International Journal of Oceans and Oceanography
ISSN 0973-2667 Vol.1 No.1 (2006), pp. 21-44

http://www.ripublication.com/ijoo.htm

Contributing to the WSSD Targets on Oceans and Coasts in West and Central Africa: The Guinea Current Large Marine Ecosystem Project

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Abstract

The Guinea Current Large Marine Ecosystem (GCLME) borders sixteen countries from Guinea Bissau to Angola in Western African and is the number 28 of the 64 globally delineated large marine ecosystems (LMEs). The GCLME embodies some of the major coastal upwelling sub-ecosystems of the world and is an important center of marine biodiversity and marine food production. Characterized by distinctive bathymetry, hydrography, productivity, and trophodynamics, the Guinea Current System represents a Large Marine Ecosystem (LME) ranked among the most productive coastal and offshore waters in the world with rich fishery resources, oil and gas reserves, precious minerals, a high potential for tourism and serves as an important reservoir of marine biological diversity of global significance. The Transboundary Diagnostic Analysis documents the changing states of the Guinea Current ecosystem as a result of the unsustainable exploitation of the living marine resources and discharge of untreated municipal and industrial wastes. Through the Guinea Current Large Marine Ecosystem project, priority management action areas identified by the countries in the preliminary Strategic Action Programmes (SAP) would be implemented enabling the i) recovery of depleted fish stocks, (ii) restoration of degraded habitats, and (iii) reduction of land and sea-based pollution. Project implementation will contribute to the achievement of the targets of World Summit on Sustainable Development (WSSD) Johannesburg Plan of Implementation for introducing ecosystem-based assessment and management practices by 2010, recovering depleted fish

stocks to maximum sustainable yield levels by 2015, establishing a representative network of marine protected areas by 2012, and advancing reduction of Land-based Activities by 2006.

Keywords: Guinea Current, Pollution, Fisheries, Biodiversity, Hydrography, Productivity, Large Marine Ecosystem.

Introduction and Study Area

The shared transboundary waters off the coast of western Africa are defined by the Guinea Current Large Marine Ecosystem (GCLME) that extends from Bissagos Island (Guinea Bissau) in the north to Cape Lopez (Gabon) in the south [1, 2]. The oceanography of the waters of the Democratic Republic of Congo, Republic of Congo and Angola is influenced to a considerable extent by the Guinea Current thus giving ample justification for including the three countries in the Guinea Current Large Marine Ecosystem (GCLME). Figure 1 shows the area of the GCLME.

Therefore, the GCLME stretches from the coast of Guinea Bissau to Angola, covering sixteen countries (Angola, Benin, Cameroon, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Gabon, Ghana, Equatorial Guinea, Guinea, Guinea-Bissau, Liberia, Nigeria, Sao Tome and Principe, Sierra Leone and Togo. Characterized by distinctive bathymetry, hydrography, chemistry, and trophodynamics, the Guinea Current System represents a Large Marine Ecosystem (LME) ranked among the most productive coastal and offshore waters in the world with rich fishery resources, oil and gas reserves, precious minerals, a high potential for tourism and serves as an important reservoir of marine biological diversity of global significance [3]. The Guinea Current Large Marine Ecosystem is among the five most productive LMEs in the world in terms of biomass yields [1] and therefore represents a distinct economic and fish food security source with the continuum of coastal and offshore waters together with the associated watersheds. Key oceanographic processes influencing fisheries production in the Guinea Current region have been identified as coastal upwelling, river run-off and fronts (upwelling, shelf edge, etc.) [4,5,6,7,8,9]. Over-exploitation of fisheries, pollution from domestic and industrial sources, and poorly planned and managed coastal developments are, however, resulting in a rapid degradation of sensitive habitats and the depletion of shared living marine resources of the GCLME thereby putting the economies and social wellbeing of the over 300 million peoples at risk.

Oceanography and Current Systems

The Guinea Current LME embodies some of the major coastal upwelling sub-ecosystems of the world and is an important center of marine biodiversity and marine food production [7]. Wind-driven upwelling is a widespread phenomenon and is commonly accepted as the dominant nutrient enrichment mechanism in many coastal regions around the world. In the Guinea Current region, coastal upwelling occurs seasonally along the northern and eastern coasts**.** The physical system of the Guinea Current is variable in both space and time and its dynamics are complex with two upwelling seasons, major and minor, occurring annually with differing duration and intensities off Ghana and Cote d'Ivoire in the central part of the large marine ecosystem. The major upwelling season occurs from June to September and transient upwelling events occur also from January to March [4, 5, 6, 10]. In upwelling areas, the existence of multi-variable and non-linear relationships between recruitment and upwelling intensity is a recurrent pattern resulting from the interaction between several environmental processes [11]. The competition between these different processes (enrichment, mixing, dispersion...) leads to an "Optimal Environmental Window" that gives a maximum for pelagic fish recruitment success in upwelling areas for a limited averaged wind range (~ 5-7 $m.s^{-1}$) [12]. This is the case in the GCLME region as during upwelling, high biological

activity takes place; phytoplankton and zooplankton production rise considerably, and most fishes spawn at this time. The main fishing season in this area occurs during the major upwelling period [13, 14, 15, 16].

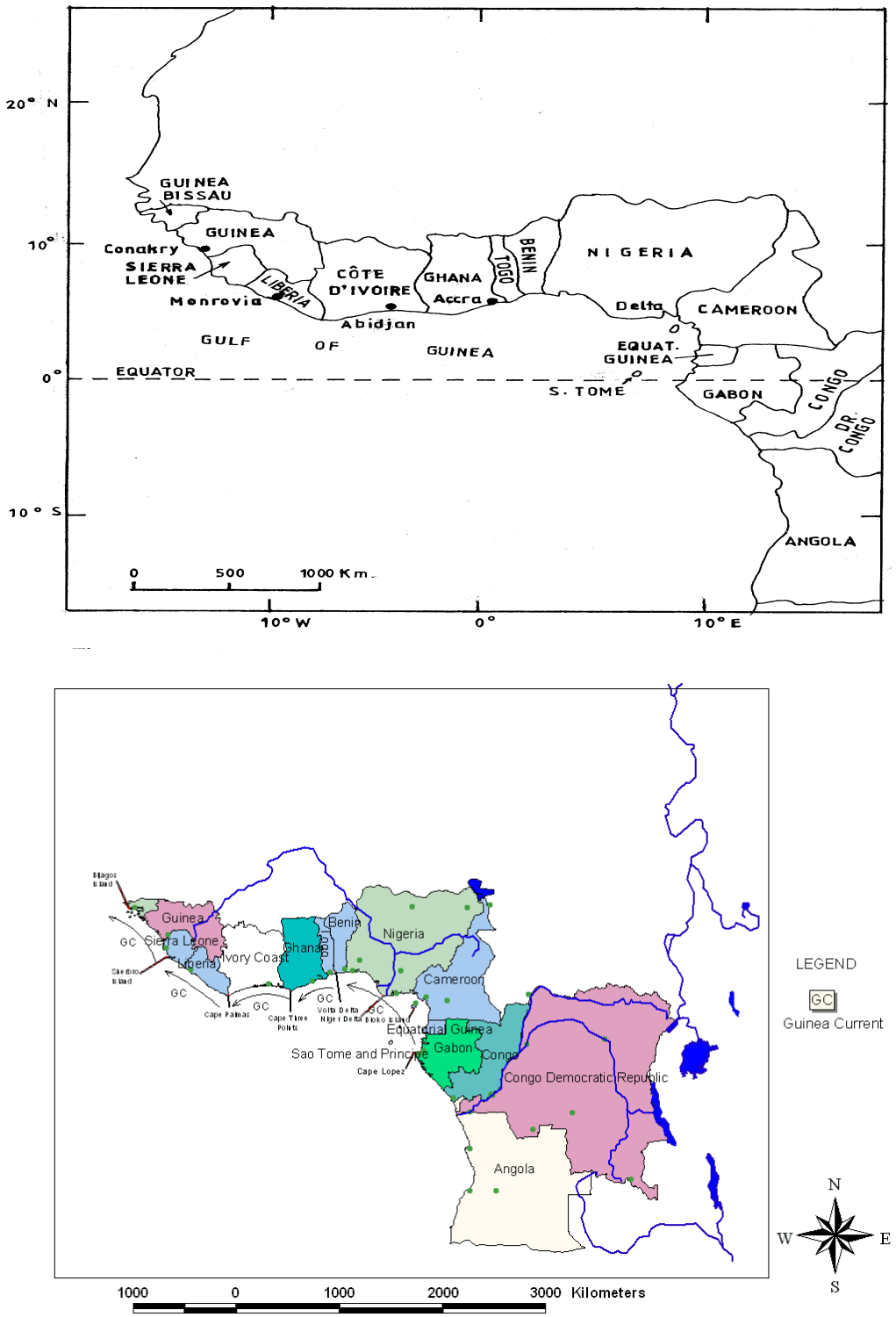

Figure 1: Location map of the GCLME [44].

The most remarkable characteristic of the Guinea Current coastal upwelling is the absence of correlation between local wind stress and coastal temperature, at least during the boreal summer season. The Guinea Current is weaker during boreal winter and intensifies during the summer [17]. This flow, like other eastern ocean boundary currents, is characterized by areas of upwelling [18] and increased biological productivity [19]. The Guinea Current (GC) is a geostrophically balanced current with isotherms sloping upwards towards the coast. As the current intensifies, the slope becomes steeper bringing the thermocline closer to the surface near the coast. The coastal upwelling and the boreal summer intensification of the GC are thus related [20]. There is evidence of a an eastward propagation of the upwelling along the equator and then southward propagation of the signal along the coast suggesting that the seasonal shoaling of the thermocline in the Gulf of Guinea is induced by Kelvin waves excited by an increase in the zonal wind stress in an unbounded ocean [21]. This remote forcing of the upwelling is well documented and supported by numerical models and data analyses [21]. However, local-forcing mechanisms, which are wind-driven and involve local winds along the coast of Ghana providing a secondary mechanism for upwelling south of the equator on an eastern boundary, may also play a role in modifying the remotely generated upwelling events. The local forcing mechanism is attributed to an increase in zonal wind stress in the western basin of the Atlantic which excites the eastward propagating Kelvin wave, which in turn produces upwelling as it propagates along the coastal boundaries [21].. [6] proposed "dynamic upwelling" to describe the process.

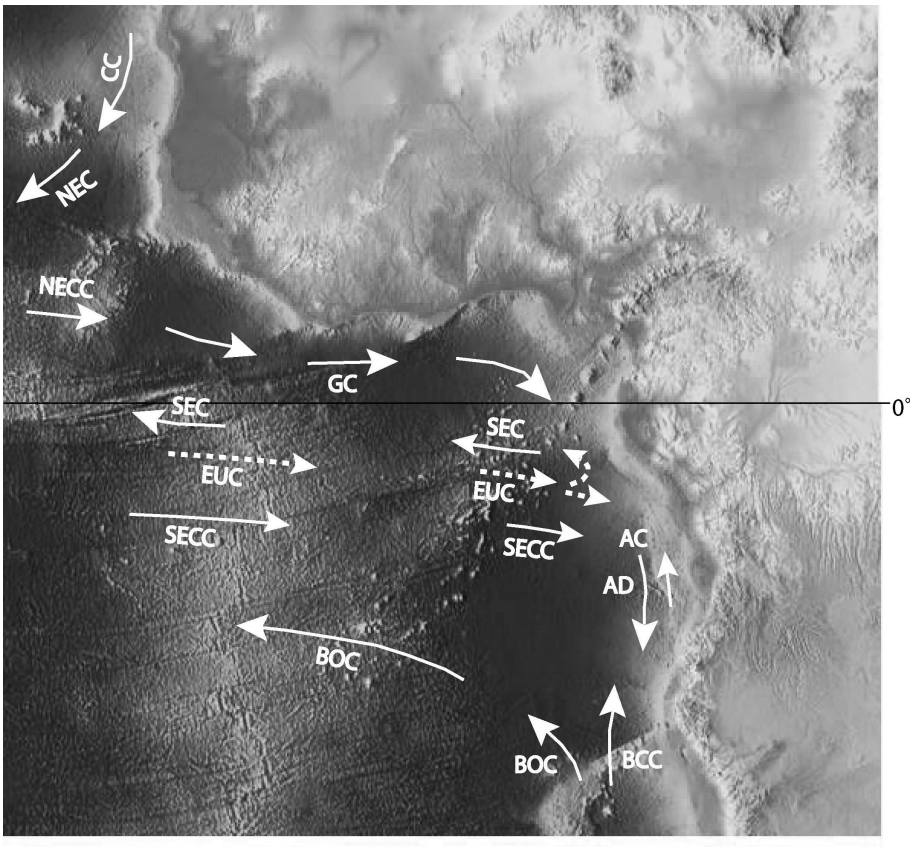

Figure 2: Major oceanographic currents in West and Central Africa [44]

The Guinea Current and adjacent areas of the eastern tropical Atlantic, bounded to the north by the Canary Current coastal upwelling region and to the south by the Benguela Current coastal upwelling region, are affected by four major basin-wide wind-driven cells of ocean circulation.

These are the North Atlantic Subtropical (NAS), North Equatorial Cyclonic (NEC), Equatorial Anticyclonic (EA), and South Equatorial Cyclonic (SEC) gyres. The circulation cells are formed due to latitudinal variations in the wind stress that is due to the existence of the subtropical anticyclones and Intertropical Convergence Zone (ITCZ), which separates the belts of the northeast and southwest trade winds. The major surface currents forming the peripheries of the gyres are the North Equatorial Current (NEC), South Equatorial Current (SEC), North Equatorial Counter Current (NECC), South Equatorial Counter Current (SECC), Guinea Current (GC), and Angola Current (AC) [22]. Other current systems that may affect near surface circulation in the region are the equatorward Canary Current (CC) feeding the NEC in the north and the Benguela Current (BCC) feeding the SEC in the south. The NEC, SEC, NECC, and SECC are the westward and eastward cross-basin flows while the CC, GC, AC, and BCC (form the system of the tropical eastern boundary currents (Figure 2). In the seasonal course, the ITCZ migrates from its southern position in winter to its northern position in summer. The south equatorial current (SEC) forms a logical boundary between the Benguela Current LME to the South and the Guinea Current to the north. A similar diagram based on averaged satellite-derived ocean productivity estimates similarly demonstrates the SEC as the logical boundary between the two large marine ecosystems (LMEs) (Figure 3).

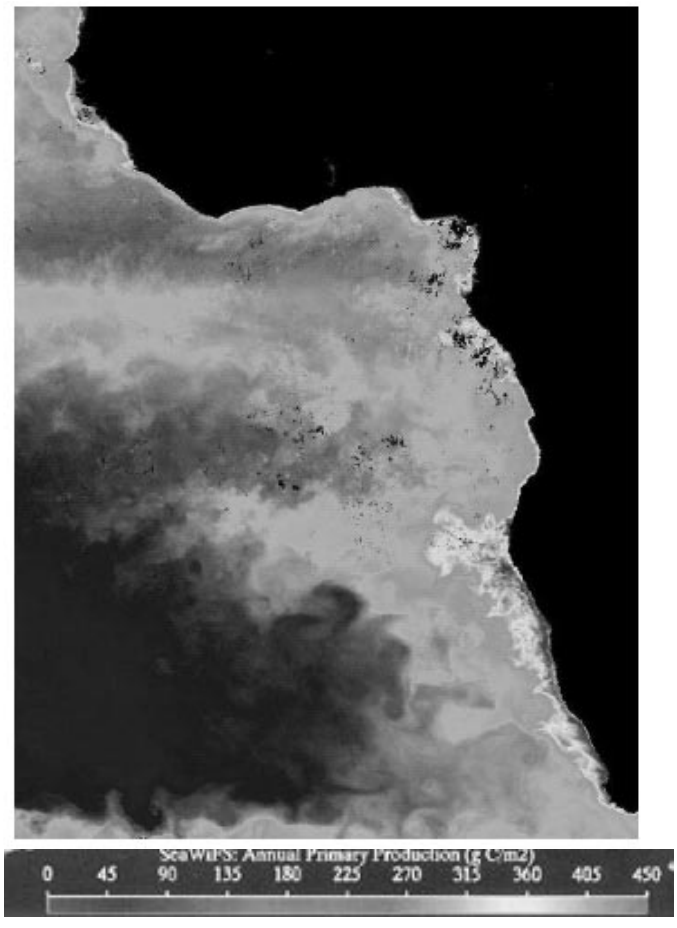

Figure 3: NASA Satellite Productivity and Chlorophyll Composite image of GCLME/ Benguela LME region. Color-enhanced image depicts a shaded gradient of primary productivity from a high of 450gC/m2-yr in red (upwelling zone off the coasts of Gabon and Congo) to <45gC/m2-yr in purple [44]
(http://oceancolor.gsfc.nasa.gov/FEATURE/IMAGES/S19972442003273.L3m_CU_CHLO.moll70W.png)

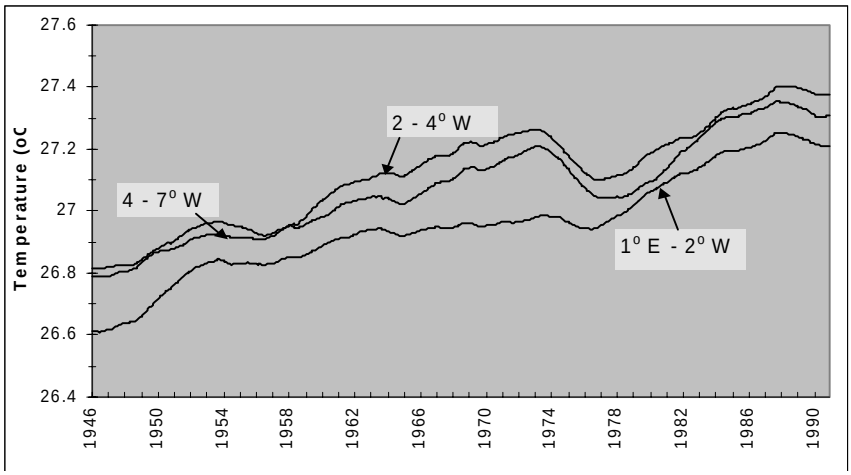

Figure 4: Sea Surface Temperature Trends in the Gulf of Guinea. Three Areas Between the Coastline and Latitude 4°N and the Indicated Longitudes [13,44].

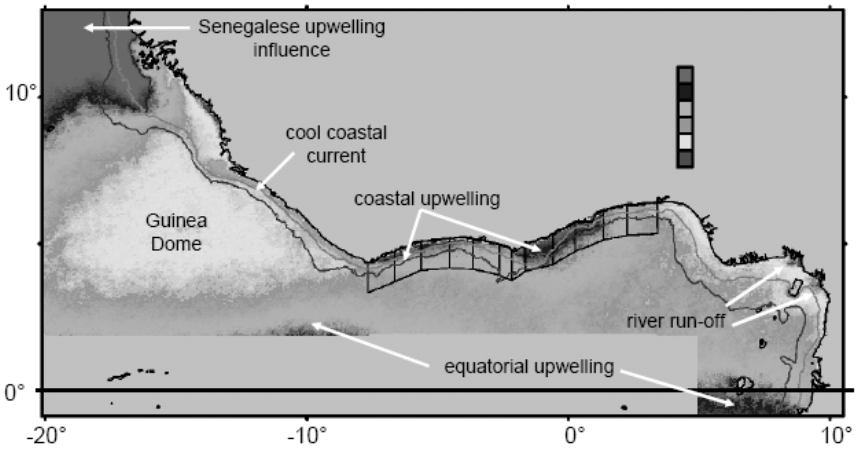

Figure 5: Mean Sea Surface Temperature (°C) for the Guinea Current region [9].

The entire GCLME is highly stratified with a thin surface layer of warm fresh tropical water (25-29°C, 33-34 PSU), overlying high salinity subtropical water (19-28°, 35-36.5 PSU). An additional contribution of saline water comes from subducted subtropical water from the North Atlantic. The lower salinities characteristic of the coastal surface water reflect excess of precipitation over evaporation in the Niger delta of Nigeria [23]**.** On this shelf, tropical surface water mass becomes much influenced by river discharges through the existence of a discrete plume of river discharge water. The stratification of the upper water column along the Guinea Current coast is generally strong except in areas subject to upwelling events. Sea-surface temperature trends for the region are shown in Figure 4. Using time series analysis, [24] reported that the trend of offshore sea surface temperature in the Guinea Current (obtained from the Comprehensive Ocean Atmosphere Dataset (COADS) [25] exhibits a general increase since 1946. Figure 5 shows the mean sea surface temperature for the Guinea Current region. The hydrographic regimes and coastal processes in the Guinea Current region are the major factors that determine fish stock abundance and distribution in

the region [26, 27]. For example, the abundance and distribution of small pelagic fish species are controlled mainly by the intensity of the seasonal coastal upwelling [5, 28].

Biogeochemical Characteristics of the Guinea Current LME Region

In a review of the biogeochemical characteristics of the Guinea Current LME, [29] delineated three systems each defined by its particular characteristics, but which nevertheless contribute to the functioning of the ecosystem as a whole. These include:

- Sierra Leone and Guinea Plateau: from the Bissagos Islands (Guinea Bissau) to cape Palmas (Liberia/Cote d'Ivoire). This area is characterized by the largest continental shelf in West Africa and has large riverine inputs, giving thermal stability.
- Central West African Upwelling: from Cape Palmas to Cotonou (Benin). This thermally unstable subsystem is characterized by seasonal upwelling of cold, nutrient-rich, subthermocline water, which dominates its annual cycle and drives the biology of the subsystem.
- Eastern Gulf of Guinea: from Cotonou to Cape Lopez (Gabon), including the offshore islands of Bioko and Sao Tome and principe. This area is characterized by thermal stability and a strong picnocline. It depends on nutrient input from land drainage, river flood and turbulent diffusion for its productivity [30].

Important Ecotones

The coastline of the region is generally low-lying and interspersed with marshes, lagoons and mangrove swamps. A number of estuaries interrupt the barrier beaches that separate mangrove swamps from the sea [31]. A large variety of ecotones or habitats exist in the GCLME. Among these are:

(a) Wetland habitats: The wetland is made up of permanent saline creeks, inter-tidal mangrove swamps, estuaries and beach ridges [32] with the mangrove forests being the most apparent features (close to 25,000 km^2 from Guinea Bissau to Angola). Although, most of the coastal wetlands provide unique ecological conditions and habitats for migratory birds and also function as a nursery for valuable fish and shellfish species, they remain unprotected with regards to natural and human influences and exploitation. Mangroves, typically *Rhizophora sp, Conocarpus sp, Avicennia sp, Mitragyna inermis, Laguncularia sp,* occur almost everywhere along the coasts in the GCLME **(**Table 1). The areas of highest mangrove concentration are located along the coasts of Guinea and Guinea Bissau, Sierra Leone and in the Niger delta of Nigeria which has Africa's largest and the world's third largest mangrove forests at approximately 9,415 km^2 [33, 34, 35, 36] **(**Figure 6**).** The huge marshy area formed by the Niger delta is colonized by mangroves indented by fluvial channels that are subject to tidal influence. Although these mangrove forests are less diverse in terms of species than those found in East Africa, they are the best developed and most extensive in Africa. Mangrove forests provide the nutritional inputs to adjacent shallow channel and bay systems that constitute the primary habitat of a large number of aquatic species of commercial importance. The importance of mangrove areas as spawning and breeding grounds for many transboundary fish species and shrimps is well known. Presently the mangrove forests are under pressure from over-cutting (for fuel wood and construction timber) and from other anthropogenic impacts (e.g. pollution), thereby jeopardising their roles in the regeneration of living resources and as reservoirs of biological diversity [37].

Table 1: Marine Area, Mangrove Area, and Important Coastal Lagoons of the GCLME [28]

Country	**Marine Area (m^2)**	**Mangrove Area (m^2)**	**Lagoons**	**Area (km^2)**
Benin	7,900	30	Nokoué Porto-Novo	139.50 17.52
Cameroon	4,500	4,860	*	*
Cote d'Ivoire	30,500	640	Ebrié Aby-Tendo-Ehy Grand Lahou	560 410 250
Equatorial Guinea	82,600	120	Volcanic crater lakes	*
Gabon	62,300	1,150	Nkomi Ndogo Ngobe Mbia	806 582 402 242
Ghana	63,600	630	Keta Sakumo-Accra Songaw Korle†	330 23.6 18
Nigeria	61,500	12,200	Lagos† Lekki	460 247
Sao Tome and Principe	600	10	*	*
Togo	37,400	*	Togo Vogan (Boko) Aneho	46.6 8 3

* No Lagoon of appreciable size; † heavily polluted lagoon

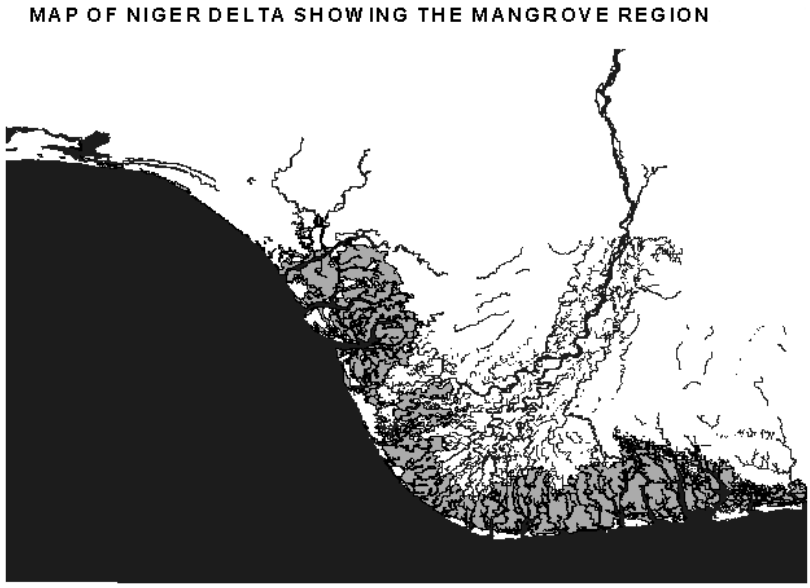

Figure 6: Map of distribution of Mangroves in the Niger Delta

(b) Coastal lagoons: These are found mainly in the Gulf of Guinea from Côte d'Ivoire to east of Nigeria, are associated with freshwater rivers, deltas, and estuaries and include a wide range of tidal swamps and seasonal marshland.
(c) Sea-grass beds: These are not very well developed in the region, although there are indications of isolated patches in some estuaries and delta mouths. There are no true reefs along the GCLME coast mainly due to the intrusion of the cool waters of the Benguela and Canary currents and the high turbidity of the waters.
(d) Sandy beaches: They are considered important nesting ecosystems, particularly for sea turtles. Their exposure to strong currents and swells make them extremely dangerous, however. These areas are often subject to marine debris and detritus accumulation.

Biological Diversity and Fisheries Resources of the GCLME

The GCLME is rich in biodiversity. The fisheries resources of the ecosystem, consisting of the freshwater and marine environment, include a diverse assemblage of fishes including small pelagics (sardinellas shad), large pelagics (tuna and billfish), crustaceans and molluscs (shrimp, lobster, cuttlefish, and demersal species (sparids and croakers). The rich fishery resources are of both local and transboundary importance with stocks supporting artisanal fisheries and offshore industrial fisheries from many nations. The United Nations Food and Agriculture Organization (FAO) estimates the total potential fisheries yield of the entire region to be in the neighborhood of 7.8 million tons per year. Most of these straddling and migratory stocks have attracted large commercial fishing fleets from around the world, especially from the former Soviet Union, European Union, Eastern Europe, Republic of Korea, and Japan. Total reported catch for 1990 was about 4.1 million tones and this declined to about 2.9 million tones in 1994 [38]. Apart from above-average landings between 1988 and 1991, annual totals varied between 2.5 million tonnes and 3.3 million tonnes throughout the 1970s and 1980s. Declines in Catch per Unit Effort (CPUE) indicate that catch is exceeding sustainable yields in some resources [28] while species diversity and average body total lengths of the most important fish assemblages have declined [39]. These conclusions were agreed by the fisheries experts of the Central Eastern Atlantic Fisheries Commission (CECAF). These variations are mainly to be attributed to fluctuations in small pelagic resources such as horse mackerel and sardine, largely influenced by climatic changes as well as changing fishing pressure from Eastern Europe countries.

Multi-species fisheries are common in the Guinea Current region. The white shrimp resources off Nigeria and Cameroon are fished exclusively by artisanal fishery while pink shrimp is exploited by trawlers of the semi-industrial fishery. Environmental changes manifesting a periodic variability in coastal upwelling intensities are playing a role in coastal pelagic fish abundance fluctuations [40, 41, 42] The wealth of estuaries, deltas, coastal lagoons and marine catchment basins contribute to maintaining the Guinea Current Large Marine Ecosystem productivity and coupled with the nutrient-rich upwelling cold waters make a major contribution to the diversity of fish life in the GCLME region with an estimated 239 fish species, including *Sardinella aurita and maderensis*, *Thunnus albacares*, etc. as pelagic species; *Arius sp*., *Pseudotolothus typus and senegalensis*, *Dentex sp., Octopus vulgaris*, *Cynoglossus sp.*, and others as demersal species [28, 43]. Pelagic tuna fishing also constitutes an important industry in the GCLME region [44].

The presence of invertebrates such as intertidal molluscs *(Anadara* s*p. Crassostrea* g.,etc.), reptiles (turtles, crocodiles), marine mammals such as the West African manatee *(Trichechus senegalensi*s), and some shark species demonstrate the variety of the species in the GCLME [45, 2, 46]. The remarkable collection of migratory birds, millions of which seasonally visit the West African coast and mainland regions, illustrates the importance of preserving and maintaining the

existing wetlands in this part of Africa [47]. Large concentrations of seabirds are found seasonally in and around Guinea Bissau: these include *Larus genei, Geochelidon nilotica, Sterna maxima lbididorsalis, etc*. The Gulf of Guinea islands, near Principe and Sao Tome also have sizeable sites with colonies of terns, noddies and boobies [48]. It is because of this species diversity and fauna richness that conservation and preservation policy has been or is being undertaken by some GCLME countries through the creation and implementation of a representative network of marine and coastal protected areas [41].

Demography and socio-economic characteristics

The population of the coastal areas of the GCLME is increasing dramatically with a potential doubling time of 20-25 years at the present population growth rate of about 3%, compared to a doubling time of 100 years in developed countries. At the national level there also has been substantial population increase in the coastal cities and towns as a result of urbanization and the growth of fishing villages and landing sites. The population in the major metropolitan cities are estimated at 2 million in metropolitan Abidjan, Côte d'Ivoire; 1,6 million in Accra, Ghana; 8 million in Lagos, Nigeria; and 1,4 million in Doula, Cameroon. If developments are not planned and diversified, it is estimated that these coastal cities may grow at the alarming rate of as high as 5% [49].

The densely populated coastal region is heavily dependent upon the biological resources of the GCLME. Approximately 40% of the region's 300 million people (more than 1/2 of the population of the African continent) live in the coastal areas of the GCLME, many of whom are dependent on the lagoons, estuaries, creeks and inshore waters surrounding them for their food security and well being [36]. Rivers, lagoons, and inshore and offshore waters of the GCLME serve as important sources of animal protein in the form of fish and shellfish, as well as provide significant income through the coastal fisheries. About 60% of the industries in Guinea Current region are located within the coastal zone, according to a UNDP/GEF report [50], contributing to the pollution of the region [51, 52]. Presently, industry accounts for 21.5% of GDP region-wide, but substantially more in Nigeria, Angola, Gabon and more recently in Sao Tome and Principe and Equatorial Guinea where oil exploitation related industries form the core of the economy [53, 3].

Method and Results of Environmental Diagnostic Analysis-Major Environmental Challenges and Problems in the GCLME Region

The State of the Coastal and Marine Environment of the Gulf of Guinea report [54], the Coastal Areas Profiles of the Gulf of Guinea Large Marine Ecosystem (GOG LME) coastal states, the National Reports and the Regional Synthesis report summarise some of the studies that have been conducted in the coastal and marine environment of the GCLME. The various studies indicate alarming rates of decline of fisheries resources and significant levels of pollution including pathogens and micro-organisms in sewage, industrial effluents with high organic loading and hazardous chemicals, heavy metals, oils and hydrocarbons, tar balls in beaches, as well as serious problems of coastal erosion and coastal areas management [55, 56, 57, 46, 3]. Other studies have also concentrated on aquatic weeds like water hyacinth and algal blooms including studies conducted on marine fisheries resources of the Guinea Current region by CECAF, FAO, FRU-ORSTOM. In addition, the West and Central Africa Action Plan (WACAF) of the UNEP Regional Seas programme have implemented marine environmental and pollution monitoring programmes in collaboration with UNEP/FAO/WHO/IAEA/UNIDO [58, 54]. A review of the status of marine fisheries resources in [28] indicates that apart from offshore demersal resources, all other fisheries in the sub-region are near to full or fully exploited. This depletion of fish resources has increased

the risk of food insecurity in the local communities and exacerbated the conflict between commercial (industrial) and artisanal (community-based) fisheries.

Many of the water and coastal resources-related environmental threats identified in the region are transboundary in nature. In this respect, the countries, under the guidance the United Nations Industrial Development Organization (UNIDO), employed the transboundary diagnostic analysis method, as defined by the Global Environment Facility (GEF), to conduct a detailed technical and scientific analysis of the major environmental issues and challenges facing the GCLME region. The GCLME Transboundary Diagnostic Analysis (TDA) fully lists the various transboundary environmental issues/problems, major root causes, transboundary impacts and consequences and possible measures to contain the threats [49]. Some of these threats are already cause for concern while others are likely to grow in importance with human population growth and increased urbanization and industrialization in the stakeholder countries. It is imperative, therefore, to begin early action in order to mitigate these transboundary threats to ecosystem health and productivity. The four major transboundary environmental problems/issues identified in the GCLME TDA are:

[1] Decline in GCLME fish stocks and unsustainable harvesting of living resources;
[2] Uncertainty regarding ecosystem status, integrity (changes in community composition, vulnerable species and biodiversity, introduction of alien species) and yields in a highly variable environment including effects of global climate change;
[3] Deterioration in water quality (chronic and catastrophic) from land and sea-based activities, eutrophication and harmful algal blooms;
[4] Habitat destruction and alteration including *inter-alia* modification of seabed and coastal zone, degradation of coastscapes, coastline erosion.

The socio-economic and cultural implications from the above broad issues can be tremendous in terms of income reduction arising from a loss of fisheries stocks and catches, loss of recreation and tourism amenities and an increase in water treatment and coastal protection costs. For instance, artisanal fisheries in West Africa are presently facing serious challenges due to the virtually open access nature of the industry and the fact that the natural resources supporting this industry are showing serious signs of stress linked to over-exploitation and natural environmental variability. This has been traced to an over-dependence on fishing and allied activities as a means of livelihood in fishing communities and also expansionary policy measures in the past that encouraged more people to enter the fishing sector [59]. The pressure on fisheries resources is expected to worsen given the rapidly increasing populations of West Africa unless suitable management measures are in place by the countries to reverse the trend and enable fisheries recovery [38, 3]. Because of the paucity of reliable, detailed and historic scientific data on coastal, marine and freshwater environment in the GCLME region, a certain degree of uncertainty still prevails in assessing the pollution loading in general. There is an urgent need for a precise qualitative and quantitative assessment of the significant sources of land-based pollution as well as comprehensive assessments of the state of the fisheries resources and extent of ecosystem degradation (including status and trends analysis) in the region. This will be achieved through the implementation of the Guinea Current Large Marine Ecosystem project.

Decline in GCLME fish stocks and unsustainable harvesting of living resources

The GCLME is already showing evidence of ecosystem stress with major fluctuations of commercially valuable species. Significant changes in species composition have occurred over time as a result of over-exploitation of several demersal and pelagic fish species especially by foreign trawlers in the offshore areas. The size spectrum of fish is moving towards smaller size classes. Trawl surveys off Ghana conducted by Ghana found that between 1985 and 1990, the

estimated biomass in waters less than 20 m declined from 122,000 to 49,000 tons in the rainy season and from 72,000 to 48,000 tons in the dry season and related that to increases in trawling effort [24, 60] indicating that significant changes were occurring in the demersal fish biomass in terms of distribution, abundance and reproductive strategy. Recently, biomass estimates of Sciaidae and Sparidae were estimated by hydroacoustic surveys for the Congo and Gabon to be 38,000 tons and were considered close to or fully exploited with the magnitude of the declines indicative of over fishing [39].

A case in point of the declining fish stocks is the continuous fluctuations between the two species, the grunt and Triggerfish in the last two decades. The grunt maintained for a time its position at the top of the list of demersal fish but later gave way to the triggerfish which dominated the ecosystem from the early 1970s to the late 1980s, after which time it dramatically decreased in abundance [38]. [61] Attribute the almost complete disappearance of the Triggerfish after the late 1980s to observed environmental changes and upwelling intensification in the central part of the GCLME, off Ghana and Cote d'Ivoire [24]. There was a subsequent increase of the Sardinella population. The Sardinella industry had collapsed in 1973, but subsequently recovered to unprecedented levels during the 1980s [62]. The exploitation rate applied to cuttlefish stocks has been increasing since 1984 and by 1990 was considered to be equal to, or slightly above, the optimal fishing effort. The rate of growth of these organisms appears faster than previously estimated [38].

Such changes in fishery patterns appear, in part, to be related to overfishing, as evidenced by a decline of Catch-Per-Unit- Effort and the taking of young immature fish by artisanal fishermen. They also appear to be related to environmentally-driven changes to pelagic stock distribution [63]. For instance, [64] assessed the biomass of the small pelagics in the western and central Gulf of Guinea as 392,000 tons. The current level of exploitation in the area is about 257,000 tons annually clearly showing over-exploitation [65]. The observed recent high catches of the resource (which exceed the estimated potential yield) are due mainly to the intensity of upwelling in the area). These declines in fisheries have led to unsustainable destructive fishing methods such as blasting and use of very small mesh nets. In 1994, the Working Group Meeting at Centre National des Sciences Halieutique de Boussoura, Conakry Guinea estimated area biomass declines in demersal species such as croackers and sicklefish was higher than 50% indicative of overfishing and related to increases in fishing effort by artisanal and industrial fishing.

Uncertainty regarding ecosystem status, integrity (changes in community composition, vulnerable species and biodiversity, introduction of alien species) and yields in a highly variable environment including effects of global climate change

Changes in biodiversity of species in the Guinea Current LME have been attributed to both natural (intensification of the minor upwelling, and water temperature changes) increase in salinity of shelf waters [40, 66] and changes in meteorological and other oceanographic conditions (reduction of rainfall, acceleration of winds and alteration of current patterns [66] and changes in nearshore biophysical processes. Environmental changes manifesting a periodic variability in coastal upwelling intensities are playing a role in coastal pelagic fish abundance fluctuations in the GCLME [40, 42]. For instance, the east and west flows and position of the Guinea Current may play a role in noticeable population fluctuations of the Triggerfish that appeared in large quantities in the 1970s but have now completely disappeared. Shifts in biomass appear to be connected to a shift in the boundary of the Guinea Current. These alterations have been linked to oceanographic changes including the southward displacement of the Intertropical Convergence Zone (ICTZ) during Atlantic El Niño events. In addition to natural variability, the ecosystem status is affected by human activities (overfishing, introduction of alien species, and contamination, for instance). Inadequate state of knowledge of the ecosystem status and lack of regional coordination in studies

of biodiversity, habitats, and ecotones hinders effective management on a national and regional level. The most significant changes on the abundance of fish species in the region are fluctuations in sardinella species, dramatic increase in the abundance of triggerfish (Balistes capriscus) between 1973 and 1988 and the decline of the species since 1989 [61].

The results from the Primary productivity (plankton) surveys using ships of opportunity (SOOP) towing Continuous Plankton Recorders (CPR) conducted in the Gulf of Guinea from 1995 to 1999 during the pilot phase Gulf of Guinea LME project have provided vital information on plankton variability in the area [67, 68, 69]. The plankton surveys indicated new and emerging patterns of productivity that contain at the same time hopeful and distressing signals. The hopeful signs come from the discovery of new areas of upwelling (e.g. off Benin and Nigeria) besides those already known which has led to upward revisions of potentially available fish stocks in the Gulf of Guinea. The distressing signs arise from the increasing occurrence of harmful algal blooms indicating intense eutrophication and therefore excessive nutrient loading in the Gulf of Guinea from anthropogenic sources [69]. The data are also being used, in conjunction with other parameters, in estimating the carrying capacity of the Guinea Current LME fishery.

Deterioration in water quality (chronic and catastrophic) from land and sea-based activities, eutrophication and harmful algal blooms

Human activities have adversely affected the coastal and marine environment of the region, leading to reduction in the amenity value, loss of biological diversity, and degradation of the water quality, poor sanitation and negative effects on human health. Pollution from land and sea-based activities has contributed significantly to the deterioration of the water quality of the countries of the GCLME. Pollution from municipal, industrial and agricultural sources significantly affect transboundary waters and living marine resources of the GCLME [70]. Although most impacts of chronic deterioration in water quality are localised (national issues), they are common to all of the countries and require collective action to address them. Moreover, chronic pollution can favour the development of less desirable species, and result in species migration. Catastrophic events such as major oil spills and maritime accidents can produce impacts across country boundaries, requiring co-operative management and sharing of clean-up equipment and manpower [71, 72]. Eutrophication and HABs occur in most of the sixteen countries, and these face similar problems in terms of impacts and management, and which require collective regional action to address [70, 52].

Detailed studies and analysis conducted in the GCLME region and in the entire twenty-two countries of the WACAF region show clearly that sewage constitutes the main source of pollution as a result of land-based activities [47]. All the countries assessed reflect high urban, domestic loads, sometimes from industrial origin, which include BOD, suspended sediments, nutrients, bacteria and pathogens. The annual BOD for the entire West and Central African (WACAF) region including the GCLME was estimated to be 288,961 tons from municipal sewage and 47,269 from industrial pollution, while the annual total suspended sediments (TSS) was estimated around 410,929 tons from municipal sewage and 81,145 tons from industrial pollution [55, 73, 47] (Table 2). It is estimated that domestic solid waste generation by the coastal population averages 3.8 million tons/year of mostly putrescible or non-hazardous waste while industrial solid waste generation average 435,000 tons, the bulk of which is of a putrescible or low-hazard nature [52, 53].

Organic pollution has resulted in eutrophication and, as reported for the Korle and Chemu II lagoons in Ghana and several bays of the Ebrie lagoon in Cote d'Ivoire, in near total oxygen depletion [74, 75, 76, 77, 78,, 79, 80]. Nutrient loading has direct impact on productivity, fisheries and water quality and is central to the general ecological functioning of the coastal ecosystem. This is especially true of the GCLME region where nutrient loading of the coastal water bodies has had a direct negative impact on the fisheries and water quality and caused outbreaks of water-borne

diseases [74, 81, 82, 83, 84, 85, 86]. The lack of oxygen on the bottom of shallow areas impacted by eutrophication has also led to massive loss of bottom-dwelling animals. For instance, eutrophication of Nigeria's coastal lagoons, rivers and streams induced the explosive growth of water hyacinth in the early 1980s covering nearly 800 km and severely impeding fishing activities and transportation [75]. The 1990 World Bank cost estimate for water hyacinth control in Nigeria is US$ 50 million annually [36].

Table 2: Estimated Amount of Municipal Sewage in Comparison with Industrial Pollution in the WACAF Region Including the GCLME Countries

ZONES	Estimated population*** 1000*	Municipal sewage				Industrial pollution			
		BOD5 t/year	%*	SS /year	%*	BOD5 t/year	%**	SS t/year	%**
Northern	17.350	62.535	21.6	88.930	21.6	15.320	24.5	18.542	20.8
Middle	117.960	205.612	71.1	292.401	71.1	29.962	14.6	61.243	20.9
Southern	36.800	20.814	7.3	29.598	7.3	1.986	9.5	1.360	4.6
TOTAL	172.110	288.961	100.0	410.929	100.0	47.269	16.3	81.145	19.7

* Percentage of the total amount of municipal sewage in the Region
** Percentage on industrial pollution of the amount of municipal sewage in certain zones
*** Estimated population of the Region, but without Mauritania, Cape Verde and Namibia (Africa South of the Sahara) [50].

Habitat destruction and alteration including inter-alia modification of seabed and coastal zone, degradation of coastscapes, coastline erosion

The physical destruction of coastal habitats, including critical wetlands in the GCLME, is causing the loss of spawning and breeding grounds for most living resources in coastal waters and the loss of the rich and varied fauna and flora of the region including some rare and endangered species. Much of the destruction is related to often-haphazard physical development, which exert phenomenal pollution pressures on this international body of water. Coastal geomorphological change, erosion and sedimentation have been identified as having a significant and progressive impact in all the countries in the GCLME, the problem being acute on the lagoon systems.

Coastal vegetation in the region has been decimated by both natural and anthropogenic activities to the extent that a large percentage of the primeval vegetation has been replaced with new species [35]. Modification of the ecosystem in Nigeria, for instance, is a result of man-made and natural activities. While 30% of the modification is caused by natural activities, the remaining 70% are caused by man-made activities [87]. The natural causes of the modification are storm surge, sea-level rise, salt-water intrusion, subsidence and flooding. The man-made causes include changes in land development and unsustainable exploitation of ecosystem resources [34]. As of 1980, about 60% of the mangroves in Guinea and nearly 70% of the mangrove vegetation in Liberia were reported to have been lost [35]. The hardy grass, *Paspalum vaginatum,* has now replaced the original mangrove vegetation in these countries [37].

Nearly all the main rivers of the Guinea Current region have been damned in at least one location, most of them in the last two decades [88]. The dam on the Volta River, for instance, eliminated the regular flooding in the wet season and as a consequence several lagoons, which used to be refilled in times of flood, have been lost [51, 89]. A particular concern in the region has been the effect on sediment transport to the sea. In Nigeria, for instance, there are now eleven River Basin Authorities manipulating the hydrological cycles and it is estimated that the construction of

their dams has resulted in a 70% loss of sediment catchment area due to the effective entrapment of silt behind dams [34]. In some cases the loss of sediment input is blamed for coastal erosion that has occurred since the construction of some dams. A particularly serious case followed the damming of the Volta River with the partial disappearance of the town of Keta [88, 31]. Similar problems have been reported in the Niger Delta of Nigeria [90, 91]. Land use pressures and change characterize the river catchments and with increasing population trends, changing and intensifying human resource uses and pockets of industrialization, the region offers a tapestry for a diverse range of biogeochemical estuarine functions, patterns and changes [92].

Coastal erosion is the most prevalent coastal hazard in the GCLME region and have significantly contributed, in most of the countries, to the uprooting of coastal settlements, decimation of agricultural and recreational grounds, destruction of harbour and navigation structures, dislodging of oil producing and export handling facilities and upsetting of the hydrological regime in the coastal areas [34]. Although natural causes like low coastal topography, high wave energy and nature of sediment are responsible for these high rates of erosion, anthropogenic activities such as construction of harbour protecting structures, jetties, beach sand mining, construction of dams upstream and deforestation are mostly responsible for the high rates of erosion [88, 93]. Harbour construction activities have altered longshore current transport of sediments and in many cases have led to major erosion and siltation problems. Erosion rates caused by port structures in Liberia, Togo, Benin and Nigeria sometimes reach a staggering 15-25 m per year and threaten infrastructure and services [89].

Discussion: Achieving the WSSD Targets on Oceans and Coasts in West and Central Africa- Contributions of the Guinea Current Large Marine Ecosystem (GCLME) Project

The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, provided the fundamental principles and the programme of action for achieving sustainable development globally. In furtherance of the achievements made since UNCED, the global community, under the leadership of the United Nations, at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, adopted the Johannesburg Plan of Implementation (JPOI) to expedite the realization of the remaining goals. The WSSD JPOI sets out clear targets to be achieved by countries in the next decade. Some of the pertinent WSSD JPOI targets pertinent to the coastal and marine environment as listed in Chapter IV on “Protecting and managing the natural resource base of economic and social development” include the following: (i) encourage the application by 2010 of the ecosystem approach; (ii) maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015; (iii) develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas consistent with international law and based on scientific information, including representative networks by 2012 and time/area closures for the protection of nursery grounds and periods, proper coastal land use; and watershed planning and the integration of marine and coastal areas management into key sectors; and (iv) advance implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and the Montreal Declaration on the Protection of the Marine Environment from Land-based Activities, with particular emphasis in the period 2002-2006 on municipal wastewater, the physical alteration and destruction of habitats, and nutrients, by actions at all levels.

Achieving the above WSSD targets in the West and Central Africa region would entail correcting decades of over-exploitation of resources and habitat degradation in the Guinea Current

ecosystem and the fragmented and sectorally based management actions (the consequence of the colonial/political past and greed). This will require a substantial coordinated effort during the next decade, to be followed by sustained action on a permanent basis. A task of this magnitude will require careful planning not only by the government agencies in the sixteen countries bordering the Guinea Current for instance, but also by the other stakeholders such as the private sector, non-governmental organizations and local coastal communities. There already exists the willingness on the part of the key players to collaborate to achieve this objective, but the real challenge will be to develop systems and structures that address the highly-variable and potentially fragile nature of the GCLME and its coastal environments within the context of a changing society and world.

The many issues and problems, as well as possible solutions, have been identified and prioritized in the Transboundary Diagnostic Analysis (TDA) formulated by the sixteen countries of the GCLME region. The resolve of the governments of the sixteen countries to correct the wrongs of the past and move forward with a new vision to ensure the achievement of the WSSD targets and the UN Millennium Development Goals and the sustainable utilization of the resources of the GCLME by future generations for the benefit of all is underlined by the collective adoption of a cooperative and integrated approach embodied in the Large Marine Ecosystem (LME) framework for the implementation of the agreed management strategies embodied in Strategic Action Programme (SAP) [94].

The communal project "Combating Living Resources Depletion and Coastal Area Degradation in the Guinea Current LME through Ecosystem-based Regional Actions" endorsed by the sixteen countries and approved by the Global Environment Facility (GEF) Council in November 2003, full implementation of which commenced in November 2004, is based on the LME approach and has a primary focus on the priority problems and issues identified by the sixteen GCLME countries that have led to unsustainable fisheries and use of other marine resources, as well as the degradation of marine and coastal ecosystems by human activities. Priority management actions in the SAP to be implemented by the countries through the Guinea Current Large Marine Ecosystem project would lead to (i) recovery of the depleted fish stocks, (ii) restoration of degraded habitats, (iii) reduction of land and sea-based pollution, and (iv) creation of a regional management framework (the Guinea Current Commission) for sustainable use of living and non-living resources of the GCLME.

The implementation of the GCLME Strategic Action Programme would advance and re-affirm the commitments of the sixteen countries to regional co-operation under the tenets of Agenda 21, the Abidjan Convention, the World Summit on Sustainable Development (WSSD) Plan of Implementation, the United Nations Millennium Development Goals, the GEF Operation Strategy, the Global Programme of Action on the Protection of Marine Environment from Land-Based Sources, and the FAO Codes of Conduct for Responsible Fishing and the Environmental Action Plan of the New Partnership for African's Development (NEPAD). The activities to be undertaken will complement other projects in the region to provide a strong foundation for the long-term sustainable environmental management of the GCLME as well as position the countries to achieving the pertinent WSSD targets related to oceans and coastal areas. One of the avenues offered by the GCLME project for accelerating early SAP implementation and achievement of the WSSD targets is through the implementation of a portfolio of nine regional and national pilot demonstration projects addressing previously-identified priority transboundary concerns conforming to the five LME operational strategies/modules (productivity, fish and fisheries and other living resources, pollution and ecosystem health, socio-economics, and governance). The demonstration projects are designed to be replicable and intended to demonstrate how concrete actions could lead to dramatic improvements in the coastal and marine ecosystem and include the following:

[1] Introduction and maintenance of an assessment and management system to achieve recovery and support the long-term sustainability of the Fish and Fisheries of the ecosystem;
[2] Integrated Regional Data and Information Management and Decision Support System;
[3] Determination of new and emerging productivity patterns in the Guinea Current LME with regard to its carrying capacity for living resources;
[4] Restoration of the Mangrove Ecosystem in Nigeria;
[5] Strengthening Industrial waste reduction and instituting a waste Stock exchange management system in Ghana;
[6] Controlling of nutrient pollution discharges in the Togo Lagoon system;
[7] Instituting Integrated Coastal Areas Management for Kribe-Limbe Lagoon in Cameroon;
[8] Application of low-cost technologies for control of coastal erosion and protection of the coastal zone in Cote d'Ivoire;
[9] Implementing Coastal and Marine Protected Areas management in Benin

The primary target beneficiary of this project is the population of the Guinea Current countries, in particular the fishing communities with an emphasis on women (as reflected by the Stakeholder consultation process). The project will contribute to the reduction of poverty in the region, by providing a roadmap to sustainable fisheries, and therefore to continued availability of a primary food source for the coastal populations. The coastal populations should benefit from each of the success criteria, which are expected to be the rehabilitation of the fishery resources, sustainable aquaculture/mariculture, improved biodiversity protection, protected/restored habitats, improved water quality, and reduced rates of coastal erosion. It is expected that policies, structures and actions developed during the implementation phase of the GCLME Programme over the next five years (2004 to 2009), would become self-sustainable in the region. To achieve this, mechanisms would be put in place to encourage, indeed ensure, a substantial degree of co-financing of activities by the countries, private sector and bilateral donors. This would be done by involving and developing effective partnerships with maritime and coastal industries, the international community and present and future beneficiaries, i.e. all those who have a stake in the long-term health, productivity and viability of the Guinea Current region as a large marine ecosystem (LME) [95]. In the short-term, governments and institutions will benefit from institutional strengthening as a result of networking, training programmes, the provision of key items of equipment, and in particular from the development of GCLME Strategic Action Programme **(**SAP). Proper environmental assessments and pre-investment studies should facilitate the release of vital credits for improving waste management and for stimulating the development of key sectors. Sustainability of implemented management actions will, thereafter, derive from the improved capacity, strengthening of national and regional institutions, improvements in policy/legislative frameworks, and the demonstration of technologies and approaches that will lead to improved ecosystem status [95].

The GCLME project is funded by the Global Environment Facility (GEF) for amount of US$ 21 million while the sixteen countries, bilateral donors and the private sector are contributing US$45 million as co-financing. The project is being executed by the United Nations Industrial Development Organization (UNIDO) and co-implemented by United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP). The project maintains active collaboration with pertinent international organizations namely the United States National Oceanic and Atmospheric Administration (US-NOAA), the International Maritime Organization (IMO), the United Nations Food and Agriculture Organization (FAO), the International Centre for Science and High Technology of UNIDO (ICS-UNIDO), African Development Bank (AfDB), and the African Union Scientific, Technical and Research Commission (AU-STRC) for joint implementation of specific project activities in their areas of competence. The private sector is a

focus for cooperation in project implementation, as they hold the key for long-term sustainability of actions. The priority problems of resource depletion, loss of biodiversity (including habitat loss and coastal erosion), and land- and sea-based pollution are all addressed through these interventions.

Conclusion

In the absence of the GCLME project intervention, it is probable that the present types of sectoral-based interventions, which have been demonstrated during the past twenty years as being ineffective in halting the pace of environmental degradation, will continue. Without a concerted ecosystem-based regional approach to environmental management, it is unlikely that the present rates of habitat degradation and living marine resources depletion will be slowed. The likely consequence of such a scenario is the continued loss of globally significant biological diversity during the next century, combined with collapse of fish stocks and food security in the region and the non-attainment of the targets set out in the GCLME SAP, WSSD JPOI and United Nations Millennium Development Goals.

The activities to be implemented by the Guinea Current Large Marine Ecosystem project within the framework of the Strategic Action Programme would effectively position the sixteen countries in achieving the WSSD targets on oceans and coasts as enumerated in paragraph 4 and place the region on the path to sustainable development. The project will also contribute and facilitate the New Partnership for Africa's Development (NEPAD) Environmental Action Plan implementation as well as contribute to the revitalization of the Abidjan Convention by bringing harmonized environmental management efforts in combination with economic development and poverty alleviation. The project will support as well, the regional implementation of the Global Programme of Action for Protection of the Marine Environment from Land-Based Activities, relevant components of the Abidjan Convention and those of the Accra Ministerial Declaration.

The major expected results from the sucessful implementation of the GCLME project include:

[1] Improved institutional structure to address priority regional issues, including a Guinea Current Commission and other regional and national bodies for conducting effective regional interventions for fisheries and biodiversity conservation and pollution prevention.

[2] Improved legal/management structure for addressing the priority regional issues, including a Protocol on Land Based Activities for the Abidjan Convention, a regional Biodiversity Action Plan, as well as legislative reforms for fisheries, land-based activities, and biodiversity

[3] Nine successful demonstration projects will serve as a basis for replication in the region and outside the region, as concrete steps towards achieving agreed environmental quality objectives.

[4] Nationally endorsed Strategic Action Program and National Action Programmes (NAPs) with accompanying sustainable financing plan will lead the way towards continued incremental improvement to the GCLME based on a solid foundation of regional commitment and consensus

[5] Realization of the pertinent WSSD JPOI Targets related to Oceans and Coasts.

Acknowledgment

The authors acknowledge the contributions of all the Thematic Experts in the sixteen countries that contributed to the successful formulation of the Guinea Current Large Marine Ecosystem project. The immense political support and contributions of Dr Imeh Okopido, former Minister of Environment (State) for Nigeria in realizing the project is greatly appreciated.

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