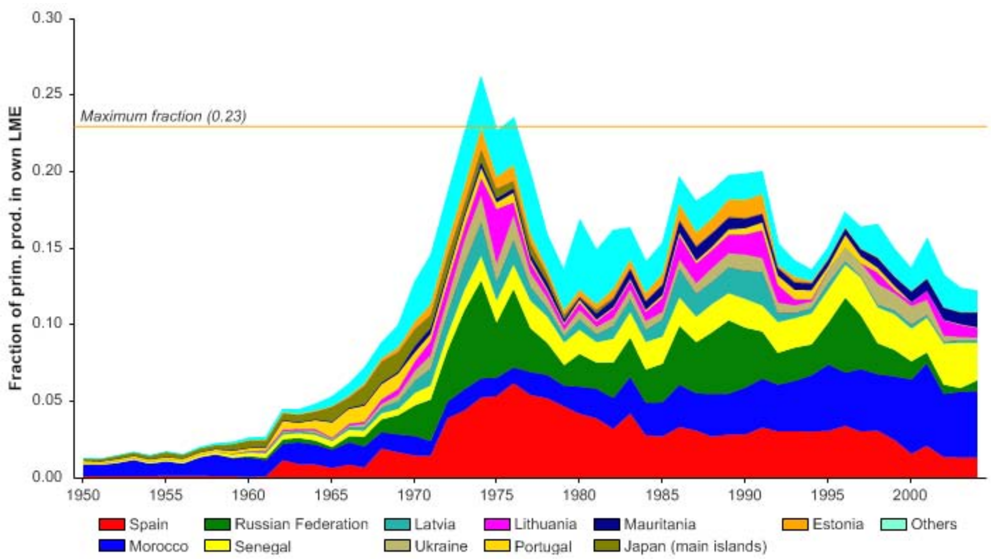

Figure I-3.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Canary Current LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) has declined since the mid 1970 (Figure I-3.7 top), an indication of a 'fishing down' of the food web (Pauly *et al*. 1998). The FiB index indicates a possible slight decline during this period (Figure I-3.7 bottom), suggesting a situation in which catches that should increase when trophic levels decrease, are in fact decreasing (Pauly & Watson 2005).

The Stock-Catch Status Plots show that about 40% of exploited stocks can be considered collapsed, and another 40% are overexploited in the LME (Figure I-3.8, top). Still, over 70% of the catch originates from stocks that are classified as 'fully exploited' (Figure I-3.8, bottom).

Thus, overexploitation is of major concern in the bordering countries (UNEP 2005) of the Canary Current LME. Many fish stocks are being fished at or beyond maximum sustainable yield (MSY) levels in Senegal, Mauritania, Morocco and Gambia, and in some countries such as Morocco, Senegal and Gambia, demersal production over the past decade has been near and even above the MSY level (FAO 2005a). With the exception of Cape Verde, the intensification of fishing activities in the region has had a

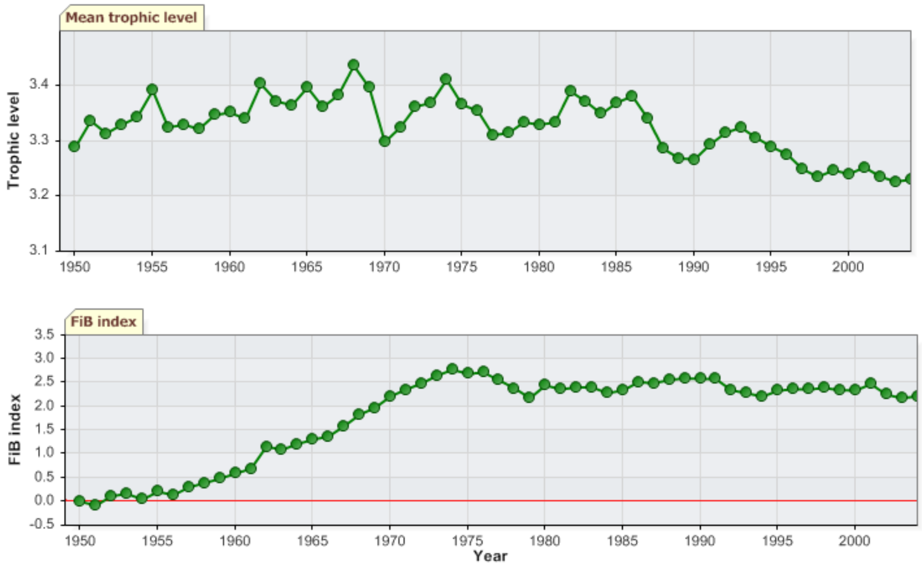

Figure I-3.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Canary Current LME (Sea Around Us 2007).

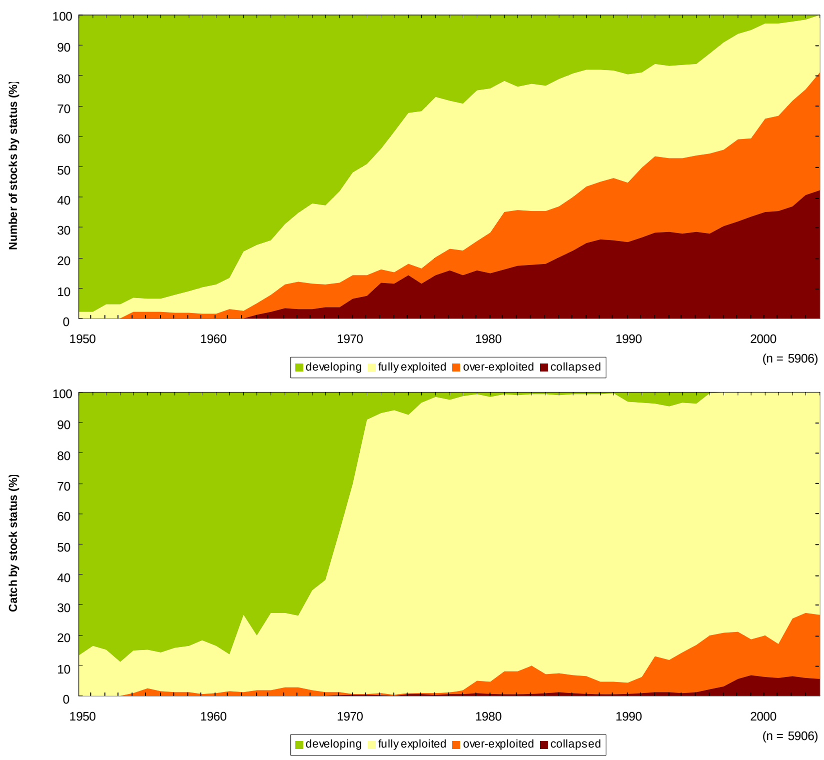

Figure I-3.8. Stock-Catch Status Plots for the Canary Current LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', 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).

drastic impact on the pelagic resources, which have undergone a strong decline in productivity (Fonseca 2000). High fishing pressure has also led to the marked decline in the catch of the demersal finfish fishery accompanied by the opportunist expansion of fisheries targeting octopus (Bas 1993, European Commission 2005). Bycatch and discards were assessed as moderate, and can be attributed to the use of small-meshed nets, especially in the artisanal fishery (UNEP 2005), although high discard rates were observed in the Spanish cephalopod trawl fishery in Morocco (Balgueiras 1997). Cephalopod trawlers fishing in Mauritania and Senegal were also found to discard 72% and 60-75% of their total catch, respectively, while the Senegalese mixed fleet targeting finfish and shrimps in shallow waters had a discard rate of 67%. Pech et al. (2001) explore the difficulties in fitting a model of flexible multifleet–multispecies fisheries to Senegalese artisanal fishery data.

Fish stocks in the LME are also expected to be influenced by global warming and the consequent rise in sea surface temperatures. Upwelling intensity and sea surface temperatures are strongly linked, and are believed to affect both the spatial distribution and abundance of fish in the LME (Cury & Roy 1991, Roy & Cury 2003). For example, periods of high sardine abundance appear to be associated with the ENSO variability (Roy & Cury 2003). Positive values of the Southern Oscillation Index are also associated with enhanced upwelling and coincide with higher catch rates (Roy & Reason 2001). The impact of climate on fish stock abundance and distribution must be taken into consideration in the development of fisheries management programmes in this LME.

III. Pollution and Ecosystem Health

Pollution*:* Pollution is a major concern in localised hotspots, especially in emerging coastal mega-cities that are primary centres of industrial development and high population densities (UNEP 2005). There is strong evidence of serious localised degradation in the coastal environment of this and adjacent LMEs (Gordon & Ibe 2006). Eutrophication and the decay of organic matter create anoxia and subsequent fish mortality particularly in areas around major cities, bays and ports. Most countries in the Canary Current LME have environmental laws related to industrial, toxic, hazardous and medical wastes. However, enforcement of these regulations is inadequate, and pollution from these sources is evident in localised areas, especially near expanding coastal cities like Dakar (pop. 2,500,000 in 2007) in Senegal and Dar-el-Beida (Casablanca: pop. 3,900,000 in 2007) and Rabat (pop. 1,810,000 in 2007) in Morocco.

Some common features across the countries of the Canary Current LME are desertification, overgrazing on fragile rangelands, cultivation of crops on steep slopes (Cape Verde) and soil erosion. The resulting run-off and increased turbidity in the major rivers leads to increased turbidity in coastal waters throughout the LME. Domestic and industrial solid waste management and disposal are of concern in the bordering countries, and efforts are being made to address the problem. Spills around oil refineries are a chronic source of localised water column contamination. There is some evidence of minor spills of hazardous materials, but this is limited to harbours and fishing ports (UNEP 2002)

Habitat and community modification: Industrial development in the coastal zone of the Canary Current LME, as well as migration of people from inland rural areas to the coastal industrial centres, have led to increasing threats of coastal degradation and moderate habitat modification in this LME (UNEP 2005). Over the last 2 - 4 decades, marshes, swamps and mangroves have been degraded and lost through natural factors such as drought, but more significantly, through human activities such as unsustainable agricultural practices, urbanisation, mining and other industries, natural resources exploitation, and modification of rivers that has reduced water supply to wetlands and marine areas.

Approximately 30% of the surface area of wetland habitats has been permanently destroyed. Those that have not been destroyed are being modified largely because of continuing human activities. In some coastal lagoons there is a progressive decline of certain endemic algae species such as *Psidona oceanica*, due to the spread of *Caulerpa prolifera*. The replacement of mangroves by ‘tannes’, with a complete disappearance of mangroves, is evident in some areas. The construction of dams across certain tributaries of, for example, the Gambia and Senegal Rivers, has resulted in the die-back of extensive areas of mangrove forests. Significant quantities of sand from coastal erosion also contribute to mangrove death, by preventing the influx of sea water into mangrove areas. In addition, data indicate the extension of aquatic plants in estuaries and bays, particularly due to flow alteration and reduction (UNEP 2002). Ongoing and planned initiatives aimed at the control of pollution and the conservation of important habitats of the Canary Current LME (see Governance) are expected to lead to an improvement in the health of this LME (UNEP 2005).

IV. Socioeconomic Conditions

The total population of the countries bordering the Canary Current LME is about 58 million, of which an estimated 70% are directly reliant on the LME for their livelihoods. More than 60% of the population lives in the coastal areas where most cities and industrial infrastructure are located (UNEP 2002). These coastal populations are engaged mostly in marine fisheries, agriculture and tourism activities. The backbone of the countries’ economy is based on agriculture and fisheries, with a very weak industrial sector contribution to GDP.

Fisheries provide livelihoods, fish protein supplies and revenue for the bordering countries, several of which are classified as Low-Income Food-Deficit Countries (FAO 2005b). These countries do not necessarily benefit from increased fish supplies or increased government revenue when foreign fleets access their waters (Kaczynski & Fluharty 2002). Much of the catch of the foreign fleets is exported or shipped directly out of the region, while compensation for access is often low compared to the value of the catch.

Overfishing has severe socioeconomic consequences in this LME, and includes reduction in national incomes, loss in fishing industries, reduction of food supply, loss of employment and increase in the cost of maritime surveillance as well as reduction of biological diversity. Loss of employment (which may be as high as 80% in Senegal) translates to impoverishment and suffering of people, among them being vulnerable groups such as women, children and the elderly. Overfishing also leads to conflicts among different user groups for dwindling resources. Depleted fisheries resources accentuate protein deficiency particularly in small children, leading to diseases such as kwashiorkor. This situation is aggravated mostly in rural areas where livestock is under severe threat from droughts. Management of the fisheries of the Canary Current LME to ensure sustainability is therefore of prime concern to all the bordering countries.

The economic sectors affected by pollution and habitat modification and loss are agriculture, fisheries, and tourism. Impacts on fisheries as well as the agriculture sectors can have severe economic ripples since they make a significant contribution to the overall national product (more than 30% of GDP in the region). Socioeconomic impacts include those of overfishing, as described above, as well as loss of tourism and recreational amenities. Migration of people (occasionally transboundary) including conflicts over resources could also arise. Loss of or modification of wetlands also results in shortage of firewood that is vital to the majority of households in rural areas. Pollution around densely populated coastal cities such as Dakar is a major cause of losses in the tourism industry in Senegal. In addition, pollution of coastal waters presents significant public health risks, through contaminated bathing beaches and consumption of contaminated fishery products. Loss and degradation of habitats also compromise the quality of water as wetlands generally act as sinks for pollutants from land-based activities. This in turn aggravates public health problems.

V. Governance

Several regional and sub-regional institutions and programmes are operating in the Canary Current LME region, including the UNEP Regional Seas Programme for the West and Central Africa Region (see the Benguela Current LME for more information), the Gambia River Development Authority, the Senegal River Development Authority and the Sub-Regional Fisheries Commission. The Ministerial Conference on Fisheries Cooperation among African States Bordering the Atlantic Ocean and the Fishery Committee for the Eastern Central Atlantic bring together all the states sharing the basins and coastal areas to ensure the proper use and management of their resources. Most of the bordering countries are signatories to various international environmental conventions, including the Abidjan Convention and Dakar Convention. Cape Verde, Guinea, Morocco and Senegal are members of the International Commission for the Conservation of Atlantic Tunas and have formally agreed to the subsequent Protocols of 1992 and 1997. All the Canary Current LME countries, except Mauritania and Morocco, are members of the Economic Community of West African States.

The coordinated management of this LME is a challenge (Prescott 1993). The historically fragmented nature of coastal and marine resource management is a legacy of the colonial past as well as of the political situation in these countries. There are regionally incompatible laws and there is a paucity of environmental regulations. The preparatory phase of the project 'Protection of the Canary Current Large Marine Ecosystem' has been finalised and a full scale project developed. The long-term environmental goal of the CCLME program is to "reverse the degradation of the Canary Current Large Marine Ecosystem caused by over-fishing, habitat modification and changes in water quality by adoption of an ecosystem-based management approach" and the CCLME project objective is to "enable the countries of the Canary Current Large Marine Ecosystem to address priority trans-boundary concerns on declining fisheries, associated biodiversity and water quality through governance reforms, investments and management programs." A Preliminary TDA has confirmed the focus of regional concern on depleted fisheries and on habitat, associated biodiversity and water quality critical to fisheries.

The project will assist the seven participating countries to meet the sustainable fisheries target of WSSD including contribution to implementation of the Environment Action Plan under NEPAD. Close linkages are to be developed with GEF projects for the river basins draining into the LME and the neighbouring GEF International Waters projects on the Guinea Current and the Benguela Current LMEs. Consistent with other GEF LME projects, a TDA and SAP will be prepared for the Canary Current LME.

References

Balguerias, E. (1997). Discards in fisheries from the eastern central Atlantic, in: Technical Consultation on Reduction of Wastage in Fisheries, Tokyo, Japan, FAO Fisheries Report 547, Supplement.

Barton E.D. (1998). Eastern boundary of the North Atlantic: Northwest Africa and Iberia, p 633-657 in: Robinson, A.R. and Brink, K.H. (eds), The Global Coastal Ocean: Regional Studies and Syntheses. The Sea Vol. II.

Barton, E. D., Aristegui, J. Tett, P., Canton, M., Garcia-Braun, J., Hernadez-Leon, S., Nyhajaer, L., Almeida, C., Almunia, J., Ballestros, S., Basterretxea, G., Escanez, J., Garcia-Weill, L., Hernandez-Guerra, A., Lopez-Laatzen, F., Molina, R., Montero, M.F., Navarro-Perez, E., Rodriguez, J.H., Lenning, K.V., Velez, H. and Wild, K. (1998). The transition zone of the Canary Current upwelling region. Progress in Oceanography 41(4): 455–504.

Bas, C. (1993). Long-term variability in the food chains, biomass yields and oceanography of the Canary Current ecosystem, p 94-103 in: Sherman K., Alexander, L.M. and Gold, B.D. (eds), Large Marine Ecosystems: Stress, Mitigation, and Sustainability. AAAS, Washington D.C., U.S.

Belkin, I.M. (2008). Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M., Cornillon, P.C. and Sherman K. (2008) Fronts in Large Marine Ecosystems of the world's oceans. Progress in Oceanography, in press.

Bonfil, R., Munro, G., Sumaila, U.R., Valtysson, H., Wright, M., Pitcher, T., Preikshot, D., Haggan, N. and Pauly, D. (1998). Impacts of distant water fleets: an ecological, economic and social assessment. Fisheries Centre Research Reports 6(6)

Chavance, P., Ba, M., Gascuel, D., Vakily, M. and Pauly, D. (eds). (2004). Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement. Actes du symposium international, Dakar - Sénégal, 24-28 juin 2002. Office des publications officielles des communautés Européennes, XXXVI, collection des rapports de recherche halieutique ACP-UE 15, 532 p. + Appendices.

Cury P. and Roy, C., eds. (1991). Pêcheries Ouest-africaines: Variabilité, Instabilité et Changement. ORSTOM éditions, Paris, France.

European Commission, 2005. Rebuilding our marine ecosystems, protecting our future. Key findings of the International Symposium on Marine Fisheries, Ecosystems and Societies in West Africa – Half a Century of Change. Dakar, Senegal, 24-28 June 2002.

FAO (2003). Trends in Oceanic Captures and Clustering of Large Marine Ecosystems – Two Studies Based on the FAO Capture Database. Fisheries Technical Paper 435.

FAO (2005a). Fishery Country Profiles. www.fao.org /countryprofiles/selectiso.asp?lang=en

FAO (2005b). Low-Income Food-Deficit Countries.

Gascuel, D. (2007). Lessons from a reconstruction of catch time series for Mauritania. The Sea Around Us Project Newsletter, Issue 39, January/February 2007. Fisheries Centre, University of British Columbia, Canada.

Gordon, C. and Ibe, C. (2006). West and Central Africa, p 5-28 in: UNEP/GPA (2006), The State of the Marine Environment: Regional Assessments. UNEP/GPA, The Hague. www.fao.org/countryprofiles/lifdc.asp?lang=en

Kaczynski, V.M. and Fluharty, D.L. (2002). European policies in West Africa: Who benefits from fisheries agreements? Marine Policy 26(2): 75-93.

McGregor, H.V., Dima, M., Fischer, H.W. and Mulitza S. (2007) Rapid 20th-century increase in coastal upwelling off Northwest Africa, *Science*, **315**(5812), 637-639, DOI: 10.1126/science.1134839.

Mittelstaedt, E. (1991). The ocean boundary along the northwest African coast: Circulation and oceanographic properties at the sea surface. Progress in Oceanography 26:307-355.

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.

Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing down marine food webs. Science 279: 860-863.

Pech, N., Samba, A., Drapeau, L., Sabatier, R. and Laloe, F. (2001). Fitting a model of flexible multifleet–multispecies fisheries to Senegalese artisanal fishery data. Aquat. Living Resour. 14 (2): 81-98.

Prescott, J.R.V. (1993). Role of national political factors in the management of LMEs: Evidence from West Africa, p 280-291 in: Sherman, K., Alexander, L.M. and Gold, B.D. (eds), Large Marine Ecosystems: Stress, Mitigation, and Sustainability. AAAS, Washington D.C., U.S.

Roy C. and Reason, C. (2001). ENSO related modulation of coastal upwelling in the Eastern Atlantic. Progress in Oceanography 49:245-255.

Roy, C. and Cury, P. (2003). Decadal environmental and ecological changes in the Canary Current Large Marine Ecosystem and adjacent waters: Patterns of connections and teleconnection, p 255 - 278 in: Hempel, G. and Sherman, K. (eds), Large Marine Ecosystems of the World – Trends in Exploitation, Protection and Research. Elsevier B.V. The Netherlands.

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=27

Sherman, K. (2003). Physical, Biological, and Human Forcing of Biomass Yields in Large Marine Ecosystems. ICES CM 2003/P: 12.

UNEP (2002). Africa Environment Outlook, Past, Present and Future perspectives. United Nations Environment Programme, Nairobi, Kenya.

UNEP (2005). Tayaa, M., Saine, A., Ndiaye, G. and Deme, M. Canary Current, GIWA Regional Assessment 41. University of Kalmar, Kalmar, Sweden. www.giwa.net/publications/r41.phtml

Zeeberg, J., Corten, A. Tjoe-Awie, P. Coca,J. and Hamady, B. (2007) Climate modulates the effects of *Sardinella aurita* fisheries off Northwest Africa, *Fisheries Research*, **89**(1), 65-75.