The Western and Central Africa Land–Sea Interface: A Vulnerable, Threatened, and Important Coastal Zone Within a Changing Environment

S. Diop, J. Fabres, R. Pravettoni, J.-P. Barusseau, C. Descamps, and J.-P. Ducrotoy

Abstract

The primary objective of this book, focusing on Western and Central African coastal areas, is to provide up-to-date scientific information and discuss quantitative data about selected estuaries and coastal ecosystems. As a volume of the series "Estuaries of the World" (EOTW), it is aiming at offering a better understanding of Land–Ocean Interactions in the Coastal Zone (LOICZ) in this region, including processes, functioning, and impacts in a changing environment. Although it focuses on estuarine and related coastal ecosystems, it includes consideration of the freshwater systems that feed these coastal environments. Indeed, the importance of the Western and Central African coastal areas cannot be overemphasized, with regard to both human and ecosystem needs, and watersheds have to be considered as influencing them directly and indirectly. Moreover, this up-to-date information and data discuss estuaries, deltas, and coastal lagoons, as well as their recent changes and evolution, and the implications of these changes in regard to managing these coastal waters. The content of this book also contributes to the global research analysis and synthesis agenda of the LOICZ especially on its primary focus related to river mouth systems, including estuaries and deltas. This book illustrates several themes organized around the concept of

S. Diop (✉)
Universite Cheikh Anta Diop de Dakar, B.P. 5346
Dakar-Fann, Senegal
e-mail: sal-fatd@orange.sn esalifdiop@gmail.com

J. Fabres · R. Pravettoni
GRID-Arendal, Postboks 183, 4802 Arendal, Norway
e-mail: joan.fabres@grida.no

R. Pravettoni
e-mail: riccardo.pravettoni@grida.no

J.-P. Barusseau
CEFREM, University Via Domitia—52, Avenue Paul-Alduy,
66860, Perpignan, France
e-mail: brs@univ-perp.fr

C. Descamps
Maitre de Conférences Emeritus, Institut Fondamental d'Afrique
Noire—Cheikh Anta Diop, B.P. 206, Dakar, Senegal
e-mail: cyrdescamps@yahoo.fr

J.-P. Ducrotoy
Institute of Estuarine and Coastal Studies, The University of Hull,
Cottingham Road, Hull, HU6 7RX, UK
e-mail: jean-paul.ducrotoy@hull.ac.uk

S. Diop et al. (eds.), *The Land/Ocean Interactions in the Coastal Zone of West and Central Africa*, Estuaries of the World, DOI: 10.1007/978-3-319-06388-1_1,
© Springer International Publishing Switzerland 2014

ecosystem services and benefits within estuaries, coastal, and marine areas in West and Central Africa, with six main objectives: (1) Introducing the framework of current studies, including factors related to oceanographic, geologic, geomorphologic, physicochemical and biogeochemical components of these ecosystems; (2) Emphasizing the need to study natural and human-induced impacts on the functioning and sustainability of estuaries and other coastal systems, with possible options for managing them for sustainable use; (3) Facilitating recognition by coastal scientists and managers of the unique features of estuaries and other relevant coastal environments in Africa, while also enhancing existing knowledge regarding the associated ecosystem services; (4) Encouraging young researchers, scientists, and advanced students to undertake holistic, integrated studies on estuaries and coastal areas in their regions, using an ecosystems assessment approach and ecosystem-based management; and (5) Providing professionals, students, and the general public with readily accessible and understandable scientific articles and papers on the economic and ecological importance of estuaries and other related coastal ecosystems in Africa.

Keywords
Ecosystem goods and services • Estuaries and coastal ecosystems • West and Central Africa • Ecosystem approach • Oceanographic • Geologic • Geomorphologic • Physicochemical • Biogeochemical • Socioeconomic factors

Introduction

The West and Central African coastline extends over around 6,000 km, from the shores of the sandy desert of Mauritania in the north to the lagoon areas and coastal belts of the Gulf of Guinea, including deeply cut coastlines of islands (for example, Guinea-Bissau and the Bissagos islands) and estuaries up to the Republic of Congo (Fig. 1). The immense Niger and Cross River delta and Congo River mouth are located at the eastern and southern end. The West African "ecomarine" region (more or less corresponding to the Canary Current Large Marine Ecosystem[1]) stretches along 3,500 km of coastline and covers six countries: Mauritania, Senegal, Gambia, Cape Verde, Guinea-Bissau, and Guinea (Diop 1990). The coastline exhibits a great variety of habitats, ranging from enormous extensions of seaweed prairies in the north, to rocky cliffs and long sandy beaches, to mangroves and well-developed estuaries in the south (UNEP-WCMC 2007). Beyond this ecoregion, the entire Guinea Current Large Marine Ecosystem is located to the south of Guinea, stretching as far as Nigeria, and well beyond Gabon, offshore of the two Congo's, Sao Tomé and Principe, and Equatorial Guinea (see chapter "Morphological and Hydrodynamic Changes in the Lower Estuary of the Senegal River: Effects on the Environment of the Breach of the 'Langue de Barbarie' Sand Spit in 2003").

[1] Large Marine Ecosystems encompass waters from river basins and estuaries to the seaward boundaries of continental shelves and margins of coastal currents and water masses (Sherman 1994).

The ecological importance of the Western and Central African coastal region and the adjacent uplands areas (from the continental margins to the offshore island nations), which contain a wide and varied range of important habitats and associated biota that exhibit a high biological diversity, cannot be overemphasized. The continental shelf along the coast is in general narrow, with widths between 20 and 50 km (but reaching up to 150 km in certain places like offshore Guinea-Bissau, Sierra Leone, and Ghana). One of the main characteristics of this African marine and coastal region is the occurrence of seasonal upwelling, which explains the abundance of substantial commercial stocks of demersal and pelagic fish in its coastal waters (World Bank Africa 1994). Indeed, the economy of most of the countries discussed in this report is highly dependent on their coasts and their marine environment.

Natural Conditions and Processes

Regional Morphology and River Basin Drainages

Four narrow coastal sedimentary basins, containing a few volcanic intrusions and other rocky outcrops at the major capes, have developed on the edges of the coastline, including the Senegalese-Mauritanian basin, the Cote d'Ivoire basin, the Niger basin (including Niger Delta), and the coastal basins from Gabon to Congo (UNEP 1999).

All four coastal sedimentary environments are strongly influenced by their river basin drainages. There are five major

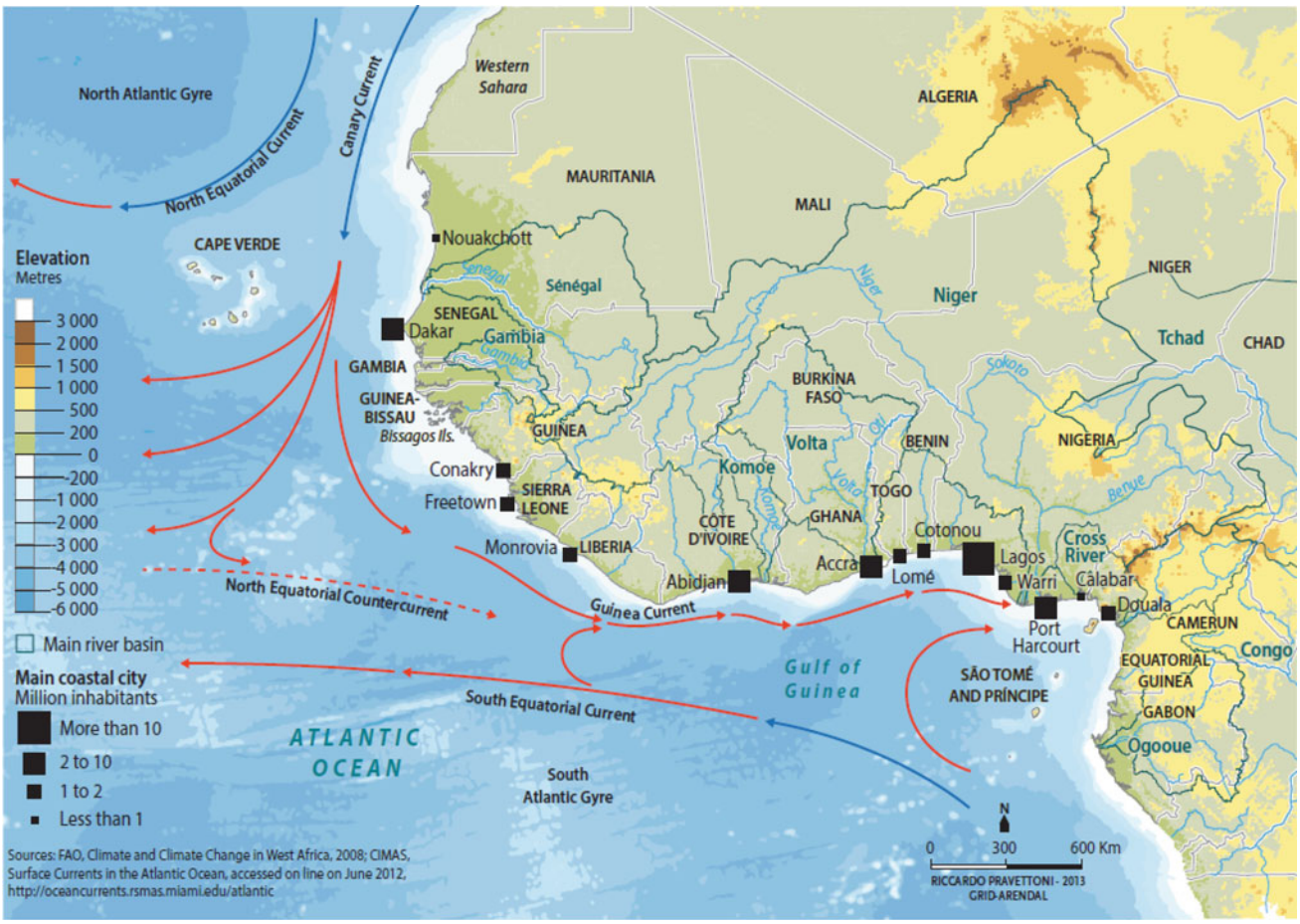


Fig. 1 Map of the coast of West Africa with main rivers and marine currents

river systems draining the entire coastline from Senegal to Congo. The most important rivers include the Niger, which drains an area of over 1 million km^2; the Volta, with a drainage basin of 390,000 km^2 (World Bank Africa 1994); and the Congo river, with the second largest mean annual runoff and catchment area in the world, freshwater and sediment discharge estimated to be 30–80 tons/km^2. For purposes of energy production, irrigation, and flood control, however, most of these rivers have been dammed, consequently significantly altering their hydrology and sediment flows, thereby causing inevitable downstream impacts and accelerating coastal erosion processes (see chapter "Management of a Tropical River: Impacts on the Resilience of the Senegal River Estuary"). The coastal basins, particularly along the Niger Delta, are gradually subsiding because of the geology of the area, as well as such human activities as oil mining and natural gas exploitation. On the other hand, the existing agrochemical and agricultural runoff within the Niger River basin, as well as the sediment load and urban and industrial wastewaters, have caused notable groundwater contamination and water quality degradation. These pollutant discharges directly affect the coastal ecosystems of the countries located along the coast. Regarding coastal concerns, the potential sea level rise and its impacts also are important, including shoreline retreat and coastal erosion, an increased frequency of coastal wetland submergence and saltwater intrusion into estuaries and coastal lagoons and aquifers.

General Oceanography, Coastal Morphology, and Processes

Four distinct and relatively persistent oceanic current systems are of importance off the shores of Western and Central African coasts (Fig. 1) in regard to the transport of substances, water temperature, meteorology, and biological conditions. They are as follows:

(a) The cold Canary Current, flowing southwestward along the coast in the northern part of the Western and Central African region (Mauritania, Senegal, Gambia, Guinea, etc.). It feeds the North Equatorial Countercurrent and the Guinea Current (Fig. 1);

(b) The North Equatorial Countercurrent flowing eastward from the central Atlantic;
(c) The Guinea Current, fed by the North Equatorial Countercurrent, involving warm waters flowing eastward and southeastward along the coast of the Gulf of Guinea (Sherman and Hempel 2008); and
(d) The South Equatorial Current, which flows at some distance from the coast, between 10°S and the Equator.

The Canary Current itself transports cool waters toward the Equator and has current speeds of approximately 20 cm/s. It is an essentially wind-driven current linked to the same regional wind systems responsible for the upwelling phenomenon that dominates the coastal waters up to several tens of kilometers offshore. The cool and richer upwelling waters prevail along the northwestern part from November to April/May and along limited parts of the northern parts of the Gulf of Guinea (Sherman and Hempel 2008).

High precipitation and numerous rivers on the central West African coast generate large masses of warm (above 24 °C) and low-salinity (less than 35‰) waters, the so-called Guinea waters.

In terms of coastal morphology, the succession consists of the following:

(a) Sandy arid coastal and plains bordered by eolian dunes (Mauritania and North coasts of Senegal);
(b) More-or-less sandy alluvial marshes with estuaries and deltas, colonized by mangrove vegetation (South of Senegal, Guinea-Bissau and Guinea, and Sierra Leone);
(c) Rocky scarps and sandy beaches with barrier islands, alternating with mangrove vegetation (Sierra Leone, Liberia, and eastern Nigeria to Gabon);
(d) Low sandy coastal plains, alternating with coastal lagoons along the Gulf of Guinea (Côte d'Ivoire, Ghana, Togo, Benin, and Congo estuary); and
(e) Huge marshy areas formed by the Niger Delta, with mangroves and rapidly growing Nypa Palms, indented by fluvial channels subject to tidal influences.

Further, a number of islands and archipelagos are located in the Atlantic Ocean offshore of the West Africa coasts (Canary and the Cape Verde Islands; Bissagos archipelago) and in the eastern part of the Gulf of Guinea (Sao Tome and Principe and Annabon in Equatorial Guinea, among others).

The tidal ranges along these west and central coasts are wide, exceeding 5 m in places, with the average for the whole coastal area being studied in the order of 1 m (See chapter "West African Coastal Area: Challenges and Outlook"). The highest tidal ranges recorded in the region are in Guinea-Bissau, Guinea, and Sierra Leone (from 2.8–4.7 m to 2.8 m; see Fig 2; Table 1).

Coastal Processes, Physical Alterations, and Habitat Modifications

Coastal erosion clearly constitutes the most serious coastal process problem in many West African countries. The rate of the coastal retreat can average several meters per year (e.g., in Fajara, Serekunda in the Gambia; in Keta, Ghana; and in the south coast of Dakar, Senegal). Although the coastline is very sensitive to natural erosion and sedimentation processes attributable to high wave energy, strong littoral drift transport, etc., human activities have significantly intensified coastal erosion, notably through sand mining, disturbance of the hydrological cycles, river damming, port construction, dredging, and mangrove deforestation, to cite a few examples. These examples are particularly relevant for the western part of Africa and mainly for the coastal countries in the Gulf of Guinea (Benin, Côte d'Ivoire, Ghana, Nigeria, and Togo).

Ecosystem Goods and Services and Species Diversity

A large variety of ecosystems and habitats exist along the western and central coasts of Africa, including the following:

(a) Wetland habitats, particularly those containing mangrove swamps and forests in a series of deltaic and estuarine formations, are the most apparent features. They extend more than 15,000 km^2 from Senegal to Congo, with the areas of highest mangrove concentration being located along the coasts south of Senegal, Guinea and Guinea-Bissau, Sierra Leone, and mainly in the Niger Delta (with more than 6,500 km^2). Although these mangrove forests are less diverse in terms of species than those in East Africa, they cover large surfaces and constitute the most extensive mangrove forests in Africa (see chapters "Combined Uses of Supervised Classification and Normalized Difference Vegetation Index Techniques to Monitor Land Degradation in the Saloum Saline Estuary System", "Importance of Mangrove Litter Production in the Protection of Atlantic Coastal Forest of Cameroon and Ghana", "Carbon Budget in Mangrove Forests of Varying Degradation Regimes in the Western Coastal Wetlands Complex (Ramsar Site 1017) of Southern Benin, West Africa", "Rapid Assessment of Mangrove Conditions for Potential Payment for Ecosystem Services in Some Estuaries of Western Region of Ghana, West Africa", "Assesment of Mangrove Carbon Stocks in Cameroon,



Fig. 2 Map of the coast of West Africa with tidal ranges (see Table 1)

Gabon, the Republic of Congo (RoC) and the Democratic Republic of Congo (DRC) Including Their Potential for Reducing Emissions from Deforestation and Forest Degradation (REDD+)"). Most of the coastal wetlands provide unique ecological conditions and habitats for migratory birds. They also function as nurseries for valuable fish and shellfish species, but remain unprotected in regard to impacts from natural and human influences and exploitation (UNEP-WCMC 2007);

(b) Coastal lagoons are found mainly in the Gulf of Guinea, from Côte d'Ivoire to east of Nigeria. They are associated with freshwater rivers, deltas, and estuaries and include a wide range of tidal swamps and seasonal marshlands;

(c) Sea grass beds are not very well developed in West Africa, although they exist off the shorelines of some estuaries and deltas (i.e., Saloum, Casamance in Senegal; Cacheu and Geba in Guinea-Bissau, etc.). There are no true coral reefs along the West African coast, mainly because of the cool waters of the Canary Currents;

(d) Sandy beaches, particularly in the Western African coast, along Mauritania and north of Senegal, and also in Guinea-Bissau, Sierra Leone, and Liberia and along the Gulf of Guinea, are considered important nesting ecosystems, particularly for sea turtles. Their exposure to strong currents and swells make the beaches extremely dangerous, often also being subject to marine debris and detritus accumulation in these areas.

In fact, the most important factor characterizing the open ocean waters off the shores of Gambia, Mauritania, and Senegal is the nearly permanent presence of upwelling, which is highly influenced in this region by the Canary Current. This is a reason why this region is well known for its rich fish production. Indeed, a large variety and diversity of marine resources species characterize the coastal marine waters of West and Central Africa. The wealth of estuaries, deltas, coastal lagoons, and the nutrient-rich upwelling of cold waters make a major contribution to the diversity of fish life. Nevertheless, these marine and coastal areas, including upstream freshwater regions, are presently affected by human activities, including over-exploitation and impacts from land-based settlements and pollutants from related industrial, agricultural, urban, and domestic sewage runoff and other mining activities (e.g., oil and gas), particularly off

Table 1 Average tidal range summary in various coastal locations along Western and Central Africa November 2013

Countries	Coastal stations	Low tide (m)	High tide (m)
Mauritania	Nouakchott	0.5	1.7
Senegal	Dakar	0.6	1.7
Gambia	Banjul	0.4	1.7
Guinea-Bissau	Bissau	1.0	4.7
Guinea	Conakry	1.0	3.2
Sierra Leone	Freetown	0.9	2.8
Liberia	Monrovia	0.3	1.5
Côte d'Ivoire	Abidjan	0.3	1.2
Ghana	Accra	0.4	1.7
Togo	Lome	0.4	1.8
Benin	Cotonou	0.2	1.5
Nigeria	Lagos	0.1	1.1
Cameroon	Douala	0.5	2.5
Equatorial Guinea	Bata	0.3	1.7
Gabon	Libreville	0.5	2.0
Congo	Pointe Noire	0.3	1.6

Source http://www.mareespeche.com

the shorelines of Angola, Gabon, and Nigeria (see chapters "Studies and Transactions on Pollution Assessment of the Lagos Lagoon System, Nigeria", "Estuarine and Ocean Circulation Dynamics in the Niger Delta, Nigeria: Implications for Oil Spill and Pollution Management", "Morphological Characteristics of the Bonny and Cross River (Calabar) Estuaries in Nigeria: Implications for Navigation and Environmental Hazards").

At the same time, however, the presence of invertebrates such as intertidal mollusks (*Senilia sp., Crassostrea sp*., etc.), reptiles (turtles and crocodiles), marine mammals such as the West African manatee (*Trichechus senegalensis*), and some shark species, often threatened by hunting and trapping, demonstrates the variety of the species in the western and central part of Africa (World Bank Africa 1994; chapter "Status of Large Marine Flagship Faunal Diversity Within Cameroon Estuaries of Central African Coast"). The most remarkable collection of millions of migratory birds that seasonally visit the West African coast and mainland regions highlights the importance of preserving and maintaining the existing wetlands in this part of Africa. Large concentrations of seabirds are found seasonally in Mauritania, Senegal, Gambia, and Guinea-Bissau, including *Larus genei, Gechelidon nilotica,* and *Thalasseus maximus albididorsalis,* as well as the regionally large populations of great white pelican, white-breasted cormorant, and Caspian tern. Many of the islands contain large seabird nesting sites, an example being the Cape Verde Islands. The Gulf of Guinea Islands, near Principe and Sao Tome, also contain sizeable colonies of terns, noddies, and boobies. This species diversity and fauna richness is facilitating conservation and preservation policies being undertaken by some Western and Central African countries through creation and implementation of marine and coastal protected areas (Banc d'Arguin and Djawling in Mauritania, Djoudj in Senegal). Plans for the near future include implementation of regional-wide protected coastal and marine along the coastal zone in West and Central Africa.

Anthropogenic Impacts: Demography and Socioeconomic Activities, Including Cultural Heritage

Socioeconomic Implications of Anthropogenic Alterations

An estimated 100 million inhabitants occupy a narrow coastal margin some 60 km wide along the Atlantic coast between Mauritania and Namibia. This region exhibits a potential doubling time of 20–25 years, noting its present annual population growth rate of about 3 %. The highest population density centers are located in some key cities along the coast, including Accra-Tema, Abidjan, Cotonou, Dakar, Douala, Lagos, and Port Harcourt. In fact, most of the highly and densely populated coastal regions depend on the biological resources of the marine and coastal areas. Offshore and inshore waters, including estuaries, lagoons, and rivers, serve as major animal protein sources, in the form of fish and shellfish. Coastal fisheries also represent significant income sources (NOAA 2003).

Further, in spite of a low level of industrial development in West and Central Africa, the rate of industrialization continues to increase along the coastal areas.

Both the increasing impacts of urban population growth and the associated industries have created negative synergies in terms of human and environmental impact along the coastal regions. A variety of pollutants can be found in the region, including sewage, industrial, and solid waste disposal. Oil spills from shipping operations also are found increasingly in the region. As a result, water quality degradation is one of the most important components of environmental degradation within the coastal, marine, and freshwater areas in the in West and Central Africa region (UNEP 1999, i.e., microbiological and bacteriological contamination in certain confine coastal regions such as the Bay of Hann, near the city of Dakar; in Ebrie and Lagos lagoons, around Abidjan and Lagos, etc., Re: chapters "Studies and Transactions on Pollution Assessment of the Lagos Lagoon System, Nigeria", "Estuarine and Ocean Circulation Dynamics in the Niger Delta, Nigeria: Implications for Oil Spill and Pollution Management").

Agricultural runoff attributable to irrigation in the river valleys and floodplains (i.e., Senegal River delta, interior Niger Delta, Volta delta), including elevated concentrations of nutrients and pesticides, also contributes to increased eutrophication in the estuaries, deltas, coastal, and freshwater environments in West and Central Africa. River inputs also carry significant amounts of sediment resulting from soil erosion and deforestation, which contribute significantly to the siltation of coastal habitats and declining productivity. Combined with the pollutant inputs, it illustrates the problems currently encountered with significant seasonal invasive aquatic weeds in most freshwater aquatic areas, including Côte d'Ivoire, Nigeria, and Benin coastal lagoons. The same degradation is now occurring in the northern part of West Africa, particularly in the Lac de Guiers and the Senegal River delta.

Although tourism constitutes an important industry in many West and Central African coastal countries, including Senegal, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Nigeria, and Gabon (see chapters" Morphology Analysis of Niger Delta Shoreline and Estuaries for Ecotourism Potential in Nigeria, Plantation Agriculture as a Driver of Deforestation and Degradation of Central African Coastal Estuarine Forest Landscape of South Western Cameroon"), it can nevertheless result in severe impacts on the coastal areas from Dakar to Douala. The constructions of hotels and other recreational facilities directly on the shore have been responsible for clearing of coastal vegetation, filling of wetlands, and increasing sewage and solid waste loads. At the same time, such constructions have contributed to accelerate coastal erosion, e.g., Southern coast of Senegal. Overall, such negative situation has been exacerbated over past decades by inadequate maintenance infrastructures.

Over-exploitation of marine resources and degradation of nurseries and habitats is currently a serious and accelerating phenomenon in this region. Because of over-fishing in the highly productive West African offshore and coastal waters, for example, the region is facing gradually and significantly depleted fish stocks. Accordingly, fishing activities, an important source of foreign currency for the economy of several West African countries, must be carefully managed, including appropriate quotas for the exploitation of different species, use of appropriate fishing equipment and fishing methods, improved management, legislation and regulatory measures, and reduction in and/or elimination of coastal water pollution from both land- and marine-based sources.

Human Impacts on Cultural Heritage Sites

In regard to cultural heritage sites, West and Central African coastal zones have been areas of human settlements for a long time. Evidence of early human occupation of the rich mangrove fishing areas was confirmed through the discovery of shell middens and pottery in many estuaries and on deltaic islands (Diop 1990; Diop et al. 2002). Additional evidence of pre-colonial occupation of the West African coastal regions exists at Grand Popo and Ouidah on the coast of Benin. Further, colonial buildings of considerable architectural interest can also be found in Porto Novo, Benin, and Grand Bassam in Côte d'Ivoire. Indeed, archeological and historical sites are located in all these African coastal countries, particularly Equatorial Guinea, Gambia, Ghana, and Senegal. Those cultural heritage sites must be preserved and included as integral parts in the coastal and marine protected areas. They must be protected from degradation or damage attributable to unplanned urbanization, pollution, and intensive industrialization activities (Diop et al. 2011).

Conclusions

It is clear that human-based land-use activities in coastal and marine areas of West and Central Africa, in combination with natural degradation processes, can induce significant impacts on the coastal environment. These impacts include loss of habitats, productivity and biodiversity, degraded water quality, and changes in natural coastal and marine environment equilibrium including increasing harmful effects.

Against this background, major environmental concerns regarding the associated socioeconomic impacts requiring closer monitoring and clear options for sustainable management include the following:

(a) Water quality deterioration, mainly around urban areas, including eutrophication and its associated impacts on environment and public health;
(b) Increasing pollution of coastal and associated freshwater environments from industrial and agricultural activities;
(c) Physical alterations and degradation, coastal erosion, and habitat modifications; and
(d) Loss of fishery resources and marine biodiversity, including associated ecosystem services.

In recognizing and utilizing the economic and ecological importance of estuaries and coastal ecosystems, coastal countries have the responsibility to provide the means to manage and protect the sustainability of such vital coastal features and their resources for the benefit of future generations.

This book is meant to provide a synthesis of some of the scientific knowledge of the region. To accurately determine the nature and severity of the problems occurring in the coastal Western and Central Africa region, in-depth scientific assessments, including socioeconomic aspects, had to be undertaken, particularly with regard to food security, poverty alleviation, public and ecosystem health, sustainable coastal and marine resources, biological diversity, and ecosystem services, including their socioeconomic benefits and uses. To

this end, the various chapters in this book constitute a contribution to such scientific studies and research for managing the estuaries and the coastal waters of West and Central Africa for sustainable human and ecosystem use.

The content of this book also contributes to the global research analysis and synthesis agenda of the Land–Ocean Interactions in the Coastal Zone (LOICZ) especially on its core program of Earth System Science Project convened under the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP). The primary focus of LOICZ concerns related to river mouth systems, including estuaries and deltas (see www.loiczs.org).

References

Diop ES (ed) (1990) La côte Ouest-Africaine: du Saloum (Sénégal) à la Mellacorée (Rep de Guinée). In: Coll. Etudes et Thèses—Editions de l'ORSTOM – Paris, 2 vols + illustrations and map plates, 379p

Diop ES, Gordon C, Semesi AK et al (2002) Mangroves of Africa. In: de Lacerda LD (ed) Mangroves ecosystems: functions and management; and 55 tables. Springer Verlag Environmental Science Series, Berlin, , pp 61–121

Diop S, Arthurton R, Scheren P, Kitheka J, Koranteng K, Payet R (2011) The coastal and marine environment of Western and Eastern Africa: challenges to sustainable management and socio-economic development. In: Wolanski E, McLusky DS (eds) Treatise on estuarine and coastal science, vol 11. Academic Press, Waltham, pp 315–335

NOAA (2003) Guinea current large marine ecosystem, LM E No. 28. http://na.nefsc.noaa.gov/lme/text/lme28.htm

Sherman K (1994) Sustainability, biomass yields and health of coastal ecosystems: an ecological perspective. Mar Ecol Prog Ser 112:277–301

Sherman K, Hempel G (eds) (2008) The UNEP large marine ecosystem report: a perspective on changing conditions in LMEs of the World's Regional Seas. UNEP Regional Seas Reports and Studies No. 182. UNEP, Nairobi

UNEP (1999) Regional overview of land-based sources and activities affecting the coastal and associated freshwater environment in West and Central African region. In: Diop S (Report) UNEP/GPA Co-ordination Office and UNEP Regional Seas Programme, Nairobi, 110 p

UNEP-WCMC (2007) Mangroves of Western and Central Africa—UNEP-Regional Seas Programme and UN EP-WCMC report, p 88

World Bank Africa (1994) A framework for integrated coastal zone management. Land, water and natural division. Africa Environmentally Sustainable Division, Washington DC, 139 p