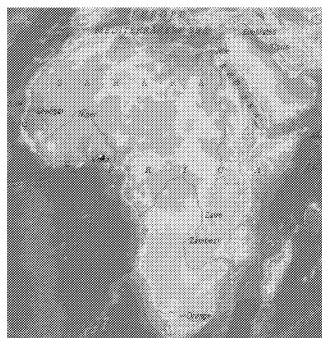


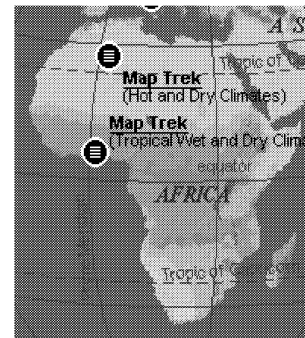
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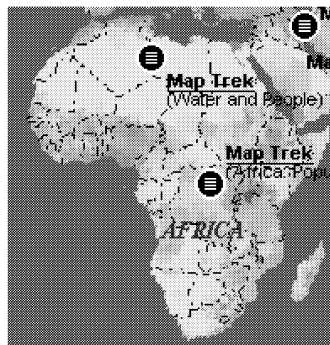
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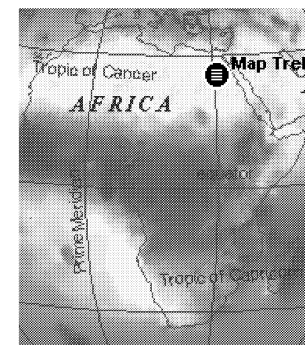
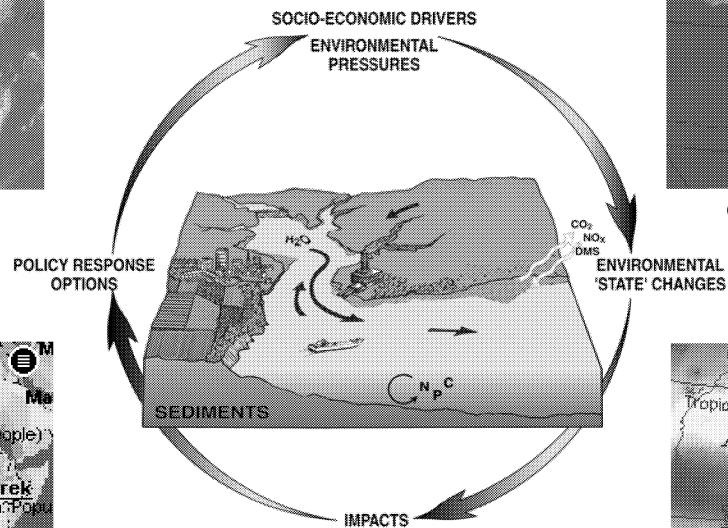
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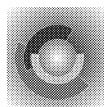
African Basins

LOICZ Global Change Assessment and Synthesis of River Catchment–Coastal Sea Interaction and Human Dimensions

Compiled and edited by R.S. Arthurton, H.H. Kremer, E. Odada, W. Salomons and J.I. Marshall Crossland



Ministerie van Verkeer en Waterstaat
Directoraat-Generaal Rijkswaterstaat
Rijksinstituut voor Kust en Zee/RIKZ



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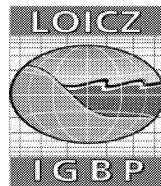
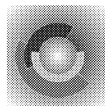
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NORWEGIAN AGENCY FOR
DEVELOPMENT COOPERATION

Published in the Netherlands, 2002 by:
LOICZ International Project Office
Netherlands Institute for Sea Research
P.O. Box 59
1790 AB Den Burg - Texel
The Netherlands
Email: loicz@nioz.nl

The Land-Ocean Interactions in the Coastal Zone Project is a Core Project of the “International Geosphere-Biosphere Programme: A Study Of Global Change” (IGBP), of the International Council of Scientific Unions.

The LOICZ IPO is financially supported through the Netherlands Organisation for Scientific Research by: the Ministry of Education, Culture and Science (OCenW); the Ministry of Transport, Public Works and Water Management (V&W RIKZ); and by The Royal Netherlands Academy of Sciences (KNAW), and The Netherlands Institute for Sea Research (NIOZ).

This report and allied workshops are contributions to the global LOICZ Basins assessment and synthesis core project: The Biogeochemical and Human Dimensions of Land-Based Fluxes to the Coastal Zone.

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Citation: Arthurton, R.S., H.H. Kremer, E. Odada, W. Salomons and J.I. Marshall Crossland 2002. African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment–Coastal Sea Interaction and Human Dimensions. LOICZ Reports & Studies No. 25: ii+344 pages, LOICZ, Texel, The Netherlands.

ISSN: 1383-4304

Cover: The cover shows various images of Africa from MS Encarta Interactive World Atlas (1999) and the DPSIR framework cycle as shown in LOICZ R&S No 11 (from Turner *et al.* 1998).

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Workshops Structure

This report provides a synthesis of the contributed papers and regional investigations of the two-phase LOICZ African Basins assessment process conducted in July 2000 and October/November 2001.

Acknowledgements

LOICZ is grateful for the generous sponsorship and support for the meetings by the Global Change System for Analysis, Research and Training, START, the Norwegian Development Agency, NORAD, the Intergovernmental Oceanographic Commission, IOC of UNESCO and the local host, Regional Office of Africa of the United Nations Environment Programme, UNEP/ROA in cooperation with the Pan-African START Secretariat, PASS.

LOICZ is indebted to Professor Eric Odada and his team from PASS and the University of Nairobi, Drs Sekou Toure and Yinka Adebayo of UNEP/ROA and Dr Salif Diop, UNEP Division on Early Warning and Assessment, in dealing with the local organizational requirements needed for the successful meetings and the substantial scientific contribution that they made to the progress of the AfriBasins workshops.

These meetings set the scientific stage on regional scale for the upcoming second phase of the LOICZ project from 2003 and related LOICZ-Basins core activities in Africa. These steps will help to strengthen support for regional networks and lead the way to continued work. We thank all participants who ensured the vitality of the highly interactive meetings, and contributed to this report.

The editors wish to thank Dr Jacques Denis, of Ifremer, for his assistance with the manuscripts written in French.

1. EXECUTIVE SUMMARY

by R.S. Arthurton and H.H. Kremer

The LOICZ-Basins project

The Land Ocean Interactions in the Coastal Zone (LOICZ) core project of the International Geosphere Biosphere Project, IGBP, is evaluating the physical, biogeochemical and human interactions influencing coastal change. The coastal zone is an integral part of the water cascade between catchments and oceans that is subject to external and internal forcing from both anthropogenic and natural pressures. LOICZ has four foci, under which there are three categories of projects. The LOICZ-Basins project is working to assess at local to global levels the impacts on the coastal environment of changes caused by such pressures and drivers within river catchments. Drivers such as damming, deforestation, agriculture and urbanisation influence the flows of water, nutrients, sediments and pollutants to the coastal sea. Studies addressing these issues have produced large amounts of data, but generally these data have not been subject to integrated assessment and synthesis. Only recently have the interactions of human historical evolution and biogeochemical environments been considered.

In LOICZ-Basins a river catchment (or island) and its associated coastal area are treated as one system (Figure 1.1). The focus is on the horizontal fluxes of substances within this system. This approach, integrating the natural and social sciences, addresses issues such as critical concentrations and loads, biological resilience and carrying capacity. To generate a global picture, a set of standardised (and thus comparable) regional assessment workshops has been implemented, using an adaption of the Driver-Pressure-State-Impact-Response (DPSIR) framework, developed by the OECD (see Appendix 1). The assessment aims to up-scale information from individual river catchment-to-coastal sea systems to sub-regional, then regional, levels. Characteristic types of coastal issue and change are identified and prioritised, and linked to their perceived major drivers.

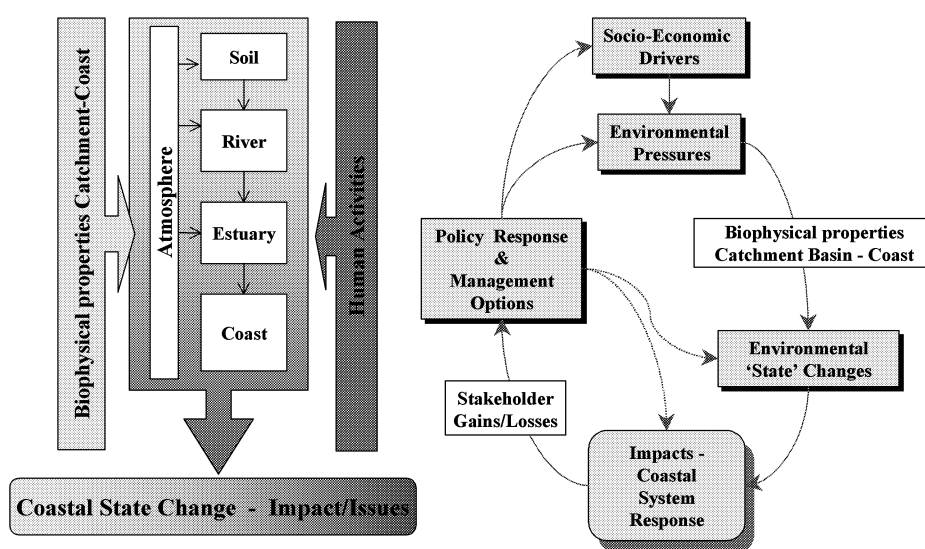


Figure 1.1 The catchment (island)-coastal zone system and the DPSIR framework.

LOICZ-Basins contributes directly to UNEP's Integrated Coastal Area and River Basin Management initiative (ICARM) as well as UNESCO/IOC Integrated Coastal Area Management (ICAM) and Coastal GOOS (Global Ocean Observing System) programmes. Links with other global projects including the Global International Waters Assessment (GIWA), with which LOICZ-Basins has some common interests, have been established.

The African Basins (AfriBasins) workshops

Two workshops were held in Africa to address LOICZ-Basin issues. The introductory workshop (AfriBasins I) was held at the UNEP headquarters at Gigiri, Nairobi, Kenya and hosted by the Regional Office for Africa (ROA) in July 2000. The second workshop (AfriBasins II, also in Nairobi, Oct/Nov 2001, and hosted by ROA) refined the preliminary assessments and focused on human dimensions. A principal objective was to highlight at local to regional scales the linkages between human activity drivers in the catchments and environmental and socio-economic issues and impacts in the coastal areas. Using this information, a second objective was to establish a sound basis upon which to develop proposals for interdisciplinary case studies on the human dimensions of land-driven coastal change within the African region, with a focus on the implications for coastal monitoring and management. For this purpose “hot spots” important for future research evaluation and a project design applicable to various spatial and temporal scales was to be identified. The workshop considered a draft “AfriCat” proposal, developed from the on-going “EuroCat” project, as an umbrella for the case studies. The proposal would have an emphasis on addressing the regional African needs, in the context of the priority areas for action as identified by the African Ministerial Conference on the Environment (AMCEN) in preparation for the World Summit on Sustainable Development in Johannesburg, September 2002.

Overview of the African catchment–coastal zone system

Building upon the output from AfriBasins I, eight sub-regions were identified for assessment within the Africa region, on the basis of geomorphological and climatic characteristics (Figure 1.2). The various sub-regions differ widely not only in the biophysical nature of their catchments but also in the availability and quality of existing data relating to their material fluxes. The named catchments assessed (Figures 1.3 and 2.1) were chosen as representative of their respective sub-regions.

1. North West Africa – relatively arid, medium basins (Sebou, Moulouya) with seasonal runoff and (in Morocco) major human pressure through diversion and damming causing coastal change issues; includes coastal stretches of Algeria and Tunisia but no information on systems there was gathered during the AfriBasins process.

2. West Africa – featuring a variety of large, transboundary (Niger, Volta, Senegal) basins subject to major damming resulting in reduced sediment and water fluxes and reduced coastal stability as a growing threat to the lagoon-based cities; also the medium basin of the Cross River. Damming, deforestation and agriculture are considered to be the principal drivers of state changes at the coast through modifications of the hydrological regime, water quality and sediment discharge in the large catchments.

3. Congo – a sub-region with extensive, though diminishing, rainforest. Available information about its land-based drivers and how they relate to coastal issues is scarce. The large transboundary Congo basin has little variation in discharge through the year.

4. South West Africa (Cape to southern Angola) – mostly dominated by the upwelling system of the Benguela current; cool and temperate small (Berg) and medium (Olifants) catchments in the south, arid large catchment (Gariep, formerly Orange) in the north with limited river runoff. Damming and agriculture are the principal drivers considered responsible for minor-to-medium but progressive state changes and impacts at the coast, causing modifications to runoff, water quality and coastal geomorphology.

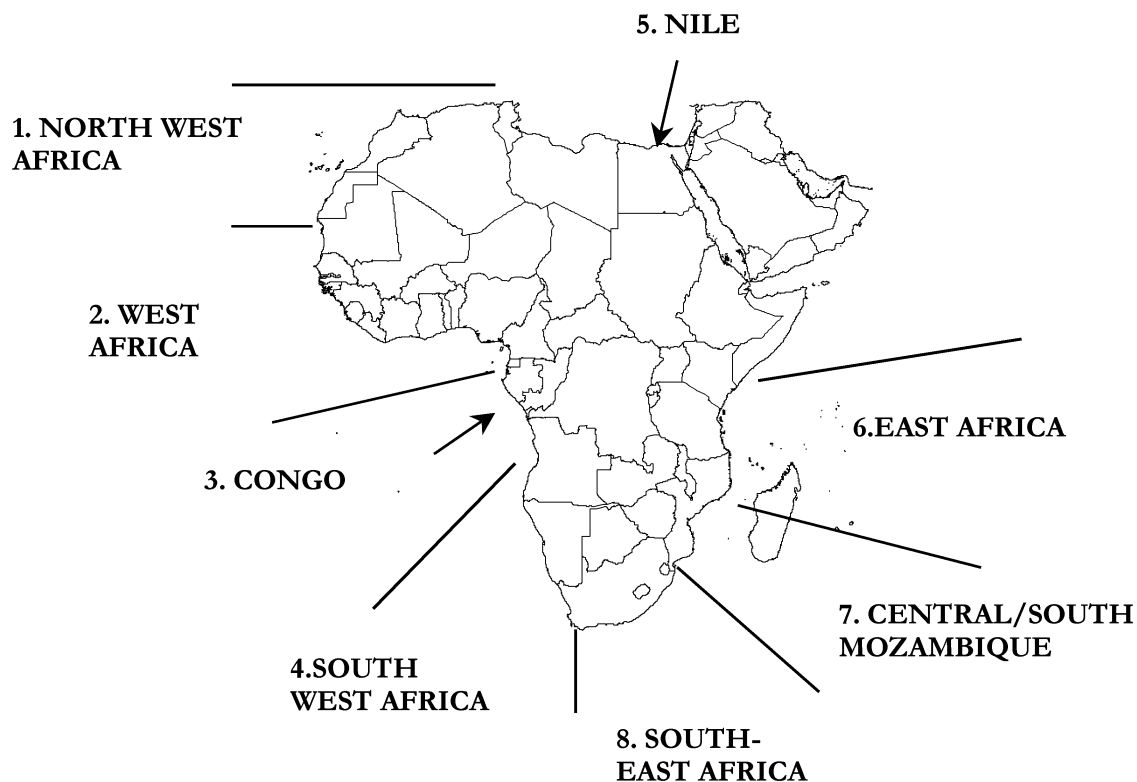


Figure 1.2. Sub-regions for the assessment of river catchment-coastal sea interaction classes determined in the LOICZ AfriBasins workshops.

5. Nile – a single-catchment sub-region incorporating the wider coastal stretches influenced by the Nile catchment with land-based drivers including the Aswan dam, urbanisation and agriculture. The damming of this transboundary river system has led to profound changes in fluxes through the Nile delta and in the associated coastal sea (the Mediterranean). This is exacerbated by a rapid growth of urbanisation and industrialisation around Cairo and changes in agricultural practice in the Nile River valley and its delta region.

6. East Africa (Somalia to northern Mozambique) – featuring medium (Tana, Sabaki, Rufiji) and small catchments with monsoonal (seasonal) flushing and subject to damming; also extensive coral reefs. Coastal erosion and sedimentation, pollution and loss of biological functioning are the principal impacts. Damming, deforestation and agriculture are the principal drivers and these are expected to become increasingly significant in respect of their impacts.

7. Central/south Mozambique – medium (Incomati) and large, transboundary (Zambezi, Limpopo) catchments with high seasonality in runoff and subject to extreme cyclonic events; an estuarine/deltaic coast characterised by beach plains and mangrove-fringed creeks. The principal issues are reduction in stream flow, coastal erosion, salinisation and nutrient depletion, all attributed to damming.

8. South East Africa – ranging from subtropical in the north to warm temperate on the Cape coast and characterized by medium (Thukela, Great Fish) and small (Groot Brak, Kromme) catchments that are subject to various anthropogenic pressures, particularly water abstraction. Damming is an important driver, with freshwater retention in semi-arid conditions, and there are plans in place for further intensive damming.

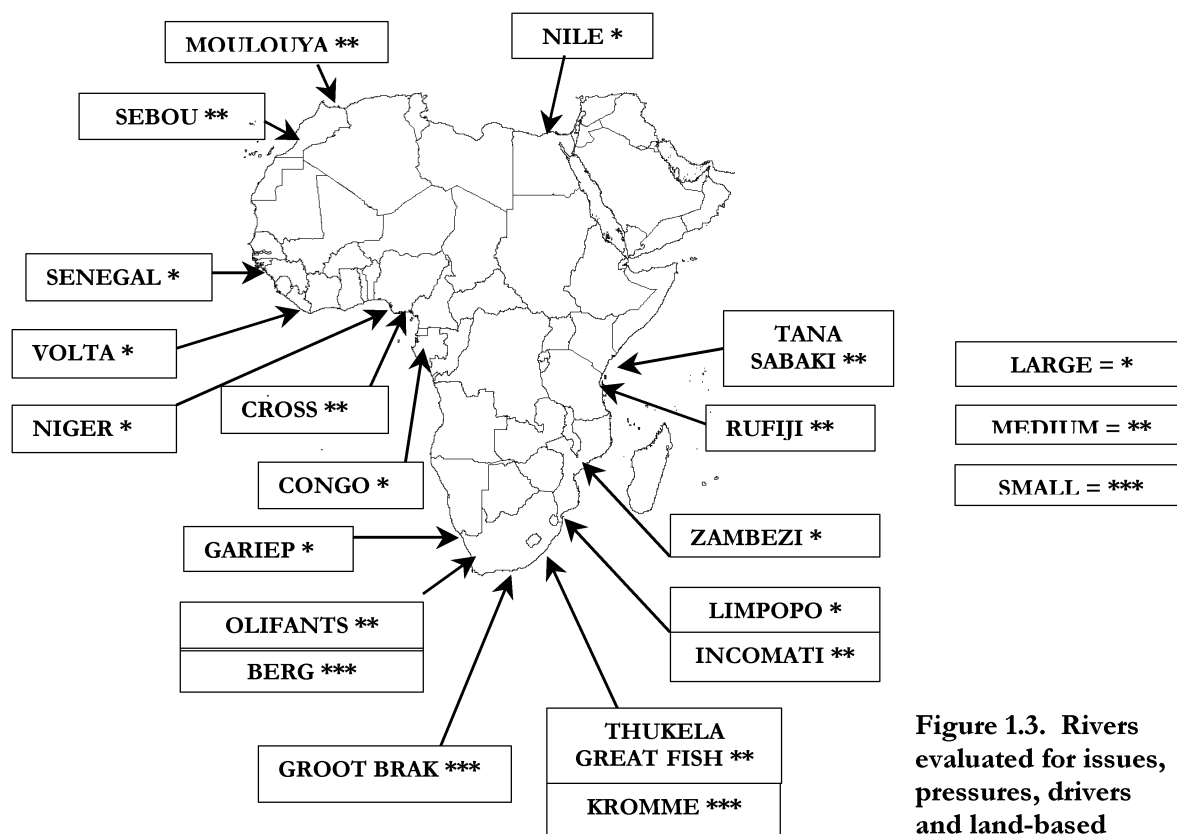


Figure 1.3. Rivers evaluated for issues, pressures, drivers and land-based activities in the AfriBasins II.

Impacts and state changes and their future trends

For the Africa region a preliminary ranking order was drawn up together with expected future trends in impacts (Table 1.1).

Table 1.1 Major activities (drivers) and present status and trends affecting the coastal zone in Africa.

Anthropogenic drivers	Major state changes and impact	Present status	Trend expectations	Major areas affected
Damming Diversion	Erosion Sedimentation	Major	Increasing	Almost all sub-regions, with 2 and 5 as particular “hot spots”
	Salinisation	Local	unknown	1, 7
	Nutrient depletion			7, 8
Various drivers	Biodiversity loss	Major	Increasing	Almost all sub-regions
Deforestation	Erosion Sedimentation	Medium		Medium ranking for most sub-regions, but major for coastal impact generated in small and medium catchments in 1 and 6
Agriculture	Eutrophication Pollution			Medium overall but major in 5
Urbanisation				As above, but in most cases more coastal than catchment-based – 4 , 5, 6
Industrialisation				Pollution

Coastal erosion and sedimentation were identified as significant and progressive impacts in nearly all of the sub-regions, the problems being acute in the Nile delta and West African lagoon systems. Damming was viewed as the principal driver, with reductions in stream flow and sediment flushing. Damming also contributed to estuarine salinisation, e.g., the Incomati River in Mozambique, and nutrient depletion in the coastal sea, e.g., off KwaZulu Natal. In most sub-regions deforestation and agriculture were regarded as important drivers, particularly in respect of coastal sedimentation from medium and small catchments, e.g., the Tana and Sabaki rivers in Kenya. Human settlement was identified as a major contributor to eutrophication and the proliferation of aquatic weeds in the large West African catchments. Elsewhere, while eutrophication and pollution were recognised, they were mostly restricted to local (coastal) urban-industrial sources, e.g., Alexandria, Mombasa, Saldanha Bay and Cape Town. Loss of biodiversity or biological functioning was seen as another common issue, related to a complex interplay of human and natural drivers.

In general these data are characteristic of developing economy situations where economic growth and water use exceed the development of the necessary urban and industrial infrastructure. This finding parallels those made in the South American (SAmBas), and East Asian Basins assessment and synthesis processes (Lacerda *et al.* 2001; Hong *et al.* in prep.). However, heterogeneity of the sub-regions seems to be more pronounced in Africa than in the other world regions, making the ranking of issues and drivers in Africa a more complex challenge.

The AfriBasins assessment process

In the preparation and execution of AfriBasins II, the standardised LOICZ-Basins assessment tables (Appendix 1) were used to guide the following sequence of assessment steps:

- Assessing and ranking coastal **issues/impacts** (together with their critical thresholds) due to human activities within catchments based on documented coastal changes.
- Assessing and ranking major catchment-based **drivers** and their consequent environmental **pressures** impacting the coast.
- Assessing and ranking the various **driver/pressure** settings generating the coastal **issues/impacts** and identifying the trends of **state** changes in the coastal environment; up-scaling to sub-regional then regional levels.
- Assessing and synthesising scientific, policy and/or management **responses**.
- Assessing and synthesising gaps in understanding, “hot spots” and research needs.

The issues were assessed for the rivers shown in Figures 1.3 and 2.1. A summary of the major concerns arising from the assessment is presented in Table 1.2.

A scarcity of relevant standardised data is a recurrent problem in most of the sub-regions assessed. This shortcoming applies both to scientific data and, particularly, to socio-economic information, whether concerning activities in the catchments or impacts at the coast. Time-series data generated from routine monitoring programmes is particularly sparse. The workshops highlighted a considerable dearth of knowledge about the critical loads and thresholds of material fluxes passing from the catchments to (or through) the coastal area to the coastal sea that, if exceeded, would significantly change the coastal environment. There was a need for common parameters to be established in respect of the indicators of change that were relevant to the region.

Supposed “multi-driver” impacts posed a major research challenge, particularly in the medium and large, transboundary catchments. The specific contributions (positive or negative) arising from, for example, agricultural practices, deforestation and damming to the fluxes of water and sediment that reach the coast need especially careful analysis, bearing in mind the socio-economic implications of regulation in these areas. In the AfriBasins process the rates of changes in the coastal environmental state resulting from catchment-generated pressures were assessed only in general terms – ‘direct’ or ‘progressive’. In some cases there was uncertainty in the assessment. In order to prioritise appropriate responses in the catchments at management and policy levels, there is a need for more specific information on the rates of change as well as the time-lags between the incidence of anthropogenic pressures and the corresponding changes in the state of the coastal environment.

In addition to the material fluxes generated or influenced by human activities in the catchments, the coastal sea of the region also receives significant nutrient and pollutant discharge from the urban-industrial nodes at the coast itself. Research is needed to assess and quantify the impacts of such coast-generated pollution and eutrophication for comparison with the impacts ascribed to catchment drivers. The contributions that natural drivers make (or have made) to changes in the state of the coastal environment over a range of time-scales is another area for consideration by regionally integrated research. Understanding natural processes and their variability over time (e.g., short- and long-term climate change), as they affect both the catchments and the coast, is an important prerequisite for an assessment of the contribution that human activities may make to coastal change. The coastal impacts of human activities in catchments need to be set in the context of natural driving forces in the African context.

While the working groups accepted the various difficulties implicit in the AfriBasins assessment process, the input to the assessment tables and the conclusions drawn from them represent their expert judgement, making the best of the data available.

The AfriCat proposal

From the results of the DPSIR assessment, the workshop identified a number of river catchments within the region that were appropriate for detailed case study, examining various aspects of the catchment driver - coastal impact linkage. Such initiatives would become the input to the planned AfriCat proposal envisaged as providing a conceptual umbrella for the individual proposals to be developed by the LOICZ AfriBasins scientist network. AfriCat's broad principles would be similar to those of the established EuroCat programme (<http://www.iiu-cnr.unical.it/EUROCAT/project.htm>).

The selection of demonstration sites provides coverage of the key issues identified by the AfriBasins workshops and also a representation of the various sub-regional river-coast classes. Many of the chosen catchments are large – greater than 200,000 km² – and extend over several countries, thus involving a range of transboundary issues. In each case study there would be an integrated, systematic approach to the understanding of the water cascade, taking the catchment and coast as a single system. There would be emphasis on robust science and relevant data-building and communication. It was recognised that the studies must add value to existing work, and have a strong socio-economic input, showing how the needs of a clearly identified user community were being addressed. As well as serving local and regional needs, the integrated studies of AfriCat will also feed the global aims of Earth System Science, through provision of reliable bases for up-scaling in a region where, compared with Europe for example, recent and reliable data are scarce.

Within the AfriBasins network, the key contact persons identified for each of the case study sites agreed to assist in further developing specific research proposals and to investigate the options for potential funding on national and international levels. The workshop reiterated that, regardless whether national or international financial support was targeted, the initiative and detailed networking needs at site level would need to come from the regional scientific community. LOICZ could provide a framework and assist in sustaining the necessary links.

The workshop affirmed the need for effective sub-regional coordination and a scientific coordinator for each study site, working under the general guidance of a Policy Advisory Board. The overall coordination of the further drafting process was dedicated to the Centre of African Wetlands, Ghana and the Pan African START Secretariat. UNEP-ROA confirmed its support in generating the national, governmental approval for the initiative through the AMCEN process. AMCEN was identified as an appropriate platform to facilitate the governmental approval for the various site study plans in a broader context of the Abidjan Declaration.

Demonstration sites (see Table 1.2)

For the eastern side of the region, the inclusion of the Nile was confirmed; also the Tana and Sabaki rivers as a linked site, the Rufiji, the Zambezi and the Incomati. For the Incomati site, the study could be built on earlier assessment and planning efforts conducted at the University Eduardo Mondlane in Maputo and a draft trilateral project plan between Mozambique, South Africa and Swaziland, all of which were developed with support of the Coastal Management Centre of RIKZ in the Netherlands. A project on the integrated evaluation of riverine fluxes to the Maputo Bay region, "Catchment2Coast" recently funded by the

European Commission, could be associated with the AfriCat project. This could be a key exercise in a continued second phase of the global LOICZ programme. For the western coast six sites were confirmed as providing suitable case study opportunities for AfriCat – the large catchments of the Congo, Niger, Volta and Senegal, the medium Cross, and two medium catchments in Morocco.

Table 1.2 Suggested demonstration sites* for key case studies of catchment–coastal sea systems in Africa.

Area/sub-regions	Major rivers	Regional characteristics and major coastal issues	Major drivers	Comments	Contact person(s)
<i>West Coast</i>					
1. North-west Africa	Moroccan catchm'ts	Semi-arid climate, small to medium catchments, high seasonal runoff variability, coastal erosion/sedimentation, salinisation	Damming Agriculture	Good coverage of flux data within catchments, few comprehensive studies on coastal linkage. Socio-economic profiles and analysis to be integrated	M. Snoussi
2. West Africa	Senegal, Volta, Niger, Cross	Transboundary catchments under strong human influence, coastal erosion, changes in nutrient supply and habitats due to changes of material transports	Damming Deforestation	Fair coverage of biogeochemical data, socio-economic information expected to be limited; baseline project development (Volta - PDF-B status).	I. Diop, A. Kane, G. S. Umoh, O. Martins, C. Gordon
3. Congo	Congo	Nutrient input	Uncontrolled urban growth	Apparently very limited data	tba
<i>North-east Med. and East Coast</i>					
5. Nile	Nile catchment and delta, Alexandria city coast	Transboundary river under extreme anthropogenic influence, flux changes to the floodplains and delta – high waste load	Damming, intensive agriculture, high population density	Good data coverage Add integrative value to existing projects	H. Awad
6. East Africa	Tana/Sabaki	Monsoonal runoff with sediment load changes	Damming, agriculture	Holistic study, flux data generation	J. Kitheka, J. Ochiewo
	Rufiji	Monsoonal discharge through mangrove to Mafia marine park with coral reefs	Agriculture, high population density	Flux data generally very limited	A. Ngusaru
7. Central/south Mozambique	Zambezi	Large transboundary catchment with the largest reservoir in Africa, discharge to delta/beach plain coast	Damming	No comprehensive study available; investigations would partly have to generate data	T. Forbes, L. Mhlanga
	Incomati	Transboundary catchment with major erosion and salinisation impacts, medium eutrophication and biodiversity loss	Damming Agriculture	Reasonable data coverage, earlier assessment and project development carried out	A. Hogueane, F. Tauacale
	Maputo Bay (incl. Incomati River etc)		Urbanisation	Integrated modelling project “Catchment2Coast” with potential for association with “AfriCat”	P. Monteiro

* This list of suggested sites is not exclusive and is subject to amendment.

2. REGIONAL ASSESSMENT AND SYNTHESIS OF AFRIBASINS

by R.S. Arthurton, H.H. Kremer, Wim Salomons and O. Martins

2.1 Introduction

The **Land Ocean Interactions in the Coastal Zone (LOICZ)** core project of the International Geosphere Biosphere Project (IGBP) is evaluating the physical, biogeochemical and human interactions that influence changes in the state of the coastal environment. The LOICZ key questions that aim to address these issues are:

- How are humans altering the mass balances of water, sediment, nutrient and contaminant fluxes, and what are the consequences?
- How do changes in land use, climate and sea-level alter fluxes and the retention of water and particulate matter in coastal zones, and affect morphodynamics?
- How can we apply knowledge of the processes and impacts of physical, biogeochemical and socio-economic changes to improve integrated coastal management?

Coastal zones worldwide are subject to many pressures, both natural and anthropogenic, which change over time. Management practices in Europe and North America over recent decades have significantly decreased the impacts there of “classical” contaminants such as heavy metals, nutrients and PCBs, but nutrient inputs show only minor reductions. In emerging economies, these latter substances have a high priority. In addition, new classes of industrial and agricultural chemicals have entered the priority lists of international organisations and should become the subjects of coastal impact and monitoring studies. Increasingly coastal areas are subject to a “competition for space” – urban and industrial development pressures, tourism and increased traffic all demand physical space, constraining the size and functioning of coastal ecosystems and creating major challenges for managers and regulators. Past and planned physical changes in river catchments, particularly by damming and diversion, influence the natural flow of water, nutrients, sediments and pollutants to the coast. Numerous studies have addressed these issues and produced large amounts of data, but these data have seldom been subjected to integrated assessment and synthesis. Only recently have the interactions of the physical and biogeochemical environments and human historical evolution been considered. As a step in this process, information and response strategies relating to coastal states, including many in Africa (UNEP 1999; UNEP *et al.* 1997, 1998), have been reviewed under the “Global Programme of Action for the Protection of the Marine Environment from Land-based Activities”.

The LOICZ-Basins project is working *inter alia* to develop a global assessment of the importance of changes in river catchments and their impacts on coastal seas by applying a “systems” approach. The river catchment and its associated coastal zone are treated as one system (Figure 1.1). Changes in the coastal zone are affected both by local human activities and by its biophysical properties. Thus, on a global scale, regional coastal zones will show differences in their responses to a similar human activity. The regional systems are subject to outside (long-term) pressures and drivers including climate change and global socio-economic changes. To elucidate these intricate relationships, LOICZ-Basins focuses on the horizontal fluxes of substances within the catchment-to-coastal sea system. This systems approach, integrating the natural and social sciences, addresses issues such as critical concentrations and loads, biological resilience and carrying capacity of the coastal environment. Airborne flux of fine sediment is not considered in this approach.

LOICZ-Basins uses a standardised DPSIR framework, developed by the OECD (1993), for the assessment, analysis and integration of the results of past studies (see Appendix 1). This permits a combination of the results from the natural and social sciences as well as feedback from and to policy/management options (Turner *et al.* 1998; Salomons *et al.* 1999). To generate a global picture, a set of standardised (and thus comparable) regional assessment workshops has been implemented, aiming to scale up information from individual river catchment-to-coastal sea systems to sub-regional and, finally, regional scales. Characteristic types or classes of coastal issues and changes are identified, prioritised and linked to their major natural and anthropogenic drivers on a catchment scale. Numerical or qualitative indices are developed to allow this

prioritisation and to permit qualitative or semi-quantitative comparison of the scenarios of land-driven coastal change within and across regions.

LOICZ-Basins therefore deals with the roles of human society on the transport of materials – water, sediments, nutrients, heavy metals and man-made chemicals – within the catchments and the impacts of those roles at the coast and in the coastal sea. In addition it aims to propose feasible management options along with an analysis of the successes and failures of past regulatory measures. Since the changes in fluxes are mostly land- or river catchment-based, the catchment-coastal sea system is treated as one unit – a water continuum. Applying this scale to coastal change phenomena, human activity drivers including agriculture, fisheries, urbanisation, industrialisation, transport and tourism, as well as morphological changes in the catchment (notably damming) have to be taken into account in as far as they affect the fluxes. In particular the following parameters are assessed:

- material flow of water, sediments, nutrients and priority polluting substances (past, present and future trends);
- socio-economic drivers that have changed or will change the material flows;
- indicators for the impact on coastal functioning; and to derive from them
- a “critical load” for the coastal zone and “critical thresholds” for system functioning.

The assessment enables the visualisation/mapping and up-scaling of the issues and scenario simulation on various spatial and temporal scales. It is expected, ultimately, to use the LOICZ typology approach for global up-scaling, which is under continued development in co-operation with IGBP-BAHC (Biospheric Aspects of the Hydrological Cycle core project).

Basins has established links with other global assessment projects including the UNEP-led, GEF-funded Global International Waters Assessment (GIWA), with which it has much of its DPSIR methodology in common. It contributes directly to UNEP’s Integrated Coastal Area and River Basin Management initiative (ICARM) as well as UNESCO IOC Integrated Coastal Area Management (ICAM) and Coastal GOOS (Global Ocean Observing System) programmes. LOICZ has agreed to channel the AfriBasins results into the joint ACOPS (Advisory Committee for the Protection of the Sea)-IOC African Process, which already has the political endorsement of at least 11 countries in the region and will feed into the Johannesburg World Summit on Sustainable Development to be held in September 2002.

Outputs from the AfriBasins I workshop (contributor – O. Martins)

During the first LOICZ AfriBasins workshop held in Nairobi 25-28 July 2000, a comprehensive scientific and institutional network was established. This included representatives of the Global Environment Facility (GEF, Biodiversity and Land Degradation), the World Bank (African Water Resources Management Forum Interim Task Force) and UNEP (Division of Environmental Impact Assessment and Early Warning and the Division of Policy Development and Law).

The AfriBasins I workshop was successful in building a regional, multidisciplinary network of scientists, bringing together their experience and knowledge of published work and other relevant existing information, and identifying projects within the region with mutual agendas and/or the potential to be associated with the regional synthesis. The workshop identified the pertinent regional issues, providing a preliminary rank order of current and predicted impacts with analyses of their trends on the basis of the expert judgement of the participants and published scientific information.

AfriBasins I proposed an interim shortlist of potential demonstration sites for the development of case studies addressing some of the prioritised driver-impact issues. It identified the following catchment-coastal systems from five geographical African sub-regions:

North Africa – Alexandria delta (Nile representing a large transboundary system with well investigated drivers of change, especially damming, and a good coverage of biogeochemical and other scientific data)

South East and East Africa – Zambezi and Tana rivers representing systems of different sizes, one (Zambezi) under huge damming pressure and with no comprehensive investigation in place and the other (Tana) currently the subject of planned damming and with an holistic scientific investigation underway.

Also up to two smaller catchments under variable human pressure representing the mainly monsoon-driven East African systems with high seasonality in biogeophysical and hydrological characteristics.

West Africa – the three basins of the Niger, Volta and Senegal rivers (all with potential for up-scaling being transboundary, under strong human impact such as damming and deforestation and subject to various on-going and planned initiatives);

North West Africa – 2 or 3 smaller catchments in Morocco (representing highly influenced river systems in an arid climate with seasonal variance in runoff).

Finalising the regional synthesis: AfriBasins II

Drawing on the work by the network of African scientists in AfriBasins I and attempting to fill the disciplinary and knowledge gaps identified at that workshop, AfriBasins II aimed to finalise the preliminary integrated regional assessment and to provide a link to the first global LOICZ-Basins synthesis. A state-of-the-art regional overview and an identification of “hot spots” to be picked up in a proposal for future regional integrated research were the immediate products expected from the workshop. It was recognised, however, that the information and participant-experience bases for this assessment exercise were, of necessity, restricted and that there would be a need for a comprehensive bibliography and a thorough review process.

The assessment took into consideration the variety of geographical/climatic sub-regions and river catchments of various sizes, many with transboundary issues. It recognised that African regional seas and rivers are most visibly influenced by global change and anthropogenic activity, and that human adaptation to this forcing is itself generating severe impacts on systems functioning. The workshop therefore aimed to provide a range of current and future trend information on loads and critical thresholds, which would feed into the scenario simulation efforts of new research.

The AfriBasins II workshop adjusted the sub-regional divisions that had been proposed in AfriBasins I, now recognising a total of eight sub-regions (see 2.3). Using the standardised proforma tables based on the DPSIR framework (Figure 1.1), two working groups completed the assessment compilations at catchment and sub-regional levels for the western and eastern/north-eastern coasts of Africa respectively. The emphasis throughout was on a close coupling of the physical and biogeochemical sciences with the human dimensions both of the driver-pressure settings in the catchments and of the issues and impacts at the coast. Finally the sub-regional assessments were scaled up to the regional level.

The standardised LOICZ-Basins assessment tables were used to guide a detailed sequence of assessment steps (see Chapter 5). Key questions were posed at each step.

1. Assessing and ranking coastal **Issues/Impacts** (together with their **critical thresholds**) due to human activities within catchments based on documented coastal changes in the region:
 - What are the major impacts (coastal issues) identified at the coast or in the coastal sea?
 - How close are these impacts to their respective critical thresholds of system functioning?
2. Assessment and ranking major catchment-based **Drivers** and their consequent environmental **Pressures** impacting on the coastal system:
 - What are the major driver/pressure settings at catchment level causing coastal change and what are the temporal trends of the changes?
 - What are the spatial scales on which specific driver/pressure settings impact on the coastal system?
3. Assessing and ranking the various **Driver/Pressure** settings generating the coastal **Issues/Impacts** and identifying the trends of changes to the **state** of the coastal environment; then up-scaling to sub-regional then regional levels:
 - What are the major driver/pressure settings causing observed coastal impacts?
 - What are the future trends at sub-regional level; at regional level?

4. Assessment and synthesis of **scientific, policy and/or management responses**:

- What is the current status of the responses taken on scientific, policy or management levels to address the perceived major coastal issues in the region?

5. Assessment and synthesis of **gaps in understanding, “hot spots” and research needs**:

- What are the major gaps in our understanding of river catchment-coastal sea interactions in the Africa region and which “hot spots” should be addressed with priority in a future integrated scientific work proposal (natural and socio-economic disciplines)?

The issues were evaluated according to the sub-regional division made by the experts for the river systems shown in Figure 2.1. These rivers represent a reasonable coverage of the geographic and/or climatic sub-regions or types of catchment-coastal sea systems identified as being characteristic of the African continent.

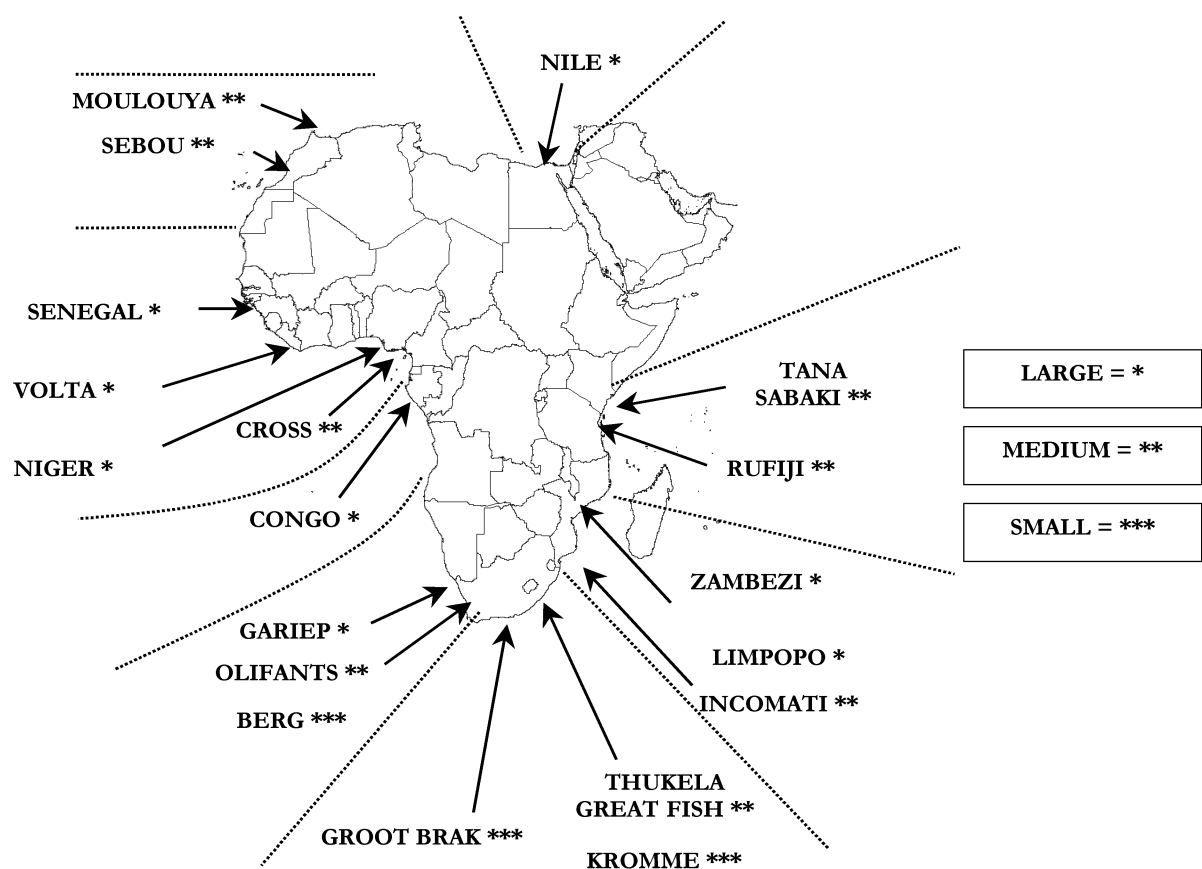


Figure 2.1 Sub-regions (dashed lines) and rivers in three catchment size classes (<10,000; 10,000 – 200,000; >200,000 km²) evaluated for issues, pressures, drivers and land-based activities in AfriBasins II workshop.

2.2 Indicators for coastal change

The availability of reliable information on critical loads and thresholds for catchments within the region is patchy. In the AfriBasins II workshop the identification of indicators for changes in environmental states at the coast was supported as being a realistic aim for the assessment process. Information gaps in respect of thresholds were not considered critical.

While some of the indicators for coastal change that have been cited in the AfriBasins II assessment are policy-related, most belong to the ecosystem approach (see section 2.1 and Table 2.1) and are supported by a wide range of measurable or otherwise observable indicator parameters. Some indicators relate directly to a coastal issue, e.g., the measurable rate of shoreline retreat or advance as an indicator for coastal erosion or sedimentation. Others are less precise, e.g., the assessment of crop yields as an indicator for estuarine salinisation. International conventions on chemical concentration thresholds provide direct indicators for water quality issues (pollution, eutrophication, nutrient depletion). Biological indicators such as algae and seagrass are used as proxy indicators of water quality, but also as direct indicators for the loss of biological function and loss of biodiversity.

The critical loads of water, sediment, nutrients and pollutant fluxes, excesses (or shortfalls) of which may cause significant changes of state and thus possibly major impacts on the coastal system, are generally poorly known for the region. Coastal erosion and sedimentation may be one of the more obvious coastal changes, but its causes may be difficult to attribute (see 2.4). Only if it is certain that the shoreline changes are due to changes in the rate of sediment discharge from rivers will the estimation of a critical threshold for system functioning be meaningful. Similar caution should be applied in assessing the critical loads of nutrients and pollutants discharged from river basins in the vicinity of major coastal urban and industrial centres unless the sources, for example of recognisable pollutants, can be determined. The capacity of the coastal environment for retention, and the potential for dispersal, of nutrients, pollutants and fine sediments are other factors to be considered in the assessment of critical loads and thresholds, though relevant data within the region are generally sparse.

Table 2.1. Summary of environmental indicators of drivers, pressures and state changes applied in the African regional context (based on OECD 1993).

Drivers/pressures	States/state changes	Indicators (examples)	Responses
Damming Diversion Water abstraction	<ul style="list-style-type: none"> Coastal erosion Sedimentation through reduced river flushing Salinisation Nutrient depletion in coastal seas Loss of biodiversity Increase in aquatic weeds 	<ul style="list-style-type: none"> Shoreline change Siltation of channels, harbours Groundwater salinity increase, reduced crop yields Fisheries stock changes Changes in species composition and abundance 	<ul style="list-style-type: none"> egislation and enforcement measures CZM strategies oastal/enviromental management authorities
Deforestation	<ul style="list-style-type: none"> Siltation Loss of biodiversity 	<ul style="list-style-type: none"> Changes in distribution of healthy corals and seagrass 	<ul style="list-style-type: none"> ICZM strategies
Agriculture	<ul style="list-style-type: none"> Siltation Eutrophication Pollution Loss of biodiversity 	<ul style="list-style-type: none"> Excessive algal growth/blooms Incidence in relation to agreed conventions 	<ul style="list-style-type: none"> Maximum allowable concentrations (MAC)
Urbanisation Human settlement	<ul style="list-style-type: none"> Eutrophication Human health issues Loss of biodiversity 	<ul style="list-style-type: none"> Excessive algal growth/blooms Incidence of water-related diseases 	<ul style="list-style-type: none"> Legislation and enforcement measures MAC
Industrial growth	<ul style="list-style-type: none"> Pollution Loss of biodiversity 	<ul style="list-style-type: none"> Incidence in relation to agreed conventions 	

2.3 Biophysical sub-regions and catchment-size classes (see Figure 2.1)

Building on the results of AfriBasins I, eight sub-regions were identified for assessment within the Africa region, on the basis of their general (catchment and coastal) geomorphological and climatic characteristics. As outlined in Chapter 1, these were:

- 1. North-west Africa** (Morocco) – a relatively arid sub-region with seasonal runoff characteristics and at least in Morocco major human pressure through diversion and damming causing a variety of coastal change issues. (This sub-region includes the coastal stretches of Algeria and Tunisia but no information on systems there was gathered during the AfriBasins process).
- 2. West Africa** (Cameroon, Nigeria to Senegal) – featuring a variety of large rivers subject to major damming resulting in reduced sediment and water fluxes and reduced coastal stability as a growing threat to the lagoon-based cities. In this sub-region there is also a class of ephemerally draining systems with considerable total annual run off such as the Cross and Imo Rivers; about 70 to 85 % of their annual runoff concentrate around the five months, from June to October (FAO, 1997).
- 3. Congo** (Central Angola to Cameroon) – central African sub-region including the very large Congo catchment with extensive rainforest but little information available about its land-based drivers and how they relate to coastal issues.
- 4. South-west Africa** (Cape of Good Hope to southern Angola) – mainly dominated by the upwelling system of the Benguela cold current; cool and temperate in the south, arid in the north with limited river runoff to the coastal sea.
- 5. Nile** – including the wider coastal stretches influenced by the Nile discharge reflecting land-based drivers including the Aswan dam, Cairo urbanisation and industrialisation, and agriculture in the Nile valley and Delta.
- 6. East Africa** (Somalia to Nampula province, northern Mozambique) – featuring small- and medium catchments under monsoonal forcing (seasonal flushing) and subject to damming, and special for the occurrence of extensive fringing and patch coral reefs.
- 7. Central/southern Mozambique** (Zambezi to Maputo Bay) – high seasonality in runoff characteristics (including intermittent cyclonic flooding) and transboundary issues including damming and impacts such as salinisation in the coastal zone; alluvial coast.
- 8. South-east Africa** (Maputo Bay to Cape of Good Hope) – ranging from subtropical in the north to warm temperate on the Eastern Cape coast and characterized by generally small catchments that are subject to various human use patterns with plans in place for intensive damming.

For the purposes of the assessment the river catchments that were selected for analysis were categorised on the basis of their areas: large basins – greater than 200,000 km²; medium – 200,000-10,000 km²; and small – less than 10,000 km² (see Table 2.2).

Table 2.2. African drainage basins assessed in AfriBasins.

River (basin classes) L = Large M = Medium S = Small	Basin size class	Basin area (10³ km²)	Water discharge (m³ s⁻¹)	Sediment load (10⁶ t yr⁻¹)	Sediment yield (t km⁻² yr⁻¹)	Receiving coastal sea
Nile	L	2870 (3349-Nile Basin Initiative)	10 (2854*)	Negligible (120 pre-damming)	no data (0*)	Mediterranean
Zambezi	L	1500 (1300*)	3361 (3170*)	47.3 (20*)	24.1 (15**)	Indian Ocean
Limpopo	L	412 (410*)	177 (168*)	34.6 (33*)	74.6 (80**)	Indian Ocean
Gariiep (formerly Orange)	L	1000 (1100*)	180 (348*)	35 (20*)	35 (18**)	South Atlantic
Congo	L	3700 (3800*)	46000 (46300+-38050*)	67.5 (43*)	11.6 (12**)	Atlantic
Niger	L	2240 (1200*)	6130 (6342*)	40.9	17.8 (18-33** depending on Basin area)	Atlantic
Volta	L	390 (400*)	800 (1268*)	1.509	<0.1	Atlantic
Senegal	L	290 (270*)	10-6736 (675) ¹	1.18-2.86 ² (21*)	(78**)	North Atlantic
Tana	M	132 (42*)	126 (149*)	3	no data	Indian Ocean
Sabaki	M	70	63 (32*)	2	no data	Indian Ocean
Rufiji	M	188 (180*)	900 (983*)	(17*)	(94**)	Indian Ocean
Incomati	M	46	101 (73*)	no data	no data	Indian Ocean
Thukela	M	29.1	146 (95+)	10.5	375	Indian Ocean
Great Fish	M	29.3 (29.9++)	17 (3.2-58++)	high but unknown	no data	Indian Ocean
Olifants	M	46	38	2.7	58.7	South Atlantic
Cross	M	48	1649 (FAO, 1997)	no data	no data	Atlantic
Sebou	M	40	131 (139*)	26	995 (650**)	North Atlantic
Moulouya	M	53.5 (51*)	13 (51*)	12 (6.7*)	240 (224**)	Mediterranean
Groot Brak	S	0.1	0.8	very little	no data	Indian Ocean
Kromme	S	0.94	3.3 (0.1+)	little – all trapped	no data	Indian Ocean
Berg	S	6.42 (7.72++)	22 (16++)	no data	no data	South Atlantic

Where possible figures derived by the AfriBasins team are displayed in comparison to earlier data such as from the GLORI database to give an impression of the partly high variability in currently available information for certain systems. Where no data could be provided during the workshop external sources have been used to fill gaps such as FAO and LOICZ information or data have been calculated from such databases.

¹ The values are relative to the Bakel station and the first ones are the minimum and maximum while the number in brackets is the mean module for a 90-year period.

² The values are relative respectively to the years 1982-83 and 1981-82.

Data from: Allanson & Read 1995; Berg 1994; CSIR 1985; Department of Water Affairs and Forestry 1996; Haida 2000; Dr D. Hughes, Institute for Water Research, Rhodes University, Grahamstown, South Africa, pers. comm.; Kane 1985; Kitheka 2001; Meybeck & Ragu 1995; Michel & Sall 2000; Morant 1983; Niang 1999; Peters 1978; Reddering & Esterhuysen, 1983; Rooseboom 1992; Snoussi *et al.* 2001; UNEP 1998; * = corresponding figures taken from or ** = calculated from the GLORI database, Milliman *et al.*, 1995; + = Dupra *et al.* 2001; ++ = Dupra *et al.* 2002; FAO 1997 – <http://www.fao.org/docrep/W4347E/w4347e0w.htm>

2.4 Coastal issues, state changes, critical loads and ranking (see Table 2.3 and Chapter 5)

On the basis of referenced information, the working groups identified for each of their respective sub-regions the key environmental and human issues or impacts affecting coastal areas (including the coastal sea) that were considered to have been caused, or influenced, by land-based human activities. The issues include matters of management concern at local, national and regional levels. Generally they involve changes in the state of the coastal environment that impact on its geomorphology and/or its ecosystem, affecting issues such as water quality, biological functioning and human health. The state changes that affect coastal geomorphology relate mainly to the sediment that is discharged from rivers. Examples are where reductions in discharge at river mouths contribute to the impoverishment of sediment on adjoining beaches and the consequent erosion of beach heads (coastal erosion) as in the Nile Delta, or where increases lead to sedimentation (siltation) and coastal progradation as with the case of discharge from the Sabaki River at Malindi in Kenya. While the coastal ecosystem has a natural biological resilience and is able to cope with biogeochemical changes to some extent, certain functions may be damaged or otherwise altered if the changes exceed critical thresholds (see 2.2). An example of this is the growth of toxic algae in an estuary where eutrophication resulting from the discharge of untreated sewage exceeds a critical level.

Distinguishing between natural and human activity drivers as influences on state changes is a particular problem in the assessment of coastal impacts and issues. For example, the possibility that marine forcing (changes in sea level and/or climate-driven longshore drift) rather than catchment activities might be the cause of some of the cases of erosion and sedimentation that are detailed in the AfriBasins assessment must be borne in mind. Understanding natural processes and their variability over time (e.g., short- and long-term climate change), as they affect both the catchments and the coast, is an important prerequisite for an assessment of the contribution that human activities may make to coastal change. Another problem in the assessment process concerns the weight to be attached to land-based human activity drivers at the coast itself, rather than within identified catchments. The situation is well illustrated by the coastal city of Alexandria with its important issues of pollution, eutrophication and human health attributed to urbanisation and industrialisation separate from any identifiable catchment. For the purposes of the listing of coastal issues, such cases have been included and ranked in the assessment, though generally there is no scope for including them, however acute they may be, in the catchment-by-catchment review of driver/pressure settings assessed in Chapter 5 (see 2.6). An exception has been made, however, in the case of coastal urban nodes in the south-west Africa sub-region.

In ranking the coastal issues and impacts, it has proved difficult to achieve a consistency of standards between, and even within, sub-regions. Local, short-term hot spots may have attracted high rankings – beyond the threshold – yet more spatially widespread and longer-term impacts that have been assigned lower rankings may actually turn out to be the more significant. Even in simple cases, ranking the issues and impacts and the state changes as part of the assessment has, by its nature, been a process of somewhat subjective judgement within the limitations of the mostly sparse data. This may have led to anomalies in the assessment output.

Information regarding both the coastal environmental state and the critical loads and thresholds relating to the various impacts varies greatly in both its quality and availability. The working groups regarded scarcity of data, particularly time-series data, as being a serious impediment to the understanding of the driver-impact linkages throughout the region.

Table 2.3 Major coastal issues/impacts and critical thresholds along the coast of Africa; overview and qualitative ranking of impacts
Impact scale: 10 = maximum; 0 = none.

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Erosion	Morocco: a. Atlantic coast b. Mediterranean coast	No specific threshold are available	a. Exceeded. Estimated erosion between 0.05 and 0.4 x10 ⁶ t/yr . b. Exceeded. Observed coastal erosion of 0.06 x10 ⁶ t/yr; 2-5m at Tangiers Bay due to the port extension	a. 7 b. 9	Snoussi <i>et al.</i> (1990) Charrouf (1991) Probst & Amiotte-Suchet (1992) Zourarah (1994) Haida (2000)
	a. Volta b. Senegal c. Niger	a. Greater than 1.5x10 ⁶ t/yr b. Greater than 1.5x10 ⁶ t/yr c. Not known	a. Exceeded b. Not exceeded in term of catchment influence c. Exceeded (not sure of cause)	a. 8 b. 5 c. 8	a. Gordon (1998) b. Diaw <i>et al.</i> (1988, 1990); Barusseau <i>et al.</i> (1993); Ba <i>et al.</i> (1995); Soumare (1996); Kane (1997) c. NEST (1989)
	a. Rosetta promontory b. Burullus Lake area c. Danietta promontory	a. Current erosion rate 53-102 m/yr b. Erosion rate: 5.5 m/yr c. Erosion rate: 10.4 m/yr	a. Aswan Dam (1968) prevented sediment discharge (160 Mt/yr) into Mediterranean.	a-c. 9	a. Hydraulic Resource Analysis (1992); Frihy & Lotfy (1994); Frihy <i>et al.</i> (1994) b. Frihy & Dowidar (1993) c. Frihy & Komar (1993)
			b.		

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Erosion continued	a. Tana delta b. North Kenya coast (Shanzu, Kanamai), South Kenya coast (Diani, Likoni); contributing rivers unknown c. Bagamoyo and Dar es Salaam (Ruvu river) d. Rufiji e. Mtwara-Lindi stretch (Mbemkuru and Ruvuma rivers) f. Kilwa (Rufiji river) g. Jambiani, Paje, Maruhubi, Nungwi areas in Zanzibar	a. Not known b. Not known c-g. Not known	a. Not known b. Critical load already passed c. Critical load already passed for Bagamoyo and Dar es Salaam (4m retreat per year) d-f. Erosion considered to be occurring, rate unknown g. Critical load passed for Jambiani, retreat estimate unknown	a. 8 a. 8	a. Raal & Barwell (1995); Knocker (1998) b. Okenwa <i>et al.</i> (1994) c-g. Mushala (1978); Ross & Saint-Ange (1986); Fay (1987, 1992), Griffiths (1987); Lwiza & Bigendako (1988); Arthurton (1992); Shaghude <i>et al.</i> (1994); Arthurton <i>et al.</i> (1999); TCMP (2000, 2001); Ngusaru <i>et al.</i> (2001); UNEP (2001)
	a. Zambezi b. Limpopo c. Incomati estuary	a. Unknown c. Unknown	a. Unknown c. Erosion becomes a continuous process	a. 8 c. 8	a. Gove (1993) c. MICOA (1998)
	a. Thukela b. Great Fish c. Kromme d. Groot Brak	a. 60% existing flow b. Unknown c. Unknown d. Unknown	a. Unknown b. Unknown c. Unknown d. Unknown	a. 3 b. 3 c. 2 d. 2	Thukela: Begg (1978)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Sedimentation	Atlantic coast and Mediterranean coasts of Morocco	Not known	Marine sedimentation exceeds fluvial sedimentation in many sites of both the Atlantic and Med. coasts, due to the impoundment of water flows and the reinforcement of the marine influence. The littoral drift is estimated between 0.25 and 8 x10 ⁶ t/yr. All ports and estuaries are silted. 0.7x10 ⁶ m ³ of sediments are deposited annually in the Sebou estuary. This affects navigation channels necessitating dredging. The inlets of the lagoons are periodically closed.	9	Charrouf (1991) Snoussi <i>et al.</i> (2001)
	a. Volta b. Senegal c. Niger	a. 2 km of shoreline development over 10 years b. Marine sedimentation exceeding fluvial sedimentation c. Not known	a. Exceeded b. Exceeded c. Exceeded	a. 7 b. 9 c. 6	a. Gordon (1998) b. Diaw <i>et al.</i> (1988, 1990); Barusseau <i>et al.</i> (1993); Ba <i>et al.</i> (1995); Soumare (1996) c. NEST (1989)
	a. Gariep b. Olifants c. Berg	a. Not known b. Not known c. Not known	a. Not exceeded, but could be near threshold b. Not exceeded c. Not exceeded	a. 4 b. 3 c. 3	a. DWAF (1989); DWAF (1993) b. Huizinga & Van Niekerk (1997) c. DWAF (1994)
	All Mediterranean coastal lagoons	Area reduced from 960,000 to 260,000 hectares in last 40 years	Uncontrolled land reclamation; urbanisation	8	Hanafi (1998)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Sedimentation Continued	a. Tana delta and Ungwana Bay b. Sabaki mouth and Malindi Bay c. Port Reitz/Mwache creek d. Rufiji e. Ruvuma	a.b. Unknown but could be about 5% of annual load. Silting of Malindi Bay. Smothering of coral in Malindi Marine Park. d. Smothering of seagrass beds and coral near Rufiji delta and the south of Mafia Island, siltation as far as Mkuranga.	a. Critical load already passed. Tana sediment load 1-8 mt/yr b. Sabaki sediment discharge 2 mt/yr d. Critical load passed e. Unknown	8	a.b. Gibb (1959); ILACO (1971); Dunne (1975); Dunne & Ongwenyi (1976), Edwards (1979); UNEP (1998); Otieno & Maingi (2000). c. Kitheka (2000) d. Francis (1992); Fisher <i>et al.</i> (1994); Ngusuru <i>et al.</i> (2001)
	a.Zambezi b.Limpopo c.Incomati	a. unknown	a. unknown	a.8 c.9	a. Balek (1972) c. MICOA (1998)
	a. Thukela b. Great Fish c. Kromme d. Groot Brak	a. 60% existing flow b. Unknown c. Unknown d. Unknown	a. Unknown b. Unknown c. Unknown d. Unknown	a. 4 b. 2 c. 2 d. 3	Great Fish: Watling & Watling (1983); Allanson & Read (1987); Whitfield (1994); Whitfield <i>et al.</i> (1994); Allanson & Read (1995); Ter Morshuizen <i>et al.</i> (1996); Grange <i>et al.</i> (2000)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Eutrophication	Atlantic & Med. coasts of Morocco	Actual limit CNP ratio not known Excessive algal growth	Occurrence of low oxygen and high values of nitrogen in estuaries and lagoons. Increasing of frequency of algal blooms	8	Lefebvre <i>et al.</i> (1996); Benasser (1997)
	a. Volta b. Senegal (potential issue) c. Niger	a-c. When CNP ratio becomes unbalanced, actual limit not known	a. Exceeded due to presence of algal blooms (offshore and in coastal lagoon) b. Not exceeded c. Exceeded	a. 7 b. 4 c. 7	a. Entz (1969) b. UNEP (1999) c. NEST (1989)
	a. Saldanha Bay	a. Occurrence of excessive algal growth (e.g., <i>Aureococcus</i> sp and <i>Ulva</i>)	a. Occasionally passes critical threshold in the mid-late summer, particularly in more stratified and depositional areas of the bay (more than would have occurred naturally)		a. Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
	Abu Qir Bay, adjacent to Nile delta	High nutrient loads, especially P through agricultural drainage and sewage NH ₄ – 6-14.2 µg/l NO ₃ – 5.7-19 µg/l PO ₄ – 1-4 µg/l O ₂ - <4 mg/l Chl.a : 15-48 µg/l	Redfield ratio is broken C : N : P 82 : 5.5 : 1	6	Abdel Aziz & Dorgham (1999); Abdel Aziz <i>et al.</i> (2001); El Rayis <i>et al.</i> (1994)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Eutrophication Continued	Alexandria City coast	Nearshore waters receive 200x10 ³ m ³ of untreated domestic sewage from two outfalls. Around these sites nutrients are normally found in high concentration: NH ₄ – 14.5-38.7 µg/l NO ₃ – 5.7-19 µg/l PO ₄ – 1-6 µg/l O ₂ - <4 mg/l Chl.a : 34-107 µg/l	Redfield ratio is broken C : N : P 218: 4 : 1	5	Zaghoul & Halim (1992); Dorgham <i>et al.</i> (2001)
	a. Tana b. Sabaki	a.b. DO level > 5mg/l and TSSC >0.05 g/l	C:N:P ratio not known	4	a. Kithika (2000)
	a. Zambezi b. Limpopo c. Incomati d. Xinaravane, over 80 km of estuary	a-c. unknown d. Anoxia or low Oxygen in estuary	a-c. unknown d. Increased nutrient	a. 2 d.10	a. Mordosova (1980) b. Mordosova <i>et al.</i> (1980); Munga (1987); Caralap <i>et al.</i> (1993); Masundire & Matiza (1995)
	a. Thukela b. Great Fish c. Kromme d. Groot Brak	a. Unknown b. Unknown c. Unknown d. Unknown	a. Unknown b. Unknown c. Unknown d. Unknown	a. 3 b. 2 c. 2 d. 4	Kromme: Watling & Watling (1982b); Emmerson & Erasmus (1987); Sowman & Fuggle (1989); Adams <i>et al.</i> (1992); Adams & Talbot (1992); Schumann & de Meillon (1993); Jerling & Wooldridge (1994); Heymans & Baird (1995); Baird & Heymans (1996); Quinn <i>et al.</i> (1998); Bate & Adams (2000); Scharler & Baird (2000); Snow <i>et al.</i> (2000); Strydom & Whitfield (2000); Wooldridge & Callahan (2000)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Pollution	Morocco a. Med. coast b. Atlantic coast	WMO norms and standards. Baseline concentrations of unpolluted soils of the basin	a. Exceeded, loss of biodiversity. Zn, Cd, Hg, BOD, DOC and pesticides are monitored in the framework of MedPol Programme. Occurrence of red tides twice a year b. Increasing background level of heavy metals by a factor of 2 in most areas. High values in biota mainly bivalves	a. 8 b. 9	MAP Technical Reports Series Snoussi (1992) CNE (1995) Cheggour (1999)
	a. Volta (pesticide) b. Senegal (pesticide) c. Niger (oil, heavy metals) d. Cross (oil, heavy metals)	a-d. Generic critical thresholds can probably be derived from literature, but currently site specific values are not available	a. Exceeded, loss of biodiversity b. Not known c. Exceeded (oil pollution) d. Exceeded (oil pollution)	a. 6 b. - c. 8 d. 9	a. Czernn-Chudenitz (1971); Amoah (1999) b. - c. NEST (1989); CRP (1999) d. CRP (1999)
	Congo	Not known	?	3	UNEP (1999); Morant (2001); Morant pers. comm.

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Pollution Continued	a. Gariép (pesticides) b. Olifants (pesticides) c. Berg (pesticides) d. Saldanha Bay (oil, heavy metals) e. Table Bay (oil, heavy metals) f. False Bay (oil, heavy metals)	a-c. Generic critical thresholds can be derived from literature, but site-specific values are not available d-f. For harbours, critical thresholds have been recommended for trace metals (under the London Convention, 1973).	a. Not exceeded b. Not exceeded c. Not exceeded d-f. Localised areas in harbours are close to or exceeding critical limits	a. 2 b. 2 c. 2 d. 4 e. 4	a. DWAF (1993) b. Taljaard (1997) c. DWAF (1994) d. Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999) e. Quick & Roberts (1993); Monteiro (1997) f. Taljaard <i>et al.</i> (2000)
	Mex Bay (River Nile)	Receives 2 bm^3/yr mixed wastewater loaded with 220×10^3 t/yr BOD; 75×10^3 t/yr COD; 2×10^3 t/yr TN; 2.6×10^3 t/yr TP & 287×10^3 t/yr TSS. Standing stocks: 840 t/yr TN; 30 t/yr TP & 3000 t/yr TSM. The Bay environment also receives 75×10^3 t/yr toxic metals (Hg, Cd, Cr, Cu, Zn & Ni) and 1300 t/yr of Oil.	Hot spot in the Mediterranean; alteration in biodiversity; eutrophication; high levels of toxic heavy metals and PAH are frequently detected in marine fauna and flora; negative impact on fisheries and fish speciation.	9	UNEP (1990); Younes <i>et al.</i> (1997); UNEP/WHO (1999)
	Alexandria City coast	Receives $145 \text{ Mm}^3/\text{yr}$ domestic wastes loaded with 1.5×10^3 TN; 2.3×10^3 t/yr TP, 8.8×10^3 t/yr TSS, 540 t/yr oil wastes from refineries	Hot spot in the Mediterranean. Health hazards from near shore untreated discharge of sewage. Eutrophication and red tide. Negative impact on fisheries and on submerged archaeological heritage.	5	Atta (1985); UNEP (1990); Awad (1995); UNEP/WHO (1999)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Pollution Continued	Abu Qir Bay (River Nile)	Receives 410 Mm ³ /yr mixed wastewater With 90x10 ³ t/yr BOD; 575x10 ³ t/yr COD; 5x10 ³ t/yr TN; 8.5x10 ³ t/yr TP and 120x10 ³ t/yr TSS.	Hot spot in the Mediterranean. The bay's environment suffers from high load of industrial wastes and untreated sewage discharge especially black liquor and fertilizer industry wastes	9	El Deeb (1977); UNEP(1990); UNEP/WHO (1999); Younes <i>et al.</i> (1997); Awad & Yousef (2001)
	Edku Lake (River Nile)	Agriculture drains receive about 1bm ³ /yr drain water. Discharge 400 Mm ³ /yr of brackish water into Abu Qir Bay loaded with 12 t/yr NO ₂ , 8 t/yr NO ₃ and 9 t/yr PO ₄ . δ = 20-60 d, p-r = 3.2 mmol/m ² /d in summer and 1.3 mmol/m ² /d in winter; nfix-denit=1.6 mmol/m ² /d in summer and 22.7 mmol/m ² /d in winter	Nitrogen fixing system frequently its discharge water quality cause eutrophication in the Abu Qir Bay receiving environment	5	Saad (1997); Awad & Hassan (1998); Awad & Yousef (2001)
	Burullus Lake (River Nile)	Discharge into Mediterranean 2.2bm ³ /yr brackish water loaded with insignificant N & P; (0.03 t/yr NO ₂ ; 0.2 t/yr NO ₃ and 0.01 t/yr PO ₄)	Clean coastal lagoon considered as natural reserve	0	Saad (1997); Awad & Hassan (1998)
	Manzalla Lake (River Nile)	Receives 1.7 bm ³ /yr of partially or untreated wastes, discharges 7 bm ³ /yr into the Mediterranean loaded with 40 t/yr NO ₂ ; 156 t/yr NO ₃ and 71 t/yr PO ₄	Hot spot in the Mediterranean	9	EEAA (1992); Awad & Hassan (1998)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Pollution Continued	Damietta Nile Estuary	Stopped discharging freshwater into the Mediterranean following the construction of the El Salam Canal transporting Nile water to Sinai (3.3 bn ³ /yr) for irrigation		2	
	Bardawil Lake	Sensitive area, hypersaline lagoon, no discharge and free of pollution	Overfishing (fish catch decreased in 1992 by 40% relative to that of 1970). Biodiversity under threat following the arrival of Nile waters through the El Salam Canal and agriculture activity around the lake with increasing settlement. Impacts on groundwater quality and coastal erosion are predicted.	0	UNEP/WHO (1999)
	a. Mtwapa creek b. Makupa creek c. Kilindini channel d. Rufiji and Ruvuma			5-8	a.-c. Rees <i>et al.</i> (1996); Kithaka (2000). d. TCMP (2000, 2001); Ngusaru <i>et al.</i> (2001)
	a. Zambezi b. Limpopo c. Incomati d. Maputo Bay	a,b. unknown	a,b. unknown	d.8	d. Hogueane (2000)
	a. Thukela b. Katiga c. Kromme d. Groot Brak	a. Unknown b. Unknown c. Unknown d. Unknown	a. Unknown b. Unknown c. Unknown d. Unknown	a. 4 b. 2 c. 2 d. 3	Groot Brak: Day (1981); Watling & Watling (1982a); Morant (1983); Slinger & Breen (1995); Slinger <i>et al.</i> (1994); Coetzee <i>et al.</i> (1997)
Aquatic weeds	Med. Coast	Presence (<i>Caulerpa</i>)	Exceeded	7	MAP Technical Reports Series

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Aquatic weeds Continued	a. Volta b. Senegal c. Niger (nypa) d. Cross (nypa)	a. Presence b. Presence c. Presence d. Presence	a. Exceeded b. Exceeded c. Exceeded d. Exceeded	a. 7 b. 9 c. 7 d. 9	a. De Graft-Johnson (1999) b. Cogels <i>et al.</i> (1993); BDPA-SCEETAGRI <i>et al.</i> (1995); Matera & Malaisse (1999) c. CRP (1999) d. AKS (1989)
	a. Table Bay b. False Bay	a. Occurrence of nuisance reed beds b. Occurrence of nuisance reed beds	a. Exceeded in some estuaries due to nuisance reed growth b. Exceeded in some estuaries due to nuisance reed growth		a. Quick & Roberts (1993) b. Taljaard <i>et al.</i> (2000)
Biodiversity loss (Loss of biological function)	Morocco a. Med. Coast b. Atlantic	Change in species composition and abundance	a. Exceeded. Loss of marine turtles (5000/yr), monk seals, and red coral reefs due to overexploitation and pollution. Complete loss of <i>Posidonia</i> . b. Declining fishery stocks, lobsters (Dakhla Bay), octopus (sp) and carpet-shells	a. 7 b. 9	MAP Technical Reports Series Menioui (2001)
	a. Volta b. Senegal c. Niger (mangroves loss) d. Gambia (mangroves loss)	a-c. Change in species composition and abundance	a. Exceeded b. Exceeded c. Exceeded	a. 7 b. 8 c. 7	a. Gordon (1999) b. Bousso (1992); Cogels <i>et al.</i> (1993); BDPA-SCEETAGRI <i>et al.</i> (1995); c. Ibeanu (2000)
	Congo	Not known	?	7	UNEP (1999); Morant (2001); Morant pers. comm.

Table 2.3 continued

Coastal impact/issue	Local site /Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Biodiversity loss (Loss of biological function)	a. Gariep b. Olifants c. Berg d. Saldanha Bay e. Table Bay f. False Bay	a. Not known b. Not known c. Not known d. Not known e. Not known f. Not known	a. Probably exceeded or near through large salt marsh areas being cut off from river by the coastal road b. Not exceeded c. Not exceeded d. Exceeded in localized areas, e.g., harbour area e. Exceeded in localized areas, e.g., estuaries f. Exceeded in localized areas, e.g., estuaries	a. 6 b. 3 c. 3 d. 6 e. 6 f. 6	a. DWAF (1993) b. Huizinga & Van Niekerk (1997); Taljaard (1997) c. DWAF (1994) d. Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999) e. Quick & Roberts (1993) f. Taljaard <i>et al.</i> (2000)
	a. Ungwana Bay-Tana b. Funzi Bay c. Bamburi-Nyali lagoon d. Diani-Gazi lagoon e. Rufiji-Kilwa-Mafia complex f. Mnazi Bay - Ruvuma estuary complex.	a.-d. Fish stock and biological productivity indicators b.-d. Contributing rivers not known	a.d. Fish landing declining over the years – 10,000 t/yr e-f. Biodiversity loss in mangroves, coastal forests, coral habitats	8	Kenya Fisheries Department records; KMFRI database; Muthiga & McClanahan (1987); Wells & Sheppard (1988); McClanahan & Mutere (1994); McClanahan & Obura (1995); Watson (1996); Glaesel (1997); Mwatha (1998); Malleret-King (2000); Ochiewo (2001). e. IUCN (1996); Ngusaru <i>et al.</i> (2001)
	a. Zambezi delta b. Sofala Bank c. Limpopo d. Incomati	a,b. Ecosystem collapse – sardine fishery, <i>Posidonia</i> disappeared, primary productivity severely reduced – prawn fisheries	a,b. Exceeded	a,b.10	a,b. Da Silva (1986); Gammelstrod (1992, 1996); Horton & Munguambe (1998); Guale (2000)

Table 2.3 continued

Coastal impact/issue	Local site/Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Biodiversity loss (Loss of biological function)	a. Thukela b. Great Fish c. Kromme d. Groot Brak	a. Unknown b. Unknown c. Unknown d. Unknown	a. Unknown b. Modified by freshwater input c. Functional but marine-dominated d. Unknown	a. 4 b. 3 c. 5 d. 4	
	Coastal plains of Moulouya, Sebou, and Oualidia	Not known. Excess of salts in wells (water for drinking and irrigation)	Exceeded in most of the irrigated coastal plains, due to over extraction of groundwater. Over use of fertilizers, and droughts.	9	Moussaoui (1994) El Mandour (1998)
	a. Senegal b. Niger c. Cross	a. Not known, because the system is complex b. Not known c. Not known	a. Not exceeded b. Exceeded c. Exceeded	a. 5 b. 7 c. 7	a. BDPA-SCETAGRI <i>et al.</i> (1995); Diouf (1998); Pages <i>et al.</i> , 1987; Debenay <i>et al.</i> (1994) c. Ibeanu (2000)
	a. Gariep b. Olifants c. Berg	• a. Not known • b. Not known • c. Not known	• a. Not exceeded • b. Not exceeded • c. Not exceeded	a. 3 b. 3	a. DWAF (1989) b. Huizinga & Van Niekerk (1997) c. DWAF (1994) EEAA (1992)
Salinisation	Nile				a. Tafe (1990); Ngusaru <i>et al.</i> (2001)
	a. Rufiji delta				
	a. Zambezi b. Limpopo c. Incomati to 80km from mouth	a. unknown b. unknown	a. unknown b. unknown	c.10	c. Matola, J. (1999)

Table 2.3 continued

Coastal impact/issue	Local site /Region (contributing river basins)	Critical Threshold (for system functioning)	Distance to Critical Threshold (qualitative or quantitative)	Impact category*	References/ Data source
Human health issues	Morocco	Presence of disease	Close to threshold in some areas	6	
	a. Volta (invasion of snails/water related diseases) b. Senegal (Invasion of snails/water related diseases) c. Niger (water related diseases) d. Cross (water-related diseases)	a. Presence of disease b. Presence of disease c. Presence of disease d. Presence of disease	a. Exceeded b. Exceeded c. Exceeded d. Exceeded	a. 8 b. 8 c. 7 d. 7	a. Derban (1999) b. Handschumacher <i>et al.</i> (1992); Talla (1993); Niang (1999) c. NEST (1989) d. Ibeanu (2000)
	a. False Bay b. Table Bay	a-b. <i>E. coli</i> counts not to exceed 100 counts/100 ml for 80% of the time and 2000 counts/100 ml for 95% of the time	a-b. Thresholds exceeded in localized areas (within 500 m of river mouths and storm water discharges).	a. 4 b. 4	a. CMC (1999) b. Taljaard <i>et al.</i> (2000)
	a. Tana b. Sabaki c. Uмба estuary/Vanga d. Rufiji-Kilwa-Mafia complex e. Ruvuma estuary	Not known but there are: a. Increasing conflicts resulting in loss of human lives a & c. Increased occurrence of water-borne diseases a & c. Reduced productivity due to ill health.		8	a-c. Ochiewo (2001) d-c. Ngusaru <i>et al.</i> (2001)
	a. Thukela b. Great Fish c. Kromme d. Groot Brak	a. Unknown b. Unknown c. Unknown d. Unknown	a. Unknown b. Unknown c. Unknown d. Unknown	a. 2 b. 2 c. 2 d. 3	

2.5 Driver-Pressure-State relationships

Socio-economic **drivers** within the catchments cause environmental **pressures**, which affect, with different time delays, the inputs and fluxes of substances to the river systems and, after transformation in those systems – in their estuaries (or deltas) and associated coastal lagoons – the discharge of those substances to the coastal sea. The flow of substances is modified both temporally and spatially by the geomorphological and biogeochemical properties of the basins, the estuaries and their contiguous shores. The **state** of the three different types of aquatic ecosystem (river, estuary and coastal sea) represents the condition of significant components of the system that may be affected by these pressures. Changes to this state lead to **impacts**, which may affect both environmental and socio-economic processes at the coast and in the coastal sea. Because of the wide diversity of the African drainage basins, an attempt to present an overview picture of driver-pressure-state relationships beyond the sub-regional scale (see Chapter 5) is considered inappropriate.

The working groups considered the drivers at the sub-regional scale and ranked them numerically according to their respective state changes and consequent impacts on the coastal system. The numbers ranged from 0 (indicating no change) to 3 (indicating a major change). The rankings were applied variously to large, medium and small basins (see 2.3) as appropriate to the specific sub-regions. In the cases of the Nile and the Congo the rankings applied to only one large basin each. The working groups also assessed the time-scales over which changes in the state of the coastal environment were taking place. In some cases the changes were a direct or immediate result of catchment pressures, e.g., impoundment of water and sediment by damming; in others they were gradual or progressive, e.g., continuing deterioration in water quality through the increased discharge of sewage due to urbanisation. The workshop acknowledged the difficulties involved in achieving consistency in the state change ranking process both between the sub-regions and within sub-regions, for basins of different size classes.

2.6 Assessment of land-based drivers (see Table 2.4 and Chapter 5)

Supported by referenced information, the working groups compiled and assessed available information for each of the selected catchments regarding the relationships between the drivers (both natural and socio-economic) in the catchments and the perceived resulting environmental pressures and consequent state changes and their impacts at the coast. The groups assessed the importance of specific drivers in respect of the various impacts and issues, using numerical rankings for the present situation and indicating the trends of future change.

The difficulty in making the correct attributions of drivers to impacts has been a matter of concern throughout the assessment. In cases of pollution, eutrophication and human health there may be few doubts about the identity of the causative driver(s). Specific recognisable pollutants, for example, may be traceable to individual point sources. With erosion and sedimentation, however, the driving forces may be complex and comprise several different contributors (including natural forces) that may be positive or negative in their individual effects on material flux. For example, a river system may have a reduced sediment input as a consequence of damming, while the same system (below the dam) may receive an increased supply due to deforestation or changes in agricultural practice. To make a meaningful assessment of the respective contributions made to, say, the coastal issue of sedimentation by e.g., agriculture, deforestation or damming in the catchment may simply not be feasible on the basis of the data presently available. Thus the impact rankings that have been made should be treated with caution. To some extent such anomalies have been moderated as part of the up-scaling procedure from catchment to sub-regional scales but, where data on the spatial and temporal scales of impact or state change have been unavailable, it is recognised that some rankings, even at sub-regional scale, are tentative.

2.6.1 Catchment scale

(The contributing authors for this section are also the authors of the corresponding assessment tables in Chapter 5.)

The various sub-regions show wide variation not only in the biophysical nature of their catchments but also in the availability and quality of existing data relating to their material fluxes. As far as possible the

catchments that have been chosen for assessment are considered to be representative of the catchments in their respective sub-regions. The Nile sub-region comprises only one catchment. All of Africa's 'big four' river basins, the Niger, Congo, Nile and Zambezi have been included in the assessment, as have the important transboundary basins of the Senegal, Volta, Cross and Gariep rivers on the west coast and the Limpopo and Incomati on the east. Representative medium and small basins have also been assessed. These comprise the basins of the Sebou and Moulouya rivers in Morocco, the Olifants and Berg (west of the Cape of Good Hope) in South Africa, the Tana and Sabaki rivers in Kenya, the Rufiji in Tanzania, and the Thukela, Great Fish, Kromme and Groot Brak in South Africa east of the Cape.

1. North West Africa (contributor – M. Snoussi)

North-west Africa is characterised by young mountains and numerous medium and small drainage basins with strong slopes, while the alluvial plains are few and of limited extent. River runoff and precipitation are irregular and may be high. Poorly vegetated steep slopes are prone to surficial runoff, resulting in soil erosion and high levels of fluvial suspended sediment transport – probably among the highest in Africa.

The Sebou and Moulouya catchments (located in Morocco) are representative of the medium drainage basins that characterise the semi-arid Maghreb area. They have generally been supported by good quality recent data. A wide range of impacts and issues has been reported. Many large dams have been built over recent decades. The resulting sediment entrapment has not only reduced the reservoir capacity, but has also become the principal cause of coastal erosion. Reduced stream flows due to damming are also regarded as favouring the accumulation of marine sediments.

The main sources of coastal eutrophication and pollution are untreated domestic and industrial wastewater and fertilizers. Most of the urban sewage is directly discharged without treatment. Human health issues also arise from the discharge of untreated sewage (related to urbanisation), while loss of biodiversity (or biological functioning) is seen as a complex interplay of all the principal drivers. Increasing salinisation is recognised as a serious issue, caused variously by urbanisation and agriculture (over-abstraction of groundwater) and the natural drivers of climate change and sea-level rise.

2. West Africa (contributors – A. Kane, I. Niang Diop, C. Gordon, G. Umoh)

The assessments of these catchments, including the large basins of the Senegal, Volta and Niger (which have significant transboundary implications) and the medium-sized Cross River basin, have generally been supported by good quality, up-to-date data. A wide range of impacts and issues has been reported. Coastal erosion is a problem associated with all catchments, with critical thresholds exceeded in respect of the Volta and Niger. Damming, deforestation and agriculture are all cited as contributors, with damming the prime cause in the Volta. Coastal sedimentation is another common issue, especially at the mouth of the Senegal River though in this case not obviously directly due to catchment discharge.

Algal blooms are a manifestation of eutrophication particularly in the Volta and Niger, with urbanisation (or human settlement) and, to a lesser extent, agriculture seen as the principal drivers. Oil-related pollution is an important issue in the Cross River basin, while aquatic weeds such as *Nypa* palm are reported from all catchments and attributed to damming (Senegal) and a range of other drivers including transport. Critical thresholds for the loss of biological functioning due to a complex of drivers have been exceeded in the Volta and Niger and especially in the Senegal. Human health issues including the incidence of water-related diseases that are attributed to urbanisation have been reported in all catchments, with critical thresholds being exceeded in the Volta and Senegal. Salinisation is seen as a problem in the Niger and Cross, where the drivers are unclear, and the Senegal, where climate change (drought) is regarded as the cause.

3. Congo (contributor – P. Morant through S. Taljaard)

The Congo is the second largest river in the world on the basis of annual flow. The system extends over a distance of 4,700 km between Lake Tanganyika and its mouth on the Atlantic Ocean. The dominant characteristic of the river is the remarkable regularity of its regime. The lower reaches of the basin, i.e. below Kinshasa and Brazzaville (some 300 km upstream of the mouth) are free of major urban and industrial developments. Two harbours in the lower reaches probably produce some oil-related pollution. Near the coast human activities include fishing, gathering medicinal plants and subsistence cropping. The loss of habitat and biodiversity there as a consequence of mangrove felling for fuel wood is regarded as a

major issue. Little quantitative data, however, is available about land-based drivers and how they relate to coastal issues.

4. South West Africa (contributor – S. Taljaard)

The major perennial river basins in this sub-region that may influence the coastal zone include the Kunene (on the borders of Namibia and Angola – not assessed), the Gariep (formerly Orange, a large basin on the borders of Namibia and South Africa), and the Olifants (medium) and Berg (small) basins (both in South Africa). Urban nodes along this stretch of coast, which also have a significant influence on the coastal zone, include Walvis Bay (Namibia) (no expertise available at workshop), Saldanha Bay (West Coast, South Africa) and Table Bay and False Bay (both Cape Town, South Africa).

Quantitative data on coastal impacts of the Kunene and Gariep basins are very limited. Although some data are available for the Olifants basin, these are limited to impacts on the estuarine region mouth. Data on the coastal impacts of the Berg River basin have up to now also been limited to the estuarine region inside the mouth, but currently studies are underway to extend investigations into the larger St Helena Bay area.

The Gariep estuary is recognised as one of southern Africa's most important coastal wetlands. Its mouth is of delta type, the mouth dynamics being affected by upstream impoundments and associated water use practices. During prolonged low-flow periods, salinisation in the lower reaches, particularly of the groundwater resources, has become a concern.

Human activities in the Olifants catchment appear to have limited impact on its estuary and coastal zone, although damming and agriculture have led to a reduction of freshwater inflow. Flow in the Berg River is very seasonal, with low flows in the dry summer period and higher flows during the wet winter season. The high concentration of dissolved inorganic nitrogen in the winter runoff is attributed largely to fertilizer entering the river through the agricultural runoff.

Impacts of human activities around the urban and industrial nodes include the progressive deterioration of water quality. Eutrophication attributed to industrial development around Saldanha Bay is of considerable concern. Of the urban node embayments, only False Bay receives significant basin drainage, with 11 small catchments discharging to the bay.

5. Nile (contributor – H. Awad)

The damming of this transboundary river system has led to profound changes in fluxes through the Nile delta and in the associated coastal sea (the Mediterranean). This is exacerbated by a rapid growth of urbanisation and industrialisation around Cairo and changes in agricultural practice in the Nile River valley and its delta region. All of these socio-economic drivers, together possibly with the natural driver of climate change, have produced significant impacts at the coast and in the coastal seas around the Nile delta. Notable among these has been the acute coastal erosion around the mouths of the Rosetta and Damietta distributaries of the delta. This is largely attributed to the almost complete cessation since the 1960s of coarse sediment flux below the Aswan Dam. Damming is also seen as being responsible for the increasing salinisation of groundwater in the delta area. Other important coastal issues include eutrophication and pollution of the coastal waters due to the discharge of urban and industrial waste water (Mex Bay and Abu Qir Bay, Mediterranean pollution hot spots) and the loss of habitat resulting from the landfilling of coastal lagoons. Attribution of coastal pollution to fluvial discharge is complicated by the significant inputs from the extensive urban-industrial area of Alexandria at the western limit of the delta (also a Mediterranean pollution hot spot). The assessment is supported by good quality data, including information relating to critical thresholds.

6. East Africa (contributors – J. Kitheka, J. Ochiewo and A. Ngusaru)

The assessed catchments of this sub-region are medium basins, all subject to seasonal flushing, the principal rainfall occurring at the transitions between the north-east and south-east monsoons in April and October. All of them discharge on a coast that is characterised by fringing or patch coral reefs with an associated rich biodiversity. The Rufiji discharges through a delta dominated by mangrove forest into coastal waters that include the largely pristine Mafia Marine Park. Coastal erosion and the discharge of sediment are two of the important issues on this coast. Both the Sabaki and the Tana rivers intermittently discharge sand and

finer, the sand being transferred to beaches thence in part to dune systems that characterise the coast of northern Kenya. Fine sediment, carried in suspension as plumes through the coastal waters, may settle and smother growing coral. Beach-head erosion, mainly of earlier-formed beach deposits, is widely reported, but its attribution solely to a reduction in sediment discharge from the catchments is controversial.

The contributions that damming, deforestation and changes in agricultural practice make to increased or decreased sediment input to these systems have been the subject of several studies in the Tana and Sabaki. Most of these suggest that all of these drivers are increasingly contributing to the problems of coastal erosion and sedimentation. The Tana is already dammed and additional dams are proposed there, as they are for the Rufiji. Pollution is recognised as being a significant issue in the Tana and Sabaki basins, with agriculture, industry and urbanisation all making contributions as drivers. In the Rufiji pesticides used in rice cultivation and the impacts of prawn farming are matters of concern, as are the impacts of population growth and the clearing of mangroves for agriculture. However, inputs of pollutants from industrial development around Nairobi in the Sabaki (Galana/Athi) catchment do not appear to cause serious problems at the coast. The pollutants and nutrients (untreated or partially treated sewage) delivered to coastal creeks from the urban-industrial centres of Mombasa and Dar es Salaam may be more significant, though these sites lie outside the scope of the LOICZ-Basins assessment.

7. Central/southern Mozambique (contributors – F. Tauacale, L. Mhlanga)

The assessed catchments of this sub-region, the Zambezi, Limpopo and Incomati, are transboundary in nature, the Zambezi catchment spanning a total of 8 countries. The rivers discharge on a predominantly alluvial coast formed mainly of older beach deposits and barrier bars and spits with associated creek systems, mangrove swamps and sand dunes. Unlike other parts of the eastern coast of Africa, there is an appreciable continental shelf. Most of the coastal issues and impacts are ascribed to damming and agricultural drivers, with the reduction in stream flow recognised as a significant to acute and increasing problem. The middle course of the Zambezi River has been interrupted by two artificial impoundments, Lake Kariba and Lake Cahora Bassa, which cover 5,364 km² and 2,739 km² respectively.

Coastal erosion reported from the Zambezi delta and the Incomati River is attributed solely to damming and the consequent reduction of sediment discharge. Loss of biological productivity, particularly in the Zambezi system, is seen partly as a consequence of water abstraction for irrigation. The increasing salinisation of agricultural land flanking the Incomati estuary and the nutrient depletion in the coastal seas off the mouths of the Zambezi and Incomati are regarded as impacts of the damming in the respective catchments.

8. South East Africa (contributor – A. T. Forbes)

The catchments assessed in this region comprise one medium basin – the Thukela, discharging on to the sediment based, biologically significant Thukela Bank on the east coast – and three small basins, the Great Fish on the south-east coast and the Kromme and Groot Brak on the south coast. The coast adjoining all these systems, in keeping with the general south-east African condition, is dominated by marine processes being open and subject to strong wave action and longshore drift. Catchment-derived impacts, primarily arising from impoundments, have tended to be recognised primarily in relation to estuarine habitats. The Thukela does, however, deviate from this generalisation.

The Thukela is the largest east coast system and has already been used as a source of water via inter-basin transfer for industrial purposes in the Johannesburg area and irrigation along the Vaal River, a tributary of the Gariep. The estuary is still freshwater dominated but it is anticipated that further reduction in freshwater flow would, *inter alia*, extend periods of mouth closure, reduce sediment supply to beaches north of the river and reduce nutrient input to the already oligotrophic inshore marine environment.

The Great Fish has the second largest catchment of the four systems included here but much of it lies in relatively arid areas. Its flow has now been enhanced and stabilised by the inter-basin transfer of water from the Gariep system to the north via pipelines and canals, as well as the use of the river channel itself as a conduit for irrigation water. This has significantly changed salinity gradient patterns in the estuary.

The Kromme is a small system, which, despite a greatly reduced freshwater input because of dam construction, retains an open mouth because of the local coastal topography. The reduced freshwater

supply has, however, resulted in a marine-dominated, clear water system totally different from the original estuarine community. Present research is dedicated to establish what levels of water released from the dam are required to maintain normal estuarine function. The Groot Brak is another small system which has been significantly impounded but has also been extensively investigated and manipulated in terms of modelling, water-release patterns and mouth breaching in order to protect housing developments in the lower reaches.

2.6.2 Sub-regional scale (see also Table 2.4 and Chapter 5)

(Those areas where determination between catchment and sub-regional scale was not meaningful have already been picked up in 2.6.1; contributing authors are the same as in 2.6.1).

1. North West Africa (see 2.6.1)

2. West Africa

Damming, deforestation and agriculture are considered to be the principal drivers of state changes at the coast through modifications of the hydrological regime, water quality and sediment discharge in the large catchments. These changes impact on the coastal system through erosion and sedimentation altering the coastal geomorphology; also changes in the quality and quantity of water flux resulting in salinisation, eutrophication and pollution, with consequent impacts on biodiversity/biological functioning, the introduction of aquatic weeds and human health. Each of these drivers is seen as having a major and progressive impact. Changes in water quality and, to some extent, quantity that have significant progressive impacts on the coastal system are also attributed to human settlement or urbanisation. Mining and particularly oil-related industrialisation, through their modification of the hydrological regime, make a substantial contribution to pollution and eutrophication among other water-related issues. The role of the natural driver climate change, through accelerated sea-level rise is regarded as becoming increasingly important in respect of coastal erosion, flooding and saline intrusion.

3. Congo (see 2.6.1)

4. South West Africa

The principal drivers considered responsible for minor-to-medium but progressive state changes and impacts at the coast are damming and agriculture, both causing modifications to runoff, water quality and coastal geomorphology. Their impacts at the coast include sedimentation, salinisation and habitat/biodiversity loss, and also, in the case of agriculture, pollution. Transport-related development is seen as causing changes to coastal habitat involving habitat/biodiversity loss. The natural driver climate change may be a significant contributor to erosion, sedimentation and salinisation. Other recognised coastal issues are eutrophication, pollution, aquatic weeds and human health. These are attributed not to human activities within the river basins, but rather to activities within the urban and industrial nodes on the coast itself. These are progressive, significant issues and matters of concern.

5. Nile

The Nile is a single-catchment sub-region. See 2.6.1 for the sub-regional assessment.

6. East Africa

Coastal erosion and sedimentation, pollution and loss of biological functioning are the principal impacts/issues concerning the medium catchments of this sub-region. Damming, deforestation and agriculture are the principal drivers and these are expected to become increasingly significant in respect of their impacts. However, information on the respective contributions of these drivers tends to be ambiguous and little is known of the critical thresholds. The possible contributory roles of urbanisation (coastal engineering) and natural (climate-related) drivers in coastal erosion and sedimentation need to be investigated. Agriculture is regarded as the principal catchment driver for the occurrence of pollutants at the coast though there are also significant inputs from coastal urban-industrial centres. Deterioration in biological functioning and loss of biodiversity as a consequence of an interplay of all the main drivers is a particular concern on this highly biodiverse but sensitive coral reef-fringed coast.

7. Central/southern Mozambique

The principal issues in this sub-region of medium and large transboundary catchments are the reduction in stream flow, coastal erosion, salinisation and nutrient depletion, all of which are attributed to the damming driver. No information on the critical thresholds for these impacts was identified by the workshop, though the severity of all the impacts is expected to increase. Eutrophication resulting from agriculture and urbanisation is stable to increasing, but is of concern only at the local scale. Biodiversity loss (or loss of biological functioning) is a significant issue ascribed to damming and agriculture, but as with eutrophication there is little information concerning critical thresholds and their indicators.

8. South East Africa

This sub-region is characterized by generally small catchments that are subject to various anthropogenic pressures, particularly water abstraction. Damming is an important driver, with freshwater retention in semi-arid conditions, and there are plans in place for further intensive damming. In the small basins this impoundment impacts directly on the coastal system, especially on estuarine environments, causing reduced freshwater inflow, nutrient depletion, salinisation and sediment accumulation in estuaries due to loss of freshwater scouring and extended periods of mouth closure. In extreme cases there may be no freshwater discharge throughout the year. Deforestation and poor agricultural practices have led to increased soil erosion and, especially in the small basins free from impoundment, there is an increasing problem of sediment discharge and siltation at the coast. Agriculture has also contributed to increased nutrient and pesticide fluxes resulting in local but progressive impacts of eutrophication and groundwater degradation at the coast. Urbanisation and industrialisation are the drivers responsible for the discharge of sewage and pollutants. These have high, sometimes direct though localised impacts near the coastal cities while coastal areas further distant retain relatively unaffected conditions.

Table 2.4. The link between coastal issues/impacts and land-based drivers in the coastal zone of Africa: overview and qualitative ranking on catchment and sub-regional scales.

Impact ranking scale, 1 = minimum, 10 = maximum

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Erosion	Damming	Sebou and Moulouya, Morocco	9	↑	CNE (1995); Lahlou (1996); Haida (2000)
		Senegal, Senegal	5	⇒	Barusseau <i>et al.</i> (1993); Ba <i>et al.</i> (1995); Soumare (1996)
		Volta, Ghana	9	↑	Kane (1997); Titriku (1998)
		Nile, mouths of Damietta and Rosetta distributaries, Egypt	8	↑	Sestini (1992); Frihy & Komar (1993); Stanley (1996)
		Tana and Sabaki, Kenya	7	↑	Dunne (1974, 1975); UNEP (1998); Denga <i>et al.</i> (2000)
		Rufiji, Tanzania	7	↑	TCMP (2000, 2001); Ngusaru <i>et al.</i> (2001)
		Zambezi, Mozambique	7	↑	Gove (1993); Masundire & Matiza (1995)
		Incomati, Mozambique	6	↑	JIBS (2001)
		Thukela, South Africa	2-3	⇒/↑	Begg (1978)
		Great Fish/Kromme/Groot Brak, South Africa	2	⇒	see Ch.5 Table RA 8.1
	Deforestation	Sebou and Moulouya, Morocco	6	↑	CNE (1995); Lahlou (1996); Haida (2000)
		Volta, Ghana	6	↑	Kane (1997); Titriku (1998)
		Niger and Cross, Nigeria	8	↑	AKS (1989); NEST (1989); Okoh & Egbon (1999)
		Tana and Sabaki, Kenya	7-8	↑	Dunne (1974, 1975); UNEP (1998); Denga <i>et al.</i> (2000)
		Rufiji, Tanzania	7	↑	TCMP (2000, 2001); Ngusaru <i>et al.</i> (2001)
		Thukela, South Africa	2	⇒	Begg (1978)
Agriculture		Sebou and Moulouya, Morocco	8	↑	CNE (1995); Lahlou (1996); Haida (2000)
		Senegal, Senegal	7	⇒	Barusseau <i>et al.</i> (1993); Ba <i>et al.</i> (1995); Soumare (1996)
		Volta, Ghana	8	↑	Kane (1997); Titriku (1998)
		Niger and Cross, Nigeria	8	↑	AKS (1989)
		Thukela, South Africa	5	↑	Begg (1978)

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Erosion Continued	Urbanisation	Sebou and Moulouya, Morocco	6	↑	CNE (1995); Lahlou (1996); Haida (2000)
		Volta, Ghana	6	↑	Kane (1997); Titriku (1998)
		Tana and Sabaki, Kenya	6-7	↑	Denga <i>et al.</i> (2000)
		Thukela, South Africa	2	↑	see Ch.5 Table RA 8.1
		Great Fish, Kromme, Groot Brak	3	⇒	
		Tana, Kenya	5	↑	Ewbank & Partners (1974)
Sedimentation	Industrialisation	Thukela, South Africa	2	↑	see Ch.5 Table RA 8.1
	Climate change	Great Fish, Kromme, Groot Brak	2	⇒	
		Nile delta, Egypt	8	↑	Sestini (1992); Friby & Komar (1993); Stanley (1996)
	Damming	Sebou and Moulouya, Morocco	9	↑	Charrouf (1991); Snoussi <i>et al.</i> (2001)
		Volta, Ghana	7	⇒	Gordon (1998)
		Senegal, Senegal	9	↑	Diaw <i>et al.</i> , (1988, 1990); Barusseau <i>et al.</i> (1993); Ba <i>et al.</i> (1995); Soumare (1996)
		Niger, Nigeria	6	↑	NEST (1989)
		Gariep, South Africa	6	↑	DWAF (1989, 1993)
		Olifants, South Africa	4	↑	Huizinga & Van Niekirk (1997)
		Berg, South Africa	4	↑	DWAF (1994)
		Tana, Kenya	8	↑	ILACO (1971); Ewbank & Partners (1974)
		Sabaki, Kenya	5	↑	Kairu and Nyandwi (2000)
		Zambezi, Mozambique	3	↓	Gove (1993); Masundire & Matiza (1995)
		Incomati, Mozambique	2-3	↓	
		Thukela, South Africa	3	probable ↑	Begg (1978)
		Great Fish, Kromme, Groot Brak, South Africa	1-4	⇒	see Ch.5 Table RA 8.1

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Sedimentation Continued	Agriculture	Cross, Nigeria	6	↑	NEST (1989)
		Gariep, South Africa	4	↑	DWAF (1989, 1993)
		Olifants, South Africa	3	↑	Huizinga & Van Niekerk (1997)
		Berg, South Africa	3	↑	DWAF (1994)
		False Bay, Cape Town, S. Africa	3	↑	Taljaard <i>et al.</i> (2000)
		Tana, Kenya	6	↑	Dunne (1974, 1975); Ewbank & Partners (1974); Edwards (1979); UNEP (1998); Denga <i>et al.</i> (2000)
		Sabaki, Kenya	7	↑	Kairu and Nyandwi (2000)
		Rufiji, Tanzania	7	↑	TCMP (2000, 2001); Ngusuru <i>et al.</i> (2001)
		Zambezi, Mozambique	2	↑	Gove (1993); Masundire & Matiza (1995)
		Sabaki, Kenya	7	↑	Kairu and Nyandwi (2000)
Stream flow reduction	Deforestation	Rufiji, Tanzania	7	↑	TCMP (2000, 2001); Ngusuru <i>et al.</i> (2001)
		Table Bay/False Bay, Cape Town, South Africa	3	↑	Quick & Roberts (1993); Taljaard <i>et al.</i> (2000)
		Zambezi, Mozambique	9	↑	Chonguica (1997); UEM (1999); Taucale (1999); Guale (2000); JIBS (2001); SRI (2001)
		Limpopo, Mozambique	5	↑	
		Sebou and Moulouya, Morocco	9	↑	
		Volta, Ghana	10	↑	Mackinnon (1958); Finlayson (1998)
		Niger and Cross, Nigeria	7	↑	NEST (1989)
		Nile, Egypt	?	?	EEAA (1996)
		Incomati, Mozambique	5	↑	JIBS (2001); SRI (2001)
		Thukela, South Africa	3	↑	see Ch.5 Table RA 8.1
Eutrophication	Sewage	Great Fish, Kromme, Groot Brak, South Africa	1-4	⇒	
		Saldanha Bay, South Africa	6	↑	Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
		Nile, Egypt	?	⇒	Awad (1994)
		Sebou and Moulouya, Morocco	8	↑	
		Volta, Ghana	6	↑	Mackinnon (1958); Finlayson (1998)
		Niger and Cross, Nigeria	7	↑	NEST (1989)
		Nile, Egypt	?	?	Awad (1994)
		Sebou and Moulouya, Morocco	8	↑	
		Volta, Ghana	6	↑	Mackinnon (1958); Finlayson (1998)
		Niger and Cross, Nigeria	7	↑	NEST (1989)
Sedimentation Continued	Agriculture	Nile, Egypt	?	?	Awad (1994)
		Sebou and Moulouya, Morocco	8	↑	
		Volta, Ghana	6	↑	Mackinnon (1958); Finlayson (1998)
		Niger and Cross, Nigeria	7	↑	NEST (1989)
		Nile, Egypt	?	?	Awad (1994)
		Sebou and Moulouya, Morocco	8	↑	
		Volta, Ghana	6	↑	Mackinnon (1958); Finlayson (1998)
		Niger and Cross, Nigeria	7	↑	NEST (1989)
		Nile, Egypt	?	?	Awad (1994)
		Sebou and Moulouya, Morocco	8	↑	

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Eutrophication Continued	Agriculture continued	Limpopo, Mozambique	2	⇒	Chonguica (1997); UEM (1999); Tauacale (1999); Guale (2000); JIBS (2001); SRI (2001)
		Incomati, Mozambique	5	↑	JIBS (2001); SRI (2001)
		Great Fish, Kromme, Groot Brak, South Africa	1-4	↑	see Ch.5 Table RA 8.1
	Damming	Senegal, Senegal	4	↑	UNEP (1999)
Pollution	Bushfires	Volta, Ghana	5	⇒	Mackinnon (1958); Finlayson (1998)
	Industrial and domestic waste	Sebou and Moulouya, Morocco	8	↑	
	Urbanisation	Senegal, Senegal	?	↑	
		Saldhana Bay, South Africa	4	↑	Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
		Table Bay, Cape Town, S. Africa	4	↑	Quick & Roberts (1993); Monteiro (1997)
		False Bay, Cape Town, S. Africa	4	↑	Taljaard (2000)
		Nile, Egypt	7	⇒	
		Tana and Sabaki, Kenya	5-6	↑	
		Rufiji, Tanzania	7	↑	Kulindwa (2000); TCMP (2000, 2001); Ngusaru <i>et al.</i> (2001)
		Thukela, South Africa	3	⇒/↑	see Ch.5 Table RA 8.1
		Great Fish, Kromme, Groot Brak, South Africa	1-3	↑	
	Agriculture	Senegal, Senegal	?	↑	
		Niger and Cross, Nigeria	7	↑	NEST (1989); CRP (1999)
		Gariép, South Africa	2?	↑	
		Olifants, South Africa	2?	↑	Taljaard (1997)
		Berg, South Africa	2	↑	DWAF (1994); Slinger & Taljaard (1994)
		Nile, Egypt	7	↓	EEAA (1996)
		Tana and Sabaki, Kenya	6-7	↑	Dunne (1974, 1975); Edwards (1979); Denga <i>et al.</i> (2000)
		Rufiji, Tanzania	6	↑	Mwalyosi (1990); Kulindwa (2000); TCMP (2000, 2001)
		Zambezi	2?	↑	Chonguica (1997); UEM (1999); Tauacale (1999); Guale (2000); JIBS (2001); SRI (2001)
		Incomati	8	↑	Pers. comm.

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Pollution Continued	Industrialisation	Volta, Ghana	7	↑	Amoah (1999)
		Niger and Cross, Nigeria	9	↑	NEST (1989); AKS (1989); CRP (1999)
		Congo, Congo	3	?	
		Saldhana Bay, South Africa	4	↑	Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
		Table Bay, Cape Town, S. Africa	4	↑	Quick & Roberts (1993); Monteiro (1997)
		Nile, Egypt	7	⇒	EEAA (1992)
		Tana and Sabaki, Kenya	4-6	↑	
		Thukela, South Africa	3	↑	
		Great Fish, Kromme, Groot Brak, South Africa	1-3	⇒	
		Volta, Ghana	7	↑	Amoah (1999)
Nutrient depletion	Mining	Thukela, South Africa	3	⇒	see Ch.5 Table RA 8.1
	Fishing	Volta, Ghana	6	↓	
		Rufiji, Tanzania	8	↑	Bernacsek (1980); Boyd (1996); Kulindwa (2000); TCMP (2000, 2001)
		Great Fish, Kromme, Groot Brak, South Africa	5-8	↑	see Ch.5 Table RA 8.1
	Aquatic weeds	Sebou and Moulouya, Morocco	6	↑	Menioui (2001)
		Volta, Ghana	7	↑	De Graft-Johnson (1999)
		Senegal, Senegal	9	↓	Cogels <i>et al.</i> (1993); BDPA-SCETAGRI <i>et al.</i> (1995); Matera & Malaisse (1999)
	Sewage	Sebou and Moulouya, Morocco	7	↑	Menioui (2001)
		Volta, Ghana	7	↑	De Graft-Johnson (1999)
		Table Bay, False Bay, S. Africa	4	↑	Quick & Roberts (1993); Taljaard <i>et al.</i> (2000)
Bushfires	Agriculture	Sebou and Moulouya, Morocco	6	↑	Menioui (2001)
		Volta, Ghana	7	↑	De Graft-Johnson (1999)
		Table Bay, False Bay, S. Africa	4	↑	Quick & Roberts (1993); Taljaard <i>et al.</i> (2000)
	Transportation	Volta, Ghana	7	⇒	NEST (1989); AKS (1989)
		Niger and Cross, Nigeria	7-8	↑	

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Biodiversity loss	Multi-driver	Sebou and Moulouya, Morocco	8	↑	GERM (1994)
		Volta, Ghana	8	↑	Gordon (1999)
		Niger and Cross, Nigeria	7	↑	NEST (1989); Ibeanu (2000)
		Tana and Sabaki, Kenya	7	↑	see Ch.5 Table RA 6.1; Njuguna (1991); Raal & Barwell (1995); Klocker (1998)
		Rufiji, Tanzania	7	↑	IUCN & Rufiji Administration (1997); Ngoile & Kiwia (1996); TCMP (2000, 2001); Ngusuru <i>et al.</i> (2001)
		Thukela, South Africa	2-3	↑	see Ch.5 Table RA 8.1
		Great Fish, Kromme, Groot Brak, South Africa	5-8	↑	
		Senegal, Senegal	8	?	Ibeanu (2000)
		Gariep, South Africa	6	↑	DWAF (1989, 1993)
		Olifants and Berg, South Africa	4	↑	DWAF (1994); Huizinga & Van Niekerk (1997)
Deforestation	Urbanisation	Zambezi, Mozambique	7	↑	Balon & Coche (1974); Brinca <i>et al.</i> (1986); Da Silva (1986); Gammelsrod (1992, 1996); Timberlake (1998)
		Congo, Congo	7	↑	UNEP (1999); Morant (2001)
		Congo, Congo	3	↑	Morant (2001)
		Saldanha Bay, Table Bay, False Bay, South Africa	3-4	↑	Quick & Roberts (1993); Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999); Taljaard <i>et al.</i> (2000)
		Nile, Egypt	8	↑	Hanafy (1998)
		Congo, Congo	3	↑	Morant (2001); Morant (pers. comm.)
		Saldanha Bay	3	↑	Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
		Nile, Egypt	?	⇒	Awad (1994)
		Gariep, South Africa	4	↑	DWAF (1989, 1993)
		Olifants and Berg, South Africa	4	↑	DWAF (1994); Huizinga & Van Niekerk (1997)
Agriculture	Industrialisation	Zambezi, Mozambique	7	↑	Chonguica (1997); UEM (1999); Tauacale (1999); Guale (2000); JIBS (2001); SRI (2001)

Table 2.4 continued

Coastal impact/issue	Driver	Local catchment		Trend expectations	References/data sources
		River	Impact Category		
Salinisation	Multi-driver	Sebou and Moulouya, Morocco	9	↑	Moussaoui (1994); El Mandour (1995)
		Niger and Cross, Nigeria	7	↑	
	Drought/ climate change	Senegal, Senegal	5	↑/⇒	Pages <i>et al.</i> (1987); Debenay <i>et al.</i> , (1994); BDPA-SCE/AGRI <i>et al.</i> (1995); Diouf (1998)
	Damming	Gariep, Olifants, Berg, South Africa	4	↑	DWAF (1989); Huizinga & Van Nickerk (1997)
		Incomati, Mozambique	8	↑	SRI (2001)
Human health issues	Agriculture	Gariep, Olifants, Berg, South Africa	3-4	↑	DWAF (1989, 1993); Huizinga & Van Nickerk (1997)
	Sewage	Sebou and Moulouya, Morocco	8	↑	
		Senegal, Senegal	8	↑	Handschumacher <i>et al.</i> (1992); Talla (1993); Niang (1999)
		Volta, Ghana	8	↑	Derban (1999)
		Niger and Cross, Nigeria	7	↑	NEST (1989); Ibeanu (2000)
		Table Bay and False Bay, South Africa	4	↑	Quick & Roberts (1993); Taljaard <i>et al.</i> (2000)
		Nile, Egypt	8	↓	Abo Zahra (2000)
		Rufiji, Tanzania	7	↑	Wagner <i>et al.</i> (1998); TCMP (2000, 2001); Ngusuru <i>et al.</i> (2001)
		Thukela, South Africa	4-5	⇒	see Ch.5 Table RA 8.1
		Great Fish, Kromme, Groot Brak, South Africa	3-7	⇒/↑	
	Damming	Senegal, Senegal	8	↑	Handschumacher <i>et al.</i> (1992); Talla (1993); Niang (1999)
	Industrialisation	Saldanha Bay, South Africa	4	↑	Monteiro & Largier (1999); Monteiro <i>et al.</i> (1999)
Agriculture		Nile, Egypt	8	⇒	FEAA (1992, 1996)
		Nile, Egypt	?	↓	Awad (1994)

2.6.3 Regional scale (see Table 2.6)

A first-cut ranking order was drawn up for Africa, together with expected future trends in impacts (see Table 1.1). It should be recognised that the ranking given here attempts to create a full regional picture, although, medium-ranked statuses can become major ones if catchments of specific size classes are considered.

Coastal geomorphological change involving erosion and sedimentation was identified as a significant and progressive impact in nearly all of the sub-regions, the problem being acute on the Nile delta and in the West African lagoon systems. Damming was viewed as the principal driver in such change, with consequent reductions in stream flow and sediment flushing. Damming was also seen as being largely responsible for coastal salinisation, e.g., the Incomati estuary in Mozambique and nutrient depletion in the coastal sea, e.g., KwaZulu Natal. In most sub-regions deforestation and agriculture were regarded as important drivers, particularly in respect of coastal sedimentation from medium and small catchments, e.g., the Tana and Sabaki in Kenya. Human settlement was identified as a major contributor to eutrophication and the incidence of aquatic weeds in the large West African catchments. Elsewhere, while eutrophication and pollution were recognised, they were mostly related to coastal urban-industrial sources, e.g., Alexandria, Mombasa, Saldanha Bay and Cape Town. Loss of biodiversity or biological functioning was seen as another common issue, though related to complex ranges of human and natural drivers.

In general these data are characteristic of developing economy situations where economic growth and water use exceed development of the necessary urban and industrial infrastructure. This finding parallels those made in the South American (SAmBas), and East Asian Basins assessment and synthesis processes (de Lacerda *et al.* 2001; Hong *et al.* in prep.). However, heterogeneity of the sub-regions seems to be more pronounced in Africa than in other world regions, making the ranking of issues and drivers in Africa a more complex challenge.

Table 2.5 Summary of priority driver/pressure features by country, corresponding “hot spots” and information available in Africa (see also Section 2.6.5).

Country	Driver/Pressure	Hot spots	Available information
1. Morocco	<ul style="list-style-type: none"> • Damming • Human settlement, agriculture and industrialisation 	<ul style="list-style-type: none"> • Sedimentation through reduced flushing especially on Mediterranean coasts; salinisation of coastal plains • Eutrophication, pollution on Mediterranean and Atlantic coasts 	<ul style="list-style-type: none"> • Etat de qualité des Ressources en eau au Maroc (DRPE 1998) and many published papers and reports
2. Senegal	<ul style="list-style-type: none"> • Damming • Human settlement 	<ul style="list-style-type: none"> • Sedimentation, invasion by aquatic weeds and loss of biodiversity in Senegal river; estuarine ecosystem destroyed • Human health issues 	<ul style="list-style-type: none"> • Barrage-related impact studies, water quality assessments
2. Ghana	<ul style="list-style-type: none"> • Damming • Human settlement 	<ul style="list-style-type: none"> • Erosion of Volta delta and invasion by aquatic weeds • Eutrophication and human health issues in Volta 	<ul style="list-style-type: none"> • Lower Volta environmental impact study (VBRP 1996-2001); Coastal wetland management project (1992-1997) GEF; Integrated coastal zone management strategy (World Bank 1996)
2. Nigeria	<ul style="list-style-type: none"> • Industrialisation 	<ul style="list-style-type: none"> • Oil-related pollution in Cross and Niger 	<ul style="list-style-type: none"> • World Bank studies, 1995; Moffat & Linden (1995)
4, 8. South Africa	<ul style="list-style-type: none"> • Damming and diversion • Urbanisation and industrialisation 	<ul style="list-style-type: none"> • Nutrient depletion off south-east coast with resulting biodiversity loss; sedimentation and loss of habitat on southwest coast • Eutrophication and pollution at Saldanha Bay 	<ul style="list-style-type: none"> • Estuarine studies since 1950s; summary of available estuarine literature and the synthesis of available knowledge • CSIR monitoring and modelling programmes initiated
5. Egypt	<ul style="list-style-type: none"> • Damming and diversion • Urbanisation and industrialisation 	<ul style="list-style-type: none"> • Erosion of Nile delta • High levels of pollution and eutrophication in Abu Qir Bay, Mex Bay and on Alexandria city coast 	<ul style="list-style-type: none"> • Shoreline monitoring • Water quality monitoring
6. Kenya	<ul style="list-style-type: none"> • Damming • Deforestation 	<ul style="list-style-type: none"> • Deterioration in Tana water quality • Siltation at mouth of Sabaki 	<ul style="list-style-type: none"> • Fish stock and biological productivity data • Coral impact data
6. Tanzania	<ul style="list-style-type: none"> • Deforestation • Agriculture • Aquaculture 	<ul style="list-style-type: none"> • Siltation at mouth of Rufiji • Deterioration of Rufiji water quality • Pollution from prawn fisheries 	<ul style="list-style-type: none"> • Biodiversity data for mangrove and coral areas • EIA reports
6,7. Mozambique	<ul style="list-style-type: none"> • Damming and abstraction 	<ul style="list-style-type: none"> • Biodiversity loss in Zambezi delta and on Sofala Bank • Salinisation of Incomati • Erosion of Zambezi delta 	<ul style="list-style-type: none"> • Fish stock and biological productivity data • Incomati hydrology study

Table 2.6 Major activities (drivers), present status and trends affecting the coastal zone of Africa.

Anthropogenic drivers	Major state changes and impact	Location	Present status	Trend expectations	Major areas affected (figures refer to sub-regions)
Damming Diversion	Erosion	West coast	Major	Increasing	2. Senegal, Volta, Niger
		Nile delta	Major	Increasing	5. Nile delta distributaries
		East coast	Medium	Increasing	7. Zambezi
	Sedimentation	West coast	Local	-	5. Nile delta
		Nile delta	Local	Increasing	6. Malindi coast, Kenya
		East coast	Medium	Increasing	1. Moulouya, 2. Niger delta
	Salinisation	West coast	Medium	Increasing	5. Nile delta
		Nile delta	Medium	Increasing	6. Tana, 7. Incomati
		East coast	Medium	Increasing	
	Nutrient depletion	West coast	-	-	
		Nile delta	-	-	
		East coast	Medium	Increasing	7. Southern Mozambique, 8. KwaZulu-Natal
Various drivers	Biodiversity loss	West coast	Major	Increasing	Almost all sub-regions
		Nile delta	Major	Increasing	
		East coast	Major	Increasing	
Deforestation	Erosion	West coast	Medium	Increasing	Medium ranking for most sub-regions, however, major for coastal impacts generated in small and medium catchments in 1 and 6
		Nile delta	-		
		East coast	Medium	Increasing	
	Sedimentation	West coast	Medium	Increasing	
		Nile delta	-		
		East coast	Medium	Increasing	

Table 2.6 continued

Anthropogenic drivers	Major state changes and impact	Location	Present status	Trend expectations	Major areas affected (figures refer to sub-regions)
Agriculture	Sedimentation	West coast	Minor	Increasing	2. Cross, 4. Gariep, Olifants, Berg 6. Tana, Sabaki, Rufiji
		Nile Delta	-	-	
		East coast	Medium	Increasing	
	Eutrophication	West coast	Medium	Increasing	Medium ranking for most sub-regions, but major for coastal impacts generated in small and medium size catchments in 1 and 6
		Nile delta	-	-	
		East coast	Medium	Increasing	
	Pollution	West coast	Major	Decreasing	
		Nile Delta	Medium	Increasing	
		East coast			
Urbanisation	Eutrophication	West coast	Medium	Increasing	Medium overall but major in 5
		Nile delta	Major	Increasing	
		East coast	Medium	Increasing	
Industrialisation	Pollution	West coast	Medium	Increasing	As above, but in most cases more coastal than catchment-based – 4 , 5, 6
		Nile delta	Major	Increasing	
		East coast	Medium	Increasing	

2.6.4 Policy, scientific and management responses (see Table 2.7 and Chapter 5).

There is a growing awareness by scientists, managers and policy makers of the need to understand coastal systems in the context of their related catchments so that knowledge of the linkages between human activities in river catchments and environment-related socio-economic issues at the coast can feed into effective integrated management. While the coast and coastal seas have long attracted scientific and socio-economic research, there has been a tendency worldwide, but perhaps particularly in Africa, for that research to be sectoral, with somewhat limited application in integrated management.

The last decade or so has seen a worldwide shift towards research and management initiatives that take a broader view of land-sea interaction in both space and time. Such linked projects cover present (and past) material fluxes between the land and the ocean via rivers and lakes, groundwater, the atmosphere and coastal seas. This broadening of perspective has been accompanied by the realisation of the importance of socio-economic as well as natural factors as drivers of system changes in the coastal environment. Scientific and management responses to the need for this more integrated approach to understanding and managing the coastal resource with its complex ecosystem are becoming increasingly apparent in the region. Regional/global scientific responses include the UNEP GEF Global International Waters Assessment (GIWA), and increasingly these show a trend towards initiatives that view catchments and coasts in integrated system contexts. In general policy responses at the regional level remain in the process of formulation. Listings and brief descriptions of the initiatives, both scientific and management, developed both for catchments and sub-regionally are presented in Table 2.7.

1Table 2.7 Scientific and/or management responses to coastal impact/issues in the African coastal zones on catchment, sub-regional and regional scales

River catchment	RESPONSE Catchment scale		RESPONSE Sub-regional scale – North-west Africa		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
MOROCCO Sebou	<p>-Atlas du Sebou (1970)</p> <p>-Etat de qualité des Ressources en eau au Maroc (DRPE, 1998).</p> <p>- Diagnose de l'Etat de l'environnement dans le bassin du Gharb (Benasser, 1997)</p> <p>Bilan des flux du Sebou (Haida, 2000)</p>	<p>The 'Office Régional de Mise en Valeur Agricole du Gharb' (ORMVAG) is in charge of the management of the Sebou basin.</p> <p>The Waters and Forests Department and the Environment have carried out many projects in the basin, among them the rehabilitation of the Sebou Basin Project.</p>	<p>- Med Campus Project (UE). «<i>Gestion des réserves d'eau souterraine dans les zones affectées par la salinisation</i>».1994.</p> <p>-Avicenne Project (UE):«<i>Development of water resources management tools for Problem of seawater intrusion and contamination of fresh-water resources in coastal aquifers</i>». 1995-1999.</p> <p>-FICU Project: (Fond International de Coopération Universitaire): '<i>Gestion et protection des ressources en eaux dans les plaines semi-arides au Maroc et en Tunisie.2000-2002</i>': MATER Project ADIOS Project</p>	<p>Guidelines for Integrated Coastal Zone Management in the Mediterranean Region (UNEP 1995)</p> <ul style="list-style-type: none"> • L'eau dans le bassin Méditerranéen (Economica) (Margat 1992) 		
Moulouya	<p>Many reports and papers on how to combat siltation of dams, soil erosion and salinisation in the basin</p>	<p>Aménagement du bassin de la Moulouya (Eaux et Forêts, in press)</p>				

Table 2.7 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub regional scale - West Africa		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
SENEGAL Senegal	Michel <i>et al.</i> (1993) L'Après Barrage dans la vallée du Senegal. EQUENSEN (1993) Environnement et Qualité des Eaux du Fleuve Senegal. SEAH (1996) Transformation des Hydrosystèmes liés aux grands barrages en Afrique soudanienne et sahélienne. BDPA (1996) Bilan Diagnostic du Delta du Senegal	OMVS (Organisation pour la mise en valeur du fleuve Senegal) Initiatives to combat the invasion by macrophytes; others to combat inundations Danish Project for the elaboration of an integrated management of the delta	Large marine ecosystem Gulf of Guinea Project (1995-2004) UNIDO-GEF Transboundary diagnostic analysis for the Volta Basin UNEP-GEF (ongoing) Mahe (1993) – study referring to all basins discharging to the Atlantic Ocean	Large marine ecosystem Gulf of Guinea Project (1995-2001) UNIDO-GEF Transboundary diagnostic analysis for the Volta Basin UNEP-GEF (ongoing)		
GHANA Volta	Ghana water resources management study (1998). Lower Volta environmental impact study (VBRP 1996-2001). Ghana coastal wetland management project (1992-1997) GEF. Integrated coastal zone management strategy for Ghana (World Bank 1996).	Ghana water resources management study (1998). Lower Volta environmental impact study (VBRP 1996-2001). Ghana coastal wetland management project (1992-1997) GEF. Integrated coastal zone management strategy for Ghana (World Bank 1996).				

Table 2.7 continued

River catchment	RESPONSE Catchment scale		RESPONSE Sub-regional scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
NIGERIA Niger	Environmental Diagnostic Studies (NDES 1997). Niger Delta Development Cooperation (NDDC 2001).	Environmental Diagnostic Studies (NDES 1997). Niger Delta Development Cooperation (NDDC 2001). Federal Environmental Protection Agency (FEPA). Federal Ministry for Environment				
Cross	Control of pollution, flood in the Cross river Basin (CRBDA, 1976). Environmental Inventory survey (AKS 1989).	Federal Environmental Protection Agency (FEPA). Control of pollution, flood in the Cross river basin (CRBDA 1976). State Minister of the Environment (AKS 1989)				
CONGO Congo	?	Provision of technical support to the Dem. Rep. of the Congo through the Min. of the Environment and Tourism given to allow it to prevent and/or reduce degradation of the coastal environment caused by land-based activities (UNEP, 1999).				

Table 2.7 continued

River catchment	RESPONSE catchment scale		RESPONSE Sub- regional scale – South Africa		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
S. AFRICA						
Gariep	-	-	-	<ul style="list-style-type: none"> The National Water Act of South Africa (Act 36 of 1998) states that the natural environment has a right to water. As a result, the quantity and quality of water and other resource quality objective need to be determined for river catchments. The national Department of Water Affairs and Forestry are responsible for setting the 'Reserve and Resource Quality Objectives' for catchments, including estuaries. To facilitate implementation of these measures, the law requires that Catchment Management Agency (CMA) and Catchment Management Forums be put in place for each basin. 		
Olifants	-	-				
Berg	CSIR's catchment-2-coast initiative in this area	Department of Water Affairs and Forestry to initiate a monitoring programme in the area				
Saldanha Bay	Joint CSIR – Marine and Coastal Management (Department of Environmental Affairs) Project (Monteiro & Largier 1999)					
Table Bay	-	-				
False Bay	Review on anthropogenic inputs undertaken in 2000 (Taljaard <i>et al.</i> 2000)	-				

Table 2.7 continued

River catchment	RESPONSE catchment scale		RESPONSE Sub-regional scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
EGYPT Nile	Nile water quality monitoring. Coastal water quality monitoring. Pollution impact assessment on Nile and marine resources. Pollution hot spot monitoring. Sea-level rise monitoring.	Legislation and enforcement measures since 1994. Creation of EEAA. (Egyptian Environmental Affairs Agency) and its 8 Regional Branches. National CZM plan and committee. Implementation of national programmes for: -Nile water monitoring -Shoreline protection and planning -GIS database -Domestic/industrial waste treatment	MedPol programmes MedGOOS monitoring Environmental Information Monitoring Programme	MAP/UNEP MAMA/IOC EIMP/DANIDA	MedPol programmes MedGOOS monitoring	MAP/UNEP MAMA/IOC

Table 2.7 continued

River catchment	RESPONSE catchment scale		RESPONSE Sub-regional scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
KENYA Kenya coast including Tana and Sabaki (Athi, Galana) river basins	EU-STD II-III and EU-RTD IV project, IOC-SAREC, UNEP-UNESCO, NWP-KWS, Tana Primates World Bank-GEF	Coast Province Administration, District Development Planning, Local Government Authorities, Tana and Athi Rivers Development Authority	UNEP-BADC Eastern Africa Atlas of Coastal Resources – Kenya (1998); Tanzania (2001). IOC-UNESCO Guidelines for the study of shoreline change in the Western Indian Ocean Region (Kairu & Nyandwi 2000). Establishment of IOC Western Indian Ocean regional office in KMFRI, Mombasa.	National Environment Management Council (NEMC), Tanzania. Coast Development Authority, Kenya. Kenya Wildlife Service.		
TANZANIA Rufiji	NEMC, TCMP - GISD project (USAID) REMP (IUCN) RUBADA Mangrove management project (NORAD) FRONTIER University of Dar es Salaam RIPS (FINIDA). WWF-Ecoregion project Sida-SAREC Rufiji Flood Plain Project (Ireland and Netherlands)	Rufiji Basin Development Program Rufiji Environmental Management Program Mangrove Management Program Marine and Coastal Research Rural Integrated Program Support Coastal Forest Conservation Rufiji Flood Plain Project Biodiversity Loss ELA for Damming Pesticides and Agrochemical impact on coastal environment Impact of Industrial effluents through Rufiji River to the coastal environment Socio-economic impact Assessment				

Table 2.7 continued

River catchment MOZAMBIQUE	RESPONSE catchment scale		RESPONSE Sub-regional
	Scientific	Management	
Incomati	<p>Shared River Initiative Project. RSA. (1999 – 2000)</p> <p>Joint Inkomati Basin study, phase 1-2. Consultec and BKS Acres, Final Report (2001)</p> <p>Country situation Report – Water Resources – Mozambique vol.1-3- (1998)</p> <p>The first phase of a cumulative environmental impact assessment for the Inkomati river basin. (2000)</p> <p>MBB Consulting Engineers, Acer (Africa) Environmental Management Consultants, AWARD 2000. Proposal for the Establishment of a Catchment Management Agency for the Inkomati Basin. Final Draft. Prepared for the Inkomati; Catchment Management Agency Reference Group, under the auspices of DWAF, Mpumalanga Regional Office. (2000)</p> <p>DNA. 1991 Gestao de Recursos Hidricos na Bacia Hidrografica do Incomati. Report 56/91</p>	<p>Shared River Initiative Project. RSA. (1999 – 2000)</p> <p>Joint Inkomati Basin study, phase 1-2. Consultec and BKS Acres, Final Report (2001)</p> <p>Country situation Report – water Resources – Mozambique vol.1-3- (1998).</p> <p>The first phase of a cumulative environmental impact assessment for the Inkomati river basin. (2000)</p> <p>MBB Consulting Engineers, Acer (Africa) Environmental Management Consultants, AWARD 2000. Proposal for the Establishment of a Catchment Management Agency for the Inkomati Basin. Final Draft. Prepared for the Inkomati; Catchment Management Agency Reference Group, under the auspices of DWAF, Mpumalanga Regional Office. (2000)</p> <p>DNA. 1991. Gestao de Recursos Hidricos na Bacia Hidrografica do Incomati. Report 56/91</p>	
Limpopo	<p>Jamieson, J.G. Planning and management of water resources in Mozambique. DNA (1985)</p> <p>Koudstaal, R. Identification of major issues in Water resources master planning in Mozambique. Delft, Netherlands (1989)</p> <p>DNA, Planning for water resources management. Progress Limpopo Limpopo Study. Maputo (1991)</p>	<p>Jamieson, J.G. Planning and management of water resources in Mozambique. DNA (1985)</p> <p>Koudstaal, R. Identification of major issues in Water resources master planning in Mozambique. Delft, Netherlands (1989)</p> <p>DNA, Planning for water resources management. Progress Limpopo Study. Maputo (1991)</p>	

Table 2.7 continued

River catchment	RESPONSE		RESPONSE	
	catchment scale		Sub-regional scale	
SOUTH AFRICA	Scientific	Management	Scientific	Management
Thukela	Incorporation of estuary as well as coastal and offshore environments into the E.I.A. of the proposed T.W.P. (Thukela Water Project) by the South African Department of Water Affairs and Forestry. Report in press	Proposed consideration of the design of the impoundments and water release patterns to allow minimum disruption of natural flow patterns	<p>Marine processes dominate the very open, high energy South African coastline, with the result that catchment events are far more apparent in estuaries than offshore, although turbidity plumes are a feature of the KwaZulu Natal coast during the summer rainfall period. Consideration of the effects of land runoff have not been a priority until very recently, culminating in the T.W.P. E.I.A. referred to in this table.</p> <p>Marine research dates back at least a century while organized estuarine studies only began in about 1950 (Day 2000). For reasons outlined above the estuarine research component shows far more focus on the land-water interaction and this is reflected in Whitfield's (2000) summary of available estuarine literature and the synthesis of available knowledge by Allanson & Baird (1999).</p>	<p>Estuarine studies have, in recent years, focussed progressively more on management objectives, practicalities and techniques and have been fortunate in being able to build on a strong research foundation. The incorporation of this knowledge into management policy and action is now a major priority.</p> <p>Research and management is strongly supported by local funding agencies including the Department of Environmental Affairs and Tourism, the National Research Foundation, The Water Research Commission and the Department of Water Affairs and Forestry (at times with European and British subvention). These organizations work closely with the Consortium for Estuarine Research and Management (CERM) a voluntary network of about 80 researchers working on estuaries throughout the country (For review see SA Waterbulletin 27(6)). A significant attempt to bring estuarine science to the manager has been produced by Breen & McKenzie (2001) which incorporates a summary of the relevant legislation which provides for protection of both the estuarine and the coastal environment. Legislation is covered in more detail by Glazewski (2000) and policy and implementation is reviewed by Boyd <i>et al.</i> (2000), Glavovic (2000) and the Department of Environmental Affairs & Tourism (2000).</p>

2.6.5 Key areas for research projects (see Table 2.8 and Chapter 5)

Data

A scarcity of relevant data is a recurrent problem in most sub-regions, for scientific data but particularly for socio-economic information, and for both activities in the catchments and impacts at the coast. Time-series data generated from routine monitoring programmes is particularly sparse. In some cases older data may exist though these are yet to be accessed. The collection of standardised data relating to the large transboundary catchments presents considerable challenges. The workshop recognised the need to incorporate or initiate basic data collection and monitoring within any proposed integrated regional research programme. Data collection programmes should be designed as far as possible with the aim of establishing the causes of changes in the coastal environmental state that impact upon the coastal resource, whether those causes are natural, anthropogenic or a combination of the two.

Indicators

The workshop highlighted a considerable lack of knowledge about the critical loads and thresholds of material fluxes passing from the catchments to (or through) the coastal area to the coastal sea that, if exceeded, would significantly change the coastal environment. There is a need for common parameters to be established in respect of the indicators of change that are relevant to the region. Such an approach should take into account not only the incidence of a change of state but its spatial and temporal dimensions as well, bearing in mind the coastal type (geomorphology and oceanography) and its capacity for the retention of catchment-derived materials or their dispersal to the ocean.

Research challenges

Supposed ‘multi-driver’ impacts pose a major challenge, particularly in medium and large, transboundary catchments, where there is scope for substantial transformation or reduction of material fluxes within the system. In many sub-regions the loss of biodiversity or loss of biological functioning was ascribed to a suite of drivers, so that an appropriate, targeted response policy may be difficult to formulate. The specific contributions (positive or negative) to the fluxes of water and sediment that reach the coast arising from, e.g., agricultural practices, deforestation or damming need especially careful analysis, bearing in mind the socio-economic implications of regulation in these areas. In the AfriBasins process the rates of changes in the coastal environmental state resulting from catchment-generated pressures were assessed only in general terms – ‘direct’ or ‘progressive’. In some cases there was uncertainty in the assessment. To prioritise appropriate responses in the catchments at management and policy levels, more specific information is necessary on rates of change and time-lags between the anthropogenic pressure and the corresponding change to the state. An integrated regional research programme would provide the opportunity for the comparison of pressure-state changes in catchments of different sizes in a variety of geographical settings within the region.

The contributions that natural drivers such as climate change have made and will make to the state of the coastal environment over a range of time-scales is another area for consideration by regionally integrated research. For example, sporadic extreme event cyclonic flooding is a feature of catchments in central/southern Mozambique, with major fluxes of water and sediment causing widespread coastal change and socio-economic disruption. Thus, the coastal impacts of human activities in catchments need to be set in the context of natural driving forces. Similarly, the effects of sea-level rise and/or (perhaps short-term) variability of the coastal climate as possible contributors to changes in coastal geomorphology and estuarine salinisation need to be considered if the contributions to change resulting from anthropogenic catchment activities are to be properly assessed. Changes occurring over the longer (historical and pre-Anthropocene) term are subjects of research under the IGBP-PAGES core project (Past Global Changes).

The coastal sea of Africa also receives significant nutrient and pollutant discharge from urban-industrial centres along the coast. Research is needed in a range of geomorphological and oceanographic settings to assess and quantify the impacts of such coast-generated pollution and eutrophication for comparison with the impacts ascribed to catchment drivers. The maintenance of groundwater resources to support coastal communities in the face of diminishing recharge from catchments and (coastal) abstraction-induced (marine) saline intrusion is another priority issue of regional importance to be addressed by an integrated research programme.

Table 2.8 “Hot spots” of land-based coastal impact and gaps in understanding as well as the first overview of issues to be addressed in future research.

River catchment	Hot spot Catchment scale		Hot spot Regional scale	
	Key issues, trend and gaps	Scientific approach	Key issues, trend and gaps	Scientific approach
Sebou and Moulouya, Morocco	Increasing erosion/sedimentation, pollution/health issues, salinisation and biodiversity loss	Monitoring water and sediment fluxes, and water quality parameters.	Erosion	Measurement of slopes, speed of runoff and sediment loads
		Development of adequate environmental indicators and precise critical thresholds.	Sedimentation	Measurements of sediment loads
	Additional data are required to improve the calculations of natural and anthropogenic fluxes, to better understand the functioning of the estuarine zones and to predict the future potential changes.	Establishment of socio-economic profiles in relation to population changes, industrialisation, agriculture and forestry, and development of economic cost-benefit analysis.	Pollution Pesticides	Monitoring water quality parameters/use of questionnaires
		Development of numerical models and GIS in relation to future land-use and climate changes, easily readable by managers.	Aquatic weeds including invasive plant species	Assessment of species population
			Loss of habitat/ Biodiversity	Assessment of river biodiversity
			Human Health issues	Socio-economic studies/ questionnaire administration

Table 2.8 continued

River catchment	Hot spot Catchment scale		Hot spot West Africa sub-regional scale	
	Key issues, trend and gaps	Scientific approach	Key issues, trend and gaps	Scientific approach
Senegal, Senegal	Coastal changes	Use of aerial photographs and satellite images Monitoring of the Langue de Barbarie sand spit	Erosion	Measurement of slopes, speed of runoff and sediment loads
	Sediment and chemical fluxes	Field work with sampling sites		
	Control of pollutants (pesticides and fertilizers)	Sampling and analysis of water samples		
	Inundation control	Monitoring of the technical structures (sand bags mainly) and their efficiency		
Volta, Ghana	Erosion	Measurement of slopes, runoff speed and sediment loads	Sedimentation Pollution Pesticides Aquatic weeds including invasive plant species Loss of Habitat/ Biodiversity Human Health issues	Measurements of sediment loads Monitoring water quality parameters/use of questionnaires Assessment of species population Assessment of river biodiversity Socio-economic studies/questionnaire administration
	Sedimentation	Measurements of sediment loads		
	Pollution Pesticides	Monitoring water quality parameters in the Volta Lake/use of questionnaires		
	Aquatic weeds including invasive plant species	Assessment of species population		
	Loss of habitat/ biodiversity	Assessment of river biodiversity		
	Human Health issues	Socio-economic studies/questionnaire administration		

Table 2.8 continued

River catchment	Key issues, trend and gaps	Scientific approach	Hot spot Catchment scale
Niger, Nigeria	Water pollution	Studies of water quality	
	Invasion by exotic weeds (nypa palm and water hyacinth)	Assessment of the impact of nypa palm and water hyacinth on aquatic population and rural livelihood	
	Oil spillage	Assessment of impact of oil spillage on the environment	
	Siltation	The study of extent an impact of silting on the coastal environment	
	Health problems	Study of the impact of environmental pollution on human health	
Cross, Nigeria	Beach erosion	Study of the extent of impact of beach erosion on coastal environment	
	Nypa palm invasion	Assessment of impact on biodiversity	
	Oil pollution	Assessment of extent and effects of oil pollution on environment and people's livelihood	
	Biodiversity loss	Study of biodiversity loss	
	Earth tremors	Geological studies of coastal and oil-producing community	

Table 2.8 continued

River catchment	Key issues, trend and gaps	Hot spot Catchment scale
Gariep, South Africa	Impacts of altered freshwater inflow (and possibly also reduced sediment input), as a result of damming and agricultural use, on the coast (as well as associated industries such as diamond mining and fishing) has not been established	<p>Scientific approach</p> <p>Monitoring required to determine the extent and severity of current impacts on the coast and to establish linkages with catchment-derived drivers</p> <p>Predictive capabilities currently applied in other southern African catchments be implemented and adapted for the Gariep to provide scientific support underpinning effective management</p>
Berg, South Africa	<p>Changes occurred in the hydrological regime (reduction in inflow) and geomorphology due to upstream damming</p> <p>Further damming is under consideration</p> <p>Additional data are required to predict the extent, severity and implication of damming with greater confidence</p>	<p>The Department of Water Affairs and Forestry is in the process of initiating an extensive monitoring programme</p> <p>The CSIR is developing numerical tools (through the catchment-to-coast initiative) to provide sound scientific predictive capabilities essential for effective management of coastal issues</p>
Saldanha Bay, South Africa	<p>Increasing urbanisation and industrialization results in impacts such eutrophication and pollution.</p> <p>Extensive research studies have already provided valuable scientific understanding, but these need to be transformed into effective, practical management plans to address issues.</p>	<p>The Saldanha Bay Water Quality Forum has been established to coordinate management efforts towards addressing key issues</p> <p>The CSIR has set up sophisticated hydrodynamic and water quality numerical models to provide sound scientific predictive capabilities essential for effective management of the area</p>

Table 2.8 continued

River catchment	Key issues, trend and gaps	Hot spot Catchment scale Scientific approach
Nile, Egypt	River water quality Loss of fisheries Pollution Erosion Land-filling	Biogeochemical studies especially in coastal lagoons Modelling of hazardous substances dispersion in coastal waters Assessment of pollution receiving water assimilation capacity River, lagoons and coastal living resource management Biodiversity Shoreline protection/planning management Pollution control management Stakeholders awareness
Tana, Kenya	Hydrology, hydrodynamics and water circulation Deterioration of water quality River and marine biodiversity loss Population dynamics of the key fisheries Socio-economic situations	Measurements and modelling studies - river discharge dynamics, sediment loads and water exchange in the estuary Monitoring water quality parameters in the Tana delta Assessment of river and marine biodiversity Assessment of dynamics of key commercial species Study existing socio-economic set-up in the river basin and along the coastal zone
Rufiji, Tanzania	Nearshore oceanography and coastal processes Hydrogeology Sedimentation and water quality related problems River and marine biodiversity loss and conservation Trade dynamics of natural resources Agriculture and livestock development and impact on the environment Mangrove and estuarine dynamics Relation between fisheries and the flooding regime Dynamics of the natural forests and woodlands Identification of urgent conservation measures	Fundamental research to support the understanding of intricate ecological processes, which is the key to defining sustainability Applied research with case studies of processes (of specific issues or problems of the dynamics) Predictive models (natural and human-induced ecosystem changes) Monitoring and feasibility studies Flows – which include materials, and elements through the system (pollutants, DDT, nutrients, water) Stocks – in terms of quantity of environmentally provided assets such as forests, wildlife, fisheries, water, wetlands, soil, atmosphere. These provide a flow of useful goods or services. Status – in terms of measures of specific phenomena (e.g., levels of land based inputs to the sea, carrying capacity, water requirements for the survival of ecosystems, health etc.)

Table 2.8 continued

River catchment	Hot spot Catchment scale		Hot spot Central/southern Mozambique sub-regional scale	
	Key issues, trend and gaps	Scientific approach	Key issues, trend and gaps	Scientific approach
Zambezi, Mozambique	Investigate effects of upstream impoundments and flood regulation on the Mozambique coast Impact of the cessation of silt transport to the Mozambique coast Impact of nutrient retention on bio-productivity	Monitoring and investigative research	Deterioration of water quality River and marine biodiversity loss	Monitoring water quality parameters in Maputo Bay Assessment of river and marine biodiversity
Limpopo, Mozambique	Floods regulation Water quantity Water quality	Identification of flood plain risk in coastal zone. Monitoring water quality and biodiversity loss. Studies of river health.		
Incomati, Mozambique	Water quantity Water quality River and marine biodiversity loss Salt intrusion Socio-economic situations	Assessment and modelling studies river health. Monitoring water quality parameters in Incomati Assessment of dynamics of salt intrusion and land loss Study existing socio-economic set-up in the river basin and along the coastal zone		

Table 2.8 continued

River catchment	Hot spot Catchment scale	
	Key issues, trend and gaps	Scientific approach
Thukela, Mkomazi and other major east coast rivers in South Africa	Effects of land derived runoff on coastal marine productivity in oligotrophic coastal environments	Primary production studies in the water column; effects of floods, sediment plumes on biological processes in affected areas
Rivers (Mkuzi, Mfolozi, Hluhluwe) associated with the Greater St Lucia Wetland Park (a Ramsar site), South Africa	Long-term effects of flow reduction and droughts on biological processes in the St Lucia Lake.	Analysis of nutrient sources and cycles; levels of primary production in the water column and fringing vegetation; effects of different salinity levels on carbon fixation and sources, carbon and nitrogen flow patterns based on light isotope analyses

3. OUTLOOK AND PROJECT IDENTIFICATION

by H.H. Kremer, R.S. Arthurton and Wim Salomons

3.1 The AfriCat framework

From the results of the DPSIR assessment, the workshop identified river catchments within the region for proposed detailed study, examining various aspects of the driver-impact linkage. This output would feed the planned “AfriCat” proposal, envisaged as providing a conceptual umbrella covering individual study proposals, that will be developed concurrently by the AfriBasins scientists’ network. The broad principles of AfriCat will be similar to those of the established “EuroCat” (<http://www.iaa-cnr.unical.it/EUROCAT/project.htm>).

There would be an integrated, systematic approach to the understanding of the water cascade, taking the catchments and the coast as single systems, with robust science and emphasis on relevant data-building and communication. The workshop recognised that the studies must add value to existing work, have a strong socio-economic input and show how the needs of a clearly identified user community were being addressed. Some projects are likely to focus on biological resilience in estuaries or the coastal sea, identifying the critical thresholds and indicators of acceptable change. In some cases there may be opportunities to build upon existing projects, extending their scope and thus providing a more comprehensive and integrated picture of the catchment-to-coastal sea linkage. As well as serving local and regional needs, the integrated studies of AfriCat will also feed the global aims of Earth System Science, through the provision of reliable bases for up-scaling in a region where, compared with Europe in particular, recent and reliable data are very sparse.

3.2 Regional needs and linkages

The AfriCat proposal will have an emphasis on addressing the regional African needs, in the context of priority areas for action as identified by the African Ministerial Conference on the Environment (AMCEN) in preparation for the World Summit on Sustainable Development in Johannesburg, September 2002. Potential links between the AfriBasins/AfriCat activities under LOICZ with the joint ACOPS (Advisory Committee for the Protection of the Sea) – UNESCO’S IOC GEF – MSP project ‘African Process’ for the “Development and protection of the coastal and marine environment in sub-Saharan Africa” were the subject of fruitful talks at the Rio+10 meeting of the IOC in December 2001 in Paris. This is being followed up by the LOICZ participation at the second meeting of the Working Group on the Programme of Interventions (WGPI-II). LOICZ has agreed in principle to channel the AfriBasins work and the AfriCat draft (design and methodologies) into the African Process, which already has the full political endorsement of at least 11 countries in the region and will feed into the Johannesburg conference.

The need for innovation and shared experience between sites to make the most effective use of limited funding was accepted by the workshop; this would include improved data transfer within the region, long-term surveillance of the environment and building human capacity and institutional structures in coastal science. The workshop envisaged AfriCat as encompassing themes that would be attractive to specific donors. Most importantly, the goal of AfriCat must be to improve the lives of coastal communities in the context of the catchment-to-coast system. There was considered to be great potential benefit in linking rivers and coasts at the scientific, policy and management levels. Improving management was a crucial goal and the challenge for the scientists was to produce a sound information base that was accessible and understandable to the management community at local as well as more regional levels, e.g., Southern African Development Community (SADC). To be successful, AfriCat must be owned by national governments. UNEP-ROA, through the AMCEN process, will assist to promote such ownership and endorsement by providing a platform to distribute and communicate the AfriBasins results and project developments to the regional governments. LOICZ itself can be only the initiator of project development, drawing together the regional scientific network and facilitating the provision of international links.

3.3 Project focus and organisation

In accepting the need to adopt an African perspective of catchment-coastal impact problems the workshop recognised the broad diversity of coastal situations within the region. West African issues, for example, were significantly different to South African ones. The work plans must be prioritised according to these different situations, taking care to avoid duplication, but the overall project framework should be the same for all the case studies under the AfriCat umbrella.

The 'burning issues' identified by the workshop included:

- the need to clarify the organisational structure of the project, in particular the identification both of the key institutions that would act as a backbone and of the composition of the Policy Advisory Board (see below);
- the scarcity of data;
- a lack of background socio-economic data across the region;
- a concern over the adequacy of existing monitoring data, prompting a suggestion that remote sensing techniques might be applied to advantage, especially in assessments of, for example, the roles of land use change and deforestation;
- the general scarcity of flux measurements (water flows and sediment budgets) within the water continuum;
- the need for data-building and communication to be essential elements of the case study proposals so that ensuing policy can be based on high quality science with a robust database; and
- the need to develop a mechanism for relevant databanking and exchange, similar to that established for example in the IOC-RECOSCIX initiative for marine data.

The workshop affirmed the need for effective sub-regional co-ordination and a scientific co-ordinator for each study site, working under the general guidance of a Policy Advisory Board (PAB). The overall co-ordination of the further drafting process was dedicated to the Centre of African Wetlands, Ghana and the Pan-African START Secretariat (PASS). UNEP-ROA confirmed its support in generating the national, governmental approval for the initiative through the AMCEN process. The AfriCat secretariat should foster effective policy linkage by involving ministers with responsibilities for water resources, environment, tourism and development, as well as regional bodies such as SADC, river and coastal development authorities where these are established, and relevant NGOs.

Within the AfriBasins network the key contact persons identified for each of the case study sites (Table 3.1) agreed to assist in further developing specific research proposals and to investigate the options for potential funding on national and international levels. The workshop reiterated that, regardless of whether national or international financial support was targeted, the initiative and detailed networking requirements at site level would need to come from the regional scientific community. LOICZ could provide a framework and assist in sustaining the necessary links. AMCEN was identified as an appropriate platform to facilitate the governmental approval for the various site study plans in the broader context of the Abidjan Declaration.

3.4 Demonstration sites

In the selection of demonstration sites (Table 3.1) the workshop sought to provide coverage of key issues and representation of the sub-regional river-coast classes. Another aspect considered was the availability of data; an AfriCat work proposal should have a foundation in as much existing data as possible, although it was recognised that data availability and reliability will vary widely over the sites identified. The chosen catchments are mostly large, greater than 200,000 km², and extend over several countries thus involving a range of transboundary issues.

For the eastern side of the region, the inclusion of the Nile was confirmed, plus the Tana and Sabaki rivers as a linked site, the Rufiji, the Zambezi and the Incomati. For the Incomati site, the study could be built on earlier assessment and planning efforts conducted at the University Eduardo Mondlane and a draft trilateral

project plan between Mozambique, South Africa and Swaziland, all of which were developed with support of the Coastal Management Centre of RIKZ in the Netherlands. A project on the integrated evaluation of riverine fluxes to the Maputo Bay region, “Catchment2Coast” recently funded by the European Commission, can be associated with the AfriCat project. This could be a key exercise in a continued second phase of the global LOICZ programme. For the western coast six sites were confirmed as providing suitable case study opportunities for AfriCat – the large catchments of the Congo, Cross, Niger, Volta and Senegal, and a group of small and medium catchments in Morocco.

Table 3.1 Demonstration sites for key case studies of catchment–coastal sea systems in Africa

Area/sub-regions: West coast	Major rivers	Regional characteristics and major coastal issues	Major drivers	Comments	Contact person(s)
1. North-west Africa	Moroccan catchments	<ul style="list-style-type: none"> Semi-arid climate regime, small to medium catchments with high seasonal runoff variability Nutrients and the ecosystem, coastal erosion/sedimentation, salinisation 	Damming Agriculture	<p>Good coverage of flux data within catchments, but few comprehensive studies on coastal linkage. Database to be generated</p> <p>Socio-economic profiles and analysis should be integrated and the results could be transposed to other north-west African catchments</p>	M. Snoussi
2. West Africa	Senegal, Volta, Niger, Cross	<ul style="list-style-type: none"> Transboundary catchments under strong and recent human influence Coastal erosion Changes in nutrient supply and habitats due to changes of material transports 	Damming Deforestation	<p>Fair cover of recent biogeochemical data</p> <p>Socio-economic information, sectoral statistics, I/O etc. expected to be rather limited; however, baseline project development undertaken in the Volta case (PDF-B status). Association with AfriCat and coverage of complementary issues is suggested.</p>	I. Diop, A. Kane, G. Umoh, O. Martins, C. Gordon
3. Congo	Congo	<ul style="list-style-type: none"> Nutrients 	Uncontrolled urban growth	Apparently very limited	tba

Table 3.1 cont.

<i>Nile</i>					
5. Nile	Nile catchment and delta Alexandria city coast	<ul style="list-style-type: none"> • Transboundary river under extreme anthropogenic influence • Changes of material transports (sediments nutrients and water) to the floodplains and delta • Waste load 	<p>Agriculture in a narrow band along the catchment</p> <p>High population density</p> <p>Damming</p>	<p>Good coverage of biogeochemical and other scientific data.</p> <p>Socio-economic information, input-output tables = ?</p> <p>Opportunity to add integrative value to existing projects.</p>	H. Awad
<i>East Coast</i>					
6. East Africa	Tana/Sabaki	<ul style="list-style-type: none"> • Visible coastal impacts from changed sediment loads and pollution 	Damming, Agriculture	Comprehensive holistic study would partly have to generate database.	J. Kitheka, J. Ochiewo
	Rufiji	<ul style="list-style-type: none"> • Medium catchment in a monsoon-dominated climate • Delta discharges through mangrove forest to the largely pristine, richly biodiverse Mafia marine park 	<p>Potential damming</p> <p>Agriculture</p> <p>High population density</p>	Data, particularly time series, generally very limited. Data generation would be necessary.	A. Ngusaru
1. Central/southern Mozambique	Zambezi	<ul style="list-style-type: none"> • Large transboundary catchment with the largest reservoir in Africa • Erosion and changed material inputs 	Damming	No comprehensive study available; investigations would partly have to generate data.	T. Forbes, L. Mhlanga
	Incomati	<ul style="list-style-type: none"> • Transboundary catchment with strong coastal signals of erosion and salinisation • Medium ranked eutrophication and biodiversity loss effects 	<p>Damming</p> <p>Agriculture</p> <p>Urbanisation</p>	<p>Reasonable coverage of biogeochemical and other scientific data.</p> <p>Earlier assessment and project development carried out with support from CMC-RIKZ – The Hague.</p>	A. Hogueane, F. Tauacale
	Maputo Bay (including Incomati, Maputo and Umbeluzi rivers)	<ul style="list-style-type: none"> • Receives inflow from transboundary catchments with strong coastal signals of erosion and salinisation • Medium ranked eutrophication and biodiversity loss effects 	<p>Damming</p> <p>Agriculture</p> <p>Urbanisation</p>	<p>Project with potential for association to “AfriCat”.</p> <p>Catchment2Coast – Integrated modelling of catchment -coastal resource interaction and management advice – EU funded.</p>	P. Monteiro

3.5 Suggested “AfriCat” design

African Catchments – AfriCat

(Biogeochemical and Socio-Economic Dimensions of Catchment/Island-based loads to the Coastal Zones of Africa). This section gives a brief overview of the projected design of a comprehensive AfriCat umbrella project reflecting discussions during the AfriBasins assessment and synthesis process. The workshop adopted the design as a useful basis for an issue-driven project brief to be refined and developed by the regional scientists.

Introduction

Assessment and modelling of material transports to the coast considering river catchments and their associated coastal zone as one system should identify the loads to the coastal zone and determine which of the observed changes in the coastal zone can be attributed to human activities *versus* natural forcing. The actual impact observed/modelled depends on its biophysical properties. The regional system itself is subject not only to outside (long-term) pressures and drivers such as climate change but also to global socio-economic trends and changes. The integration of natural and social sciences required to address issues like critical concentrations and loads as well as resilience and carrying capacity uses the DPSIR framework, developed by the OECD and adapted.

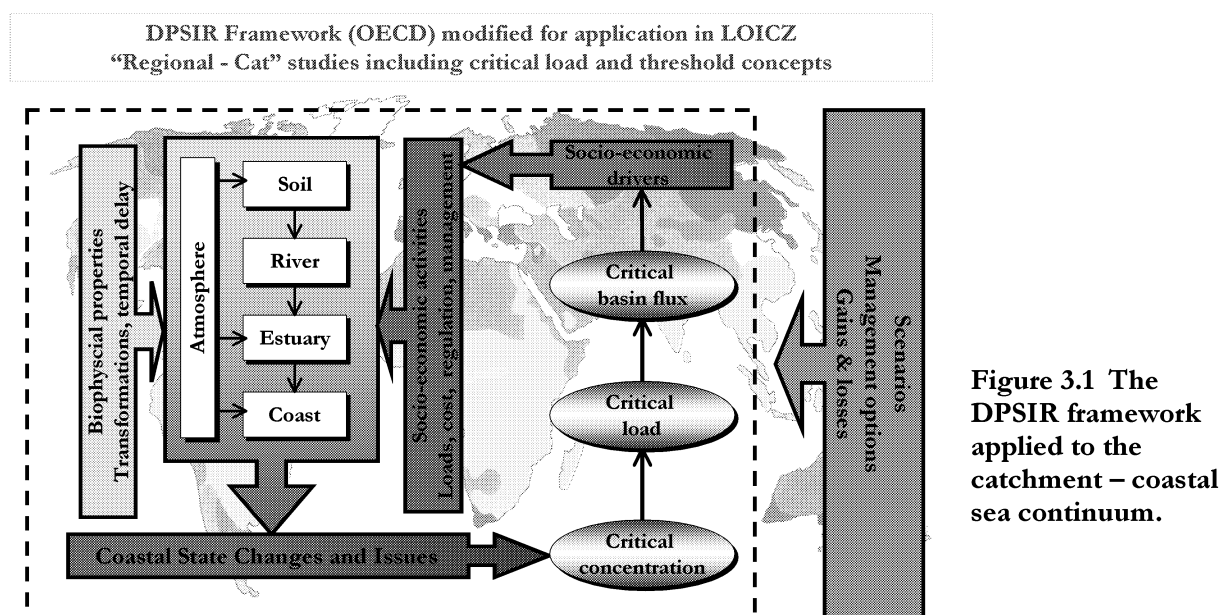


Figure 3.1 The DPSIR framework applied to the catchment – coastal sea continuum.

Structure

The AfriCat project is planned to cover between 6 and 10 regional catchments as study sites in Africa (see Table 3.1) exhibiting a range of characteristics with regard to coastal zone systems, habitats and their changes. They will be representative of a sub-region and the methodology applied aims to make intercomparison and up-scaling to broader African sub-regions possible. A set of sites may also be considered from the perspective of a common driver affecting catchment/coast systems e.g. damming thus enhancing the potential for comparison. Comparisons beyond the region will be possible through the global effort under the aegis of LOICZ.

To make the project manageable it is suggested to divide the effort into workpackages. Not all case studies will have all the necessary expertise available. Hence each workpackage will have a scientific co-ordinator with responsibility for contents and deliverables and will initiate (as necessary) capacity building across the sites and beyond. At case study level the site manager will take responsibility for the regional work packages. The workpackage co-ordinators and the site managers constitute the management team. Initial studies do not have to cover all the workpackages but will follow a common framework addressing the

priority issues/drawbacks (e.g., dearth of data) of their site and implement the most critical workpackage in a first instance. Additional support will need to be generated later for a broader coverage of workpackages.

Workpackages - General Remarks

Significant parts of the assessment and synthesis will focus on improving understanding of how present activities in the catchment determine land-based fluxes and their impacts in the coastal zone. Emphasis will be on quantifying the type and scale of this relationship and elaborating on the implications for coastal resource use.

However, for the purposes of modelling and forecasting (Figure 3.2, right side), addressing the temporal scale of ‘change’ is also of scientific relevance. This is particularly important if the detrimental economic activities in the river catchments/islands causing coastal change are likely to continue.

Analysis will include information on previous fluxes where available. It is anticipated that the scarcity of even recent information will make primary data investigation necessary in several cases.

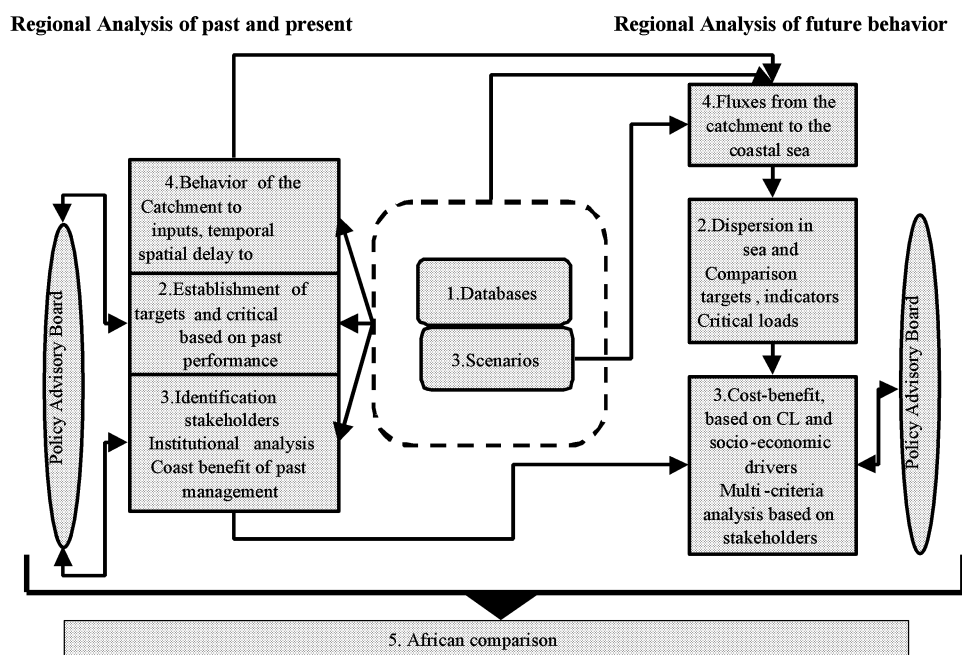


Figure 3.2 A potential “AfriCat” workplan.

The project database will include an inventory of land use in selected river catchments in Africa and an elucidation of their cause-effect relationships to coastal impact and state of coastal resources.

The ‘human dimension’ of fluxes to the coastal zone will be addressed as part of a study of comparative resource economics. The main objective will be to make a site-based macro-economic analysis of the impacts of the catchment economy on the coastal zone economy.

Finally, the proposed project will be concerned with management implications of the research findings, which will be communicated to the coastal user community through advisory boards. Scenarios representing various forcing conditions will provide information on biogeochemical changes and key questions in the realm of coastal management addressing issues such as:

- scaling of coastal change issues resulting from land-based fluxes and efforts for mitigation, i.e. specified land-use practices;
- technical and economic feasibility of modified land-use practices;
- economic instruments applicable for enforcement of improved changes in land use;

- types of public education and community participation needed to bring about appropriate changes (management response);
- institutional dimensions (national or river basin authorities) needed to formulate and achieve the desired changes.

Table 3.2. The workpackages in detail.

No	Description
1	Databases and tools
2	Impacts, indicators and critical loads
3	Scenarios and response/management options
4	Past, Present and Future changes in catchment fluxes
5	Integration at the African level

In WP 1 most of the effort will go into establishing databases for the catchments and coastal seas (monitoring data, geographical and socio-economic database). A geographical information system is the basis for the presentation of all of the spatial data and the results. This will draw on data and information provided through existing networks and other regional projects.

WP 2 will look at impacts in the coastal zone and derive indicators and critical thresholds for Africa (based on existing data and available models). Existing natural and social science models and tools will be combined to make an instrument suitable for carrying out the regional scenarios. With few exceptions there is only limited information on this topic now available.

WP 3 deals with the development of plausible scenarios of future change, based on available global scenarios but downscaled to Africa and then to the study sites and the sub-regions they represent. Socio-economic analysis of the scenarios and present functioning of the coastal zone can draw on experiences (as appropriate) and links to related LOICZ global activities. It is intended to adapt and use methodologies of the EuroCat (European Catchments) project such as the software package DEFINITE, to undertake both cost-benefit and multi-criteria analysis, the latter allowing the inclusion of costs and benefits which cannot be expressed in monetary terms.

To model catchment fluxes (WP 4) we will rely on models including point and diffuse sources as well as land cover. The model MONERIS (Modelling Nutrient Emissions in River Systems) can be evaluated and adapted for African application.

In the second phase databases and modelling tools will be used to analyze past and present behaviour of the system. Trend data will be used to assess the past influence within the drainage basin of, for example land-use change, water regulation management, industrial development and population on fluxes. The temporal and spatial delay of the response of the coastal sea to these changes at the catchment level (regulations and socio-economic) will be evaluated and incorporated in the modelling tools. WP 5 will integrate the results of the individual studies.

A Policy Advisory Board (PAB) will be involved in stakeholder identification, institutional analysis and cost-benefit analysis of past measures. Dissemination of scientific findings to various target groups will be a key objective of the PAB.

Products

The project will provide a better understanding of the functioning and changes of African coastal systems under natural and human forcing. This will be based on an integrative coupling of biogeochemistry and socio-economic sciences combined with tools using a typological approach to upscale the findings to areas for which only secondary information is available (Maxwell and Buddemeier 2002). Loads to the coastal zone and their critical thresholds for system functioning and thus the status and development of coastal resources will be addressed in the context of material transports along the whole water cascade as a single system. AfriCat aims to set up a framework for analysis for coastal zone managers and will continue to

contribute on regional scales to the overall global LOICZ assessment and synthesis effort. Products will include:

- Catchment/Coast evaluation studies and peer-reviewed articles; (Study design will be based on the “EuroCat”, adjusted to the regional needs, and will either have: a thematic approach, across the region e.g., driver-oriented across the region, or will select prominent differences between natural and anthropogenic change signals and combining them in one project or project cluster).
- Regional synthesis for evaluation in the global LOICZ network and the IGBP II integrated earth system science framework.
- Protocols for integrated assessment, modelling and forecasting for dissemination in training workshops;
- Issue-driven scientific decision support information put in a regional framework for broader application

The listing of information needs, data gaps and sites with negative trend expectations - “hot spots” - identified in the synthesis will form the basis for future proposal development. The synthesis will serve as the major regional focus 1/4 entry to the first global LOICZ synthesis and assessment book (to be published in early 2003). Proposals from this assessment process will seek links to regional initiatives. This will be promoted through LOICZ and support and close working relationships are likely with START, UNESCO’s IOC and UNEP/ROA. The AfriCat process, in combination with LOICZ biogeochemical assessments of African estuaries and regional typology efforts (see LOICZ Newsletter 22, March 2002) will contribute to the implementation of the Abidjan and Nairobi Conventions (i.e. Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, and Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region).

Earlier LOICZ-supported studies will provide a sound template for the regional approach for Africa. The AfriBasins network has started drafting proposals and various agencies have indicated their interest in funding the activities. Formal and/or operational links to ongoing international efforts such as the ICAM (Integrated Coastal Area Management) and GOOS (Global Ocean Observation System now COOP, Coastal Ocean Observation Panel) by UNESCO’s IOC and regional UNEP and GPA activities will be pursued for global application and use of the outcomes.

4. CONTRIBUTED PAPERS

4.1 The impacts of human activities on Africa's coastal and marine areas and the implications for sustainable development

Eric O. Odada

Abstract

African nations are facing a growing number of coastal and marine changes as a result of development and increased population pressure. Unregulated human activities on land and the coastal changes can be viewed as taking place in a series of concentric circles - desertification in the center; deforestation towards the coasts; erosion and pollution on the coasts; over-exploitation of marine resources, dumping of toxic and hazardous wastes and oil spillage on the high seas.

There are a number of reasons for this serious situation, including is lack of awareness and understanding of coastal and marine resources and their interaction with terrestrial and oceanic processes, aggravated by ineffective coastal and marine planning and management.

The present status and trends of coastal and ocean development in the African region are examined, along with regional capabilities to implement sustainable development strategies.

Introduction

About 40% of the world's population lives within 60 km of the coast. In Africa, trends in population growth indicate that this figure could rise to 75% within the next century. The lives and reasonable aspirations for economic advancement of these coastal residents are inextricably linked to the productivity of coastal and marine resources. The shallow tropical coastal areas bordering the African continent have traditionally supported highly productive ecosystems from which fish and other aquatic resources have been harvested. These natural systems provide valuable services in terms of recreation, coastal tourism and marine transportation in addition to their natural protective and defense functions against coastal erosion and flooding. Unfortunately, most of the natural resources are over-exploited and the coastal and marine systems severely degraded by unregulated human activities. Productivity and usefulness of these coastal and marine areas have dramatically diminished and the prospects for sustainable development are greatly jeopardized.

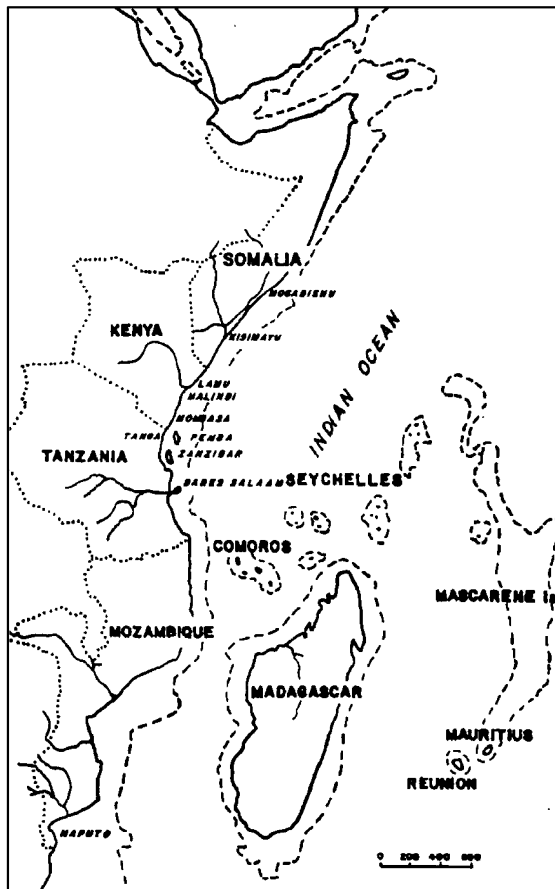
There is a general lack of awareness and understanding of the coastal and marine resources and their interaction with terrestrial and oceanic processes. Ineffective coastal planning and management further aggravates the situation. Despite the tenets of the 1992 United Nations Conference on the Environment and Development (UNCED), Chapter 17 of Agenda 21, that coastal states should "commit themselves to integrated management and sustainable development of coastal areas and the marine environment under their national jurisdiction", little has been achieved in the region.

North Africa

The coastal and marine areas in North Africa (Egypt, Libya, Algeria and Morocco) are generally regarded as developed, although less so than the northern coasts of the Mediterranean Sea. Agricultural run-off and rivers flowing into the Mediterranean Sea are responsible for substantial waste loads of organic and inorganic origin.

The biological productivity of the Mediterranean Sea is amongst the lowest in the world. Primary production in the centre of the Mediterranean Sea, and in many coastal areas away from the major rivers or urban agglomerations, is rather low, and nutrient concentration in the deep waters of the eastern basin are also very low. However, fishing activities in the Mediterranean Sea have been going on for centuries, adapting themselves to the local conditions to sustain a very high ratio of catch/production. Several factors may contribute to this high efficiency, among them, the distribution in time and space of the fertilizing mechanisms.

Eastern and Southern Africa



The coastal and marine areas of eastern Africa (Somalia, Kenya, Tanzania Mozambique) and southern Africa (South Africa and Namibia) (Figure 1) - contain some of the world's most extensive mangrove forests, vast stretches of seagrass beds, several hundreds of kilometres of sandy beaches, limestone cliffs, lagoons and rich coral reefs. These ecosystems support a wide diversity of plants and animals, and the derived economic benefits are essential for a large part of the population. These coastal and marine environments provide coastal population and inland communities with food, minerals, firewood and other vital resources.

Figure 1. The coast of East Africa. The dashed lines represents approximate limits of the continental shelves in the Western Indian Ocean.

West and Central Africa

The coastline of western and central Africa is about 8,000 km long and is characterized by marked diversity. The climate ranges from the Sahara Desert in the north through a humid tropical belt that contains two of Africa's largest rivers, the Niger and Congo, to desert again in the south - the Kalahari. The coastal zone shows equal diversity, ranging from dunes through marshy delta lands and mangroves to rias with steep cliffs. The continental shelf varies markedly in width from some 70 km or so in the Gulf of Guinea to about 4 km off Angola and Zaire (Figure 2). Even the countries that make up the sub-region differ markedly, from small island states such as Sao Tome and Principe to large mainland countries e.g., Nigeria and Mauritania. Their state of development also differs: some economies are based essentially on handicraft and subsistence farming, whereas others have developed industries.

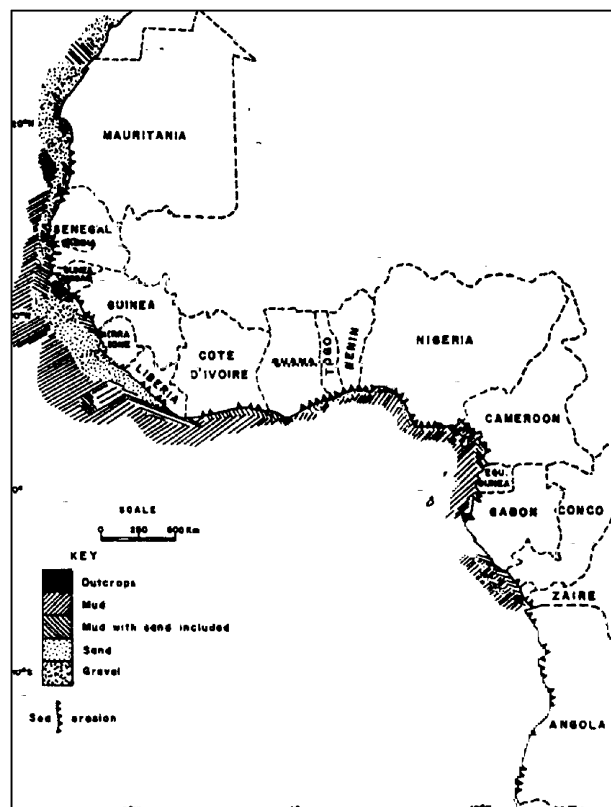


Figure 2. Coastal erosion problem sites along the West African coast (Ibe and Queennec 1989).

Coastal and marine issues in Africa

Growing populations in coastal areas of the African region, expanding coastal tourism, intensified fisheries and a large number of other economic activities pose an increasing threat that jeopardizes the quality of these coastal environments. Large-scale destruction of coastal forests and mangroves, lagoons and coral reefs has caused serious degradation of the environment, affecting the lives of coastal inhabitants and economic development of the countries in the region. The Seychelles in the western Indian Ocean, for example, was famous for its luxuriant forests and abundant wildlife. Now, many reefs have been mined for coral, and mangrove forests on the granite islands have been razed or drained and reclaimed, causing severe erosion and smothering of coral reefs.

Rapid Population Growth

As the population of Africa increases, coastal and marine environments are assuming greater importance and need to be protected from pollution, coastal erosion and over-exploitation of marine resources through an integrated interdisciplinary and multi-sectoral approach in developing management plans for the coastal and marine areas of the region.

The total population of the countries in western and central Africa is estimated to be about 175 million, of whom about 10% live in the towns and villages of the coastal zone (UNEP 1984). Lagos, with >8 million people and 85% of Nigeria's industry, and Accra-Tema with 60% of Ghana's industry are good examples. In East Africa, about 84 million people live in the coastal zone. In Madagascar about 40% of the population lives along the coast. Substantial increases in the volume of sewage and effluent being discharged into the nearshore waters (mostly untreated) is a risk to human health through contact and consumption of contaminated seafood. This problem has received little attention in the region, despite sporadic outbreaks of human diseases attributed to contact with faecal remains on beaches (UNEP 1984).

Sea level rise

The Atlantic and Indian Ocean coasts of Africa are increasingly vulnerable to sea level rise and other impacts of climate change. The coastlines of eastern Africa, for example, have retreated inwards and seawards as a result of the rise and fall in sea level due to past climate change (Odada 1991). The Intergovernmental Panel on Climate Change (IPCC) has estimated an average rate of mean global sea level rise of about 6 cm per decade over the next century or as much as 1 m in 100 years. This would mean that vast areas of coastal wetlands and lowlands in the African region would be inundated, shorelines would retreat by hundreds of metres and protective structures would be breached. Flooding would threaten lives, agriculture, livestock, buildings and infrastructure. Salt water would advance landward into aquifers and up estuaries, threatening water supplies, ecosystems and agriculture.

Development of coastal areas

Development is leading to major changes in coastal areas of Africa, such as the construction of towns with associated industries and the creation or extension of ports and harbour areas, frequently close to areas suitable for tourism. At Lagos in Nigeria, Victoria Beach has been eroded 2 km inland since the construction of breakwaters (Ibe 1985). At the Port of Abidjan where the Canal de Vridi was opened in 1950 and a road has been cut through in the area, the beach has since eroded east of the canal.

Activities in the coastal zone often lead to the creation or rapid expansion of municipal centres on the coast without infrastructure and social services. In Malindi, Kenya, for example, tourism has increased rapidly in a traditional small municipal centre with extremely limited services and infrastructure. Population growth rates have reached 20% a year, and authorities are hard-pressed to meet basic needs for sanitation, education and commercial organisation. Similar situations arise wherever new coastal zone activities stimulate extremely rapid growth in new or small existing municipal centres. Economic planning is necessary for the sustainable development of coastal areas.

Coastal erosion and flooding

This is prevalent especially in West and Central Africa (Figure 2). The seriousness of the problem and the attempts to mitigate the nuisance and negative economic consequences vary. Retreat of the coastline, with concomitant flooding, causes hazards by removing settlements, destroying agricultural and recreational

lands, disrupting harbour and navigational structures and dislodging economic facilities located along coastal towns (Ibe and Quellenec 1989). Natural factors which facilitate erosion include storm wave regimes, orientation and nature of the coastline, low relief of the coastal plain, vulnerable sediment budget, narrowness of the continental shelf, presence of off-shore canyons and gullies, global eustatic rise in sea level. Man's intervention in the natural environment, by the construction of artificial structures on the coastline, mining of beach sand, the location of dams on rivers that normally would supply sediment replenishment to the coastline, the haphazard withdrawal of water from coastal aquifers and reservoirs and the destruction of mangroves, can exacerbate the impact of natural forces.

Environmental degradation

Coastal degradation is a major problem in the African region. The main sources of pollution from land are: domestic and commercial sewage and other discharges near coastal towns and cities; agricultural waste disposal; sand-mining in the coastal zone; erosion and siltation; overcutting of forests such as mangroves on the coastal strip and timber forests inland. Poor agricultural practice, lack of agricultural land especially on the islands, over-utilisation, burning, mismanagement and over-exploitation of forest resources have resulted in extensive deforestation and severe soil erosion. This has caused severe siltation with the resultant destruction of coral reefs, erosion of beaches and destruction of the coastal mangrove and other forests. Examples of this are clearly seen in Madagascar, the Comoros and many other parts of Africa.

Environmental values and natural resources factors have not always been integrated into development plans. Industrial expansion has often been carried out at the expense of the environment. Economic and social development, both urban and rural, has tended to deplete natural resources and damage the environment and amenities. Development of ports and harbours, reclamation for construction and dredging also cause coastal erosion and siltation. Such work has been common in the African region during the past two decades without due consideration given to the environmental impacts. Extensive dredging has been carried out in the Seychelles within the last decade leading to severe siltation of the coral reefs within the marine park and along the east coast of Mahé (UNEP 1984). In coastal areas of Tanzania, Mozambique, and Mauritius, dynamiting of coral reefs as a means of catching fish has resulted in serious environmental degradation of the coasts and seas. In Madagascar, the wide beaches that previously attracted many tourists to the island have disappeared. In spite of this, many structures are still being constructed on eroding beaches.

Oil pollution

Oil spillage due to accidents, grounding, harbour operations and discharges from refineries in the Eastern African sub-region can only increase as more and bigger tankers travel through the Indian Ocean. Some routes used by these tankers are shown in Figure 3. In 1981, 3551×10^6 tonnes of oil were transported through the main route from Arabian Sea to Asia. Accidents during tanker discharge operations in Mombasa, Maputo and Dar-es-Salaam have destroyed large areas of mangrove forests. Oil refineries in Eastern Africa significantly contribute to oil pollution of the coasts and seas.

West and Central Africa export oil to Europe and America. The coastline lies to the east and is downwind of the main route of oil transport from the Middle East to Europe (Figure 3). The total volume transported annually along the Gulf of Guinea, for example, has been estimated to be 706×10^6 tonnes (Portmann 1978) and the discharge of tank washings from offshore traffic is a significant source of oil on beaches. However, much of the oil found on beaches is from spills or tank washing discharges from tankers visiting ports in the region (Portmann *et al.* 1989). In the Ebrie Lagoon, Ivory Coast (Marchand and Martin 1985) a wide range of concentrations (1000-24000 mg/kg) of total hydrocarbons was found in lagoon sediments. The highest concentrations were associated with industrial and domestic sewage discharges. However, a spill of 400 tonnes of oil at a refinery in 1981 was still clearly detectable in 1983 (Portmann *et al.* 1989).

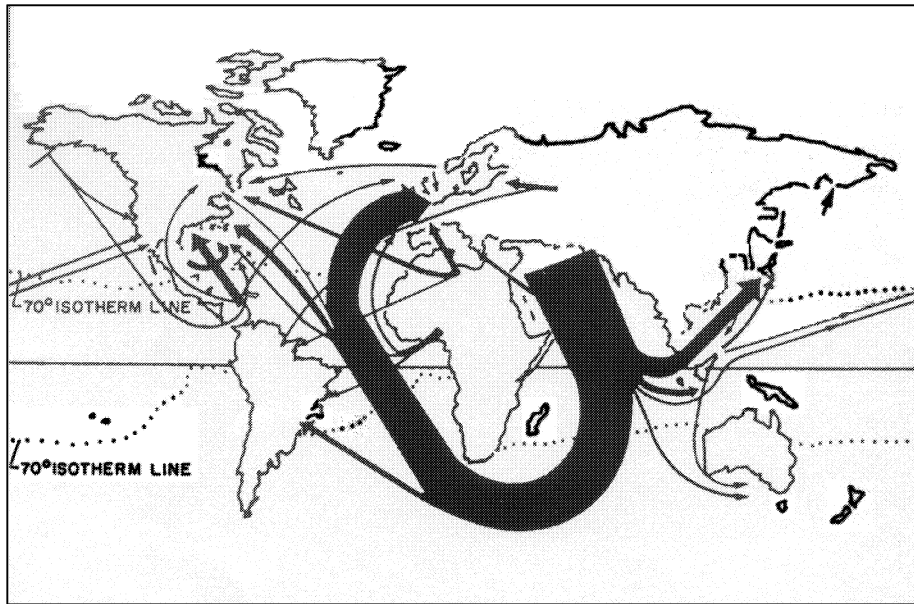


Figure 3. Main routes of oil transport from the Middle East to the Far East and the West around Africa (British Petroleum 1978).

Coastal tourism

The peoples of Africa have for a long time had visitors from Arab nations, Persia, Europe and other distant lands. The people are friendly and attractive with captivating life styles, customs and traditions, food preparation styles, costumes and distinctive artistic styles. In addition, the coastline of Africa is an area of great physical beauty, rich in living resources. In eastern Africa for example, palm-fringed beaches of white coral sand lead down to tranquil lagoons enclosed by spectacular coral reefs with their wealth of colourful fish, shell and corals. For many countries in the sub-region, coastal tourism is one of the most important sectors of their economies producing foreign exchange.

Although available evidence suggests that before the 1980s tourism in Africa occurred without significant deterioration in the coastal ecosystem, this is rapidly changing (Odada 1993).

Coastal agriculture

Agriculture is the mainstay of the economy of most African countries. Agriculture contributes between 30-60 % of their GNP and the majority of the population depends on it for their livelihood. While the population is increasing rapidly with the subsequent increase in food demand, in most African countries the land available for agriculture is shrinking because the land is used for non-agricultural purposes such as housing, industry, roads, playing fields or hotels, and also because good agricultural land is destroyed through soil erosion, salinization and modification.

Erosion related to deforestation and unwise agricultural practices is prevalent. In Kenya, silt from rivers is affecting catches of fish, smothering coral reefs and sully beaches, with serious consequences for fishing and tourism. The effects of pesticide pollution on marine life are now becoming apparent in many countries of Africa. The health of humans is threatened by toxins contained in the fish they eat (UNEP 1989). Soil conservation measures and pesticide controls need to be instituted, particularly where agriculture is being developed.

Over-exploitation of marine resources

In general, the productivity of African coastal waters is dependent on the extent of the continental shelf, coastal upwellings, mangroves, coral reefs and runoff from rivers. Fisheries reflect the availability of these factors. For West and Central Africa, the total annual catch of fish in the coastal zone is estimated to be about 2.6×10^6 tonnes per annum (FAO 1987) and about 10% of the coastal population engages in some form of fishing activity. At least 30% is canoe fishing, but larger fishing trawlers account for the bulk of the remaining catch (Portmann *et al.* 1989). Shrimp and tuna are the main commodities supporting export

ventures in eastern Africa. The extensive continental shelves of Madagascar and Mozambique support lucrative shrimp fisheries, while the absence of such areas in island countries make them dependent on offshore tuna resources.

The most serious problem in most African coastal and marine areas is over-exploitation of resources. Fish, shellfish, beche-de-mer, dugongs and turtles are all subject to over-exploitation on a massive scale, especially in East and West Africa, due to burgeoning human numbers coupled with a shortage of land-based jobs. Kenya's population of over 30 million, for example, is increasing at 4.3% annually, and is expected to double around 2020, with a consequent increase in demand for land, food, housing, water and social services. Similar situations in other parts of Africa are straining both terrestrial and marine ecosystems to breaking point.

Capacity for addressing coastal and marine issues

Institutions which will promote environmental and resource values and assure that they are taken into account in governmental decision-making are now being established in some countries of the region.

Environmental Policies

Most countries have no explicit policies relating to coastal and marine development. For the land-locked countries in the sub-region, coastal ports and harbours in other countries represent the only natural outlet for their imports and exports. The coastal states want to locate more industries on or near the coast to better utilise the main arteries of transport and communication.

Very little effort has been expended in incorporating socio-environmental concerns in development and problems discerned in the coastal areas have generally been shrugged off as being an inescapable part of the development process. Although serious environmental degradation of the marine environment has not yet occurred, disturbing and perhaps irreversible trends are beginning to appear, some in connection with activities outside the coastal zone.

Legislation and Environmental Law

Many countries have formulated regulatory measures for their resources management in coastal and marine areas, such as the issuance of permits for fishing, logging and mangrove harvesting. However, most of these measures have proven ineffective. Some countries are now enacting environmental laws which provide practical frameworks at the national level to implement environmental standards and to regulate activities. At the international level, conventions like the Law of the Sea, protocols and agreements such as the UNEP Regional Seas Programme provide a basis for co-operation among countries at bilateral, regional and global levels for the management of environmental risks, control of pollution and conservation of natural resources in coastal and marine areas. The groundwork has been carried out over the last two decades, under the aegis of UNEP, to establish a legal framework to manage regional seas.

Coastal Zone Management

A few countries are in the process of developing management plans for their coastal and marine areas. In 1992 the Seychelles initiated a plan for coastal zone management under the UNEP Eastern African Regional Seas Plans, to prepare an inventory of coastal and marine species, the state of coral reefs, mangroves and lagoons, to assess the extent, nature and causes of coastal and marine pollution and to identify policy and remedial actions. The project components include training, institutional capacity building, workshops and provision of laboratory equipment. It is managed from the Department of Environment, created in June 1989 under the direct leadership of the President of the Seychelles to solve the environmental problems that stem from a general increase in the population and the rapid development of the island.

Tanzania is in the preliminary stages of the development of an integrated coastal zone management programme. In 1991 the country began the process of creating a protected area, to be known as the Mafia Island Marine Park (MIMP). This marine park will protect the last pristine coral reef ecosystem found in Tanzania's coastal waters – an area that is important as an economic resources upon which a significant

coastal and island population group is quite dependent. The Tanzania government perceives that this project will serve as a pilot project for Tanzania's integrated coastal zone management.

Coastal and marine resources are valuable assets that can effectively contribute to sustainable development of the African region. However, uni-sectoral over-use of some resources has caused serious problems. Indiscriminate harvesting of mangroves brought short-term economic benefits to countries in East Africa, but was detrimental to fisheries, aquaculture and coastal tourism. Similarly, unregulated fishing efforts and the use of destructive fishing methods such as dynamiting have destroyed fish habitats and reduced fish stocks. There is an urgent need for integrated interdisciplinary and multi-sectoral approaches in developing management plans for the coastal and marine areas of the African region.

Institutional and administrative limitations

Most African coastal states are at present making only minimal use of their coastal and marine resources owing to limitations in scientific knowledge and technological know-how and to the lack of efficient organizational and administrative machinery. For example, shipping and navigation services, so vital for the management, control and exploitation of marine resources and for the development of international trade, are still very much in their infancy in most African coastal states. Marine technology is also very much underdeveloped in the region. Few countries have marine technology training centres with comprehensive programmes. The development of sound training and research programmes and effective linkages with the production system are basic but important steps towards enhancing the ability of African states to make full use of their coastal and marine resources.

Institutional and administrative capacities for coastal and marine resources development vary widely in the region, ranging from countries with a growing capacity and considerable resources to those with virtually no capabilities. Countries such as South Africa, Nigeria and Egypt already have good infrastructure for the development of coastal and marine areas, appropriate research and training institutions and other facilities, governments aware of the crucial role of coastal and marine resources in the development of their economies, and personnel qualified to undertake integrated management of coastal and marine areas.

Other countries, such as Benin, Gambia and Djibouti, are at a low stage of oceanographic development, with no substantial infrastructure for the development of coastal and marine resources, research and training institutions or other facilities, and shortages of trained manpower. Institutional and administrative capacity-building in ocean affairs should be a top priority in the African region.

Many African countries are confronted with serious manpower problems that are proving to be great impediments in the economic development of coastal and marine areas. In many cases, there is a lack of adequate training facilities for the type of manpower required. Although most African countries now have national universities and other institutions of higher learning, many of these institutions are young, and have problems with e.g., staffing, equipment and curriculum development. The universities are still grappling with the fundamental issues such as manpower for the civil service requiring high-level personnel, such as public administration, school education, public health and agriculture.

Other needs for manpower development, for example training of marine scientists and technologists are beyond the capability of most African states and need to be met through regional and sub-regional co-operation. Seminars, workshops and conferences such as those organised by the International Ocean Institute would be most useful and appropriate.

Measures for addressing issues of coastal and marine areas

As stated in Chapter 17 of Agenda 21 of the 1992 United Nations Conference on the Environment and Development (UNCED) in Brazil, coastal and marine management must play an important role if resources are to be exploited in a way that ensures sustainable development to a growing population. To implement sustainable development of coastal and marine areas of the region, African governments need to

- (1) develop human resources by undertaking short-term and academic training to strengthen existing

capabilities;

- (2) promote public awareness by producing educational materials on the ecological and socio-economic contributions of the coastal and marine resources and the consequences of unsustainable exploitation;
- (3) organize policy workshops involving relevant policy and law makers to increase their understanding of and commitment to the sustainable use of the resources in their coastal and marine areas; and
- (4) Implement integrated coastal zone management programmes by establishing case studies in pilot sites of coastal and island states in the African region.

Capacity building

Since the requirements for high level manpower in certain areas of marine sciences e.g., physical, chemical, biological oceanography, aquaculture, are not so great in terms of numbers needed by any one country at a time, existing institutions (e.g. universities) in the region suited for teaching and research could specialise as regional or sub-regional training centres.

Oceanographic research should be carried out on a regional or sub-regional co-operative basis using collectively-operated research vessels which are well-equipped and well-staffed for all types of oceanographic research and for the on-board training of marine scientific and technical staff. The co-ordination of research on a regional scale, the exchange and dissemination of research information and the storage of research data are important support activities.

Public awareness

African governments need to increase public awareness of the long-term ramifications of coastal development. At present the general public is unaware of problems associated with the development of coastal and marine areas. National campaigns are needed to improve public awareness of national and regional issues in the protection and development of coastal and marine resources of the region. Education in the principles of protection and development of marine resources should be part of the ordinary educational curriculum at all levels, and through seminars and courses offered to the general public.

The Western Indian Ocean Marine Science Association (WIOMSA) has been formed with the secretariat at the Institute of Marine Science in Zanzibar. Its aims are:

- (1) to promote and advance the educational, scientific and technological development of all aspects of marine science in the region;
- (2) to provide a forum for discussion and dissemination of information and organise meetings, seminars and workshops for the presentation of information, findings and experiences on all subjects related to marine sciences;
- (3) to encourage the support of marine science research, and the development and educational activities by government agencies and private sector; and
- (4) to collect and disseminate scientific, technical and other information on marine sciences.

Environmental Legislation

Environmental legislation is providing practical frameworks at national levels to implement environmental standards and to regulate activities in coastal and marine areas of the African region. At the international level conventions, protocols and agreements provide a basis for co-operation among countries at bilateral, regional and global levels for the management of development activities, and control of pollution and conservation of marine resources. However, African states urgently need to review and where necessary expand, update or strengthen national legislation and regulation pertaining to the protection and development of the coastal and marine areas. The enforcement of national regulations related to coastal and marine resources protection and development needs to be improved. There is an urgent need to expand the accession to and ratification of international conventions, such as the Law of the Sea, and institute mechanisms at national levels to ensure their application.

Management Planning

The value of coastal and marine areas as entities within the framework of national development planning is not always recognised in Africa and many countries lack the administrative and legislative basis for implementing such an approach. Industrial expansion such as construction of ports and harbours has often been carried out at the expense of the environment. Economic and social development, both in the coastal

cities and the coastal zone, has tended to deplete natural resources and damage the environment and amenities. To solve these problems, the countries of the African region need to develop an integrated interdisciplinary and multi-sectoral approach in their management plans for coastal and marine areas. Pilot coastal sites could be established in one or two countries in each sub-region, with intensive interdisciplinary involvement of resources and scientific personnel from universities, government agencies and non-governmental organisations. In addition, training courses, workshops and conferences should be organised, and publications and educational materials disseminated as part of the integrated coastal and marine resources management planning.

Summary and conclusion

The coastal and marine environments of the African region are uniquely situated to support a variety of activities and to serve diverse human needs for food, transport and recreation. However, the pressure of growing populations in coastal zones, expanded coastal tourism, intensified fisheries, and a large number of other economic activities pose an increasing threat which jeopardise the quality of these coastal and marine environments. The large-scale destruction of some of Africa's most valuable resources, the coastal forests and mangroves, the lagoons and coral reefs has caused serious degradation of the environment, affecting the life of the coastal inhabitants and the economic development of the countries of the region.

In the 1992 United Nations Conference on the Environment and Development (UNCED), protection of the coastal and marine environments to ensure sustainable use of natural resources was at the top of the agenda for action. Under Agenda 21, coastal states should "commit themselves to integrated management and sustainable development of coastal areas and marine environment under their national jurisdiction". The Conference further noted the importance of national policies and management capabilities for integrating the development and management of multi-sectoral activities in coastal and marine areas.

There are as yet no comprehensive study programmes covering the whole spectrum of marine science and technology.

To implement sustainable development of coastal and marine resources of the African region, there is an urgent need to: (1) build human resources by undertaking short-term and academic training to strengthen existing capabilities; (2) promote public awareness by producing educational materials on the ecological and socio-economic contributions of the marine resources and the consequences of unsustainable exploitation. (3) organize policy workshops, seminar and/or conferences involving relevant policy and law makers to increase their understanding of and commitment to the sustainable use of the resources in their coastal and marine areas, and (4) implement integrated coastal zone management programmes by establishing case studies in pilot sites in selected countries of the African region.

References

- British Petroleum 1978 *British Petroleum Statistical review of the world oil industry*. B.P Company Ltd., London.
- FAO 1987 Review of the state of world fishery resources. *FAO Fish. Circ. 710 Rev. 5*, 64 pages.
- Ibe, A.C. 1985 *Harbour Development related erosion at Victoria Island, Lagos*. Paper presented at the First International Conference on Geomorphology and the Environment, University of Manchester, England, 15-21 September 1985.
- Ibe, A.C. and Quelenec, R.E. 1989 Methodology for assessment and control of coastal erosion in West and Central Africa. *UNEP Regional Seas Reports and Studies* No. 107.
- Marchand, M. and Martin, J.L. 1985 Détermination de la pollution chimique (hydrocarbures, Organichlores, Metaux) dans la lagune d'Abidjan (Cote d'Ivoire) par l'étude de Sediments. *Oceanogr. Trop.* **20(1)**:25-39.
- Odada, E.O. 1991 Eroding Kenyan shoreline. the need for scientific appraisal and management planning. IOC-SAREC-KMFRI Regional Workshop on causes and Consequences of Sea Level Rise in the Western Indian Ocean coasts and islands. *IOC Workshop Report* No. 7.

- Odada, E.O. 1993 *The problem of coastal erosion and flooding in Eastern Africa*. Background paper presented at the Workshop and Policy Conference on Integrated Coastal Zone Management in East Africa, Arusha, Tanzania - April, 1993.
- Portmann, J.E., Biney, C., Ibe, A.C. and Zabi, S. 1989 State of Marine Environment in the West and Central Africa region. *UNEP Regional Seas Reports and Studies*. No. **108**.
- Portmann, J.E. 1978 The Gulf of Guinea: Pollution, the need for control and possible mechanisms thereof. Rome, FAO, *FAO/UNEP Joint Project No. FP/0503-77-02*, 55 pages.
- UNEP 1984 Environmental management problems in resource utilisation and survey of resources in the west and Central African Region. *UNEP Regional Seas Reports and Studies* No. **37**.

4.2 The sub-Saharan African coastal zone: assessment of natural and human induced changes

Larry Awosika

Abstract

The coastal zone of sub-Saharan Africa stretches from Mauritania to Cape Town (South Africa) in the west and Cape Town to Somalia in the east, encompassing a total of 32 countries. The large marine ecosystems in these coastal regions consist of the Canary Current, Guinea, Benguela, Agulhas, Somali and Mascarene ecosystems. The African coastal zone consists of barrier/lagoon systems, wetlands, mangrove swamps, marshes, sloughs and estuaries that form major habitats for a wide variety of flora and fauna. The largest wetland in the region is the Niger Delta which is 1,794,000 ha consisting of 617,000 ha of saline and 1,177,000 ha of freshwater swampland. Other important wetlands include the Okovango Delta and the Kafue River flood plains. Most of the largest river catchment basins in Africa are found in West Africa. For example the Niger/Benue, Congo, Orange, Gambia are major rivers which form major catchment basins, draining the West African pre-Cambrian craton and the coastal areas. The population of Africa is approximately 650 million. According to the World Bank, Africa's coastal population will continue to grow at a rate of no less than 3% per year. With this growth rate, the population in the coastal urban area is expected to double within the next 30 years and by the year 2025, the urban coastal population will increase from a mean of 200 inhabitants/km² to 500 inhabitants/km². The high socio-economic activities within the coastal zone of the region stem from the fact that the coastal zone is blessed with a variety of resources which include fisheries and fauna resources, oil and gas, non-fuel minerals such as diamonds, sand and heavy minerals, natural habitats such as wetlands, mangroves, estuaries, coastal agricultural land, and recreational and scenic resources including beaches, coastal lagoons and estuaries.

Coastal areas of sub-Saharan Africa are presently experiencing coastal degradation in the form of coastal pollution, coastal erosion, siltation, flooding, deforestation, salt-water intrusion and subsidence. Many of these problems are caused or exacerbated by exploitation of coastal resources. Coastal erosion is the most prevalent coastal hazard in West and East Africa. Annual erosion rates of 25 to 30 m have been observed along the Victoria Beach in Lagos. Although natural causes like low coastal topography, high wave energy and the nature of sediments 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. Rapid growth of towns and industries in the region has contributed to the clearing of large areas of virgin forest. The net deforestation rate for tropical Africa is estimated at 3.6×10^6 ha/year representing about 0.67 of the total forest reserves of tropical Africa. Cutting down of mangroves for firewood and construction of houses has been blamed for the depletion of about 50% of the mangroves in Nigeria. The need to generate cheap and abundant electricity, water for irrigating dry land and development of inland fisheries led to the damming of many of the major rivers in the continent. Trapping of sediments behind the dams is depriving the coastal areas of sand. Such deprivation of sediments along the coastline is exacerbating coastal erosion and flooding. In some areas, excessive sediments are being generated as a result of anthropogenic activities. Excessive generation of sediments from upland areas also causes sedimentation downstream. The silting up of Korlee Lagoon in Ghana is a classic example. The Koba coastal rice field in Guinea is also suffering from excessive siltation by sediments generated from the upland areas. Oil exploration, exploitation and other related activities have led to frequent oil spills, deforestation, subsidence and subsequent pollution of the marine environment. Global climate change and associated impacts like sea-level rise and flooding have had serious impacts on the socio-economic activities in both the West and East African regions. The coastal nations of West and Central Africa (e.g. Senegal, Gambia, Sierra Leone, Nigeria, Cameroon, Gabon and Angola) have low-lying lagoonal and erosive coasts and hence are likely to be threatened by sea-level rise. Environmental hazards facing sub-Saharan African coastal areas are great and need urgent and holistic approach. Although local and regional approaches may be necessary in some areas, many of the problems cut across international boundaries. A holistic approach to all environmental hazards calls for Integrated Coastal Area Management (ICAM) that will have a regional approach.

Introduction

Sub-Saharan Africa encompasses countries approximately south of the Sahara Desert to South Africa, including island states. This part of Africa is broken into two geographical regions: West and East Africa.

The West African coastal zone from Mauritania to Cape Town (South Africa) includes 22 countries: Mauritania, Gambia, Senegal, Cape Verde, Guinea Bissau, Guinea, Liberia, Sierra-Leone, Cote d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Sao Tome and Principe, Congo, Zaire, Angola, Gabon, Namibia and the western part of South Africa (Figure 1).

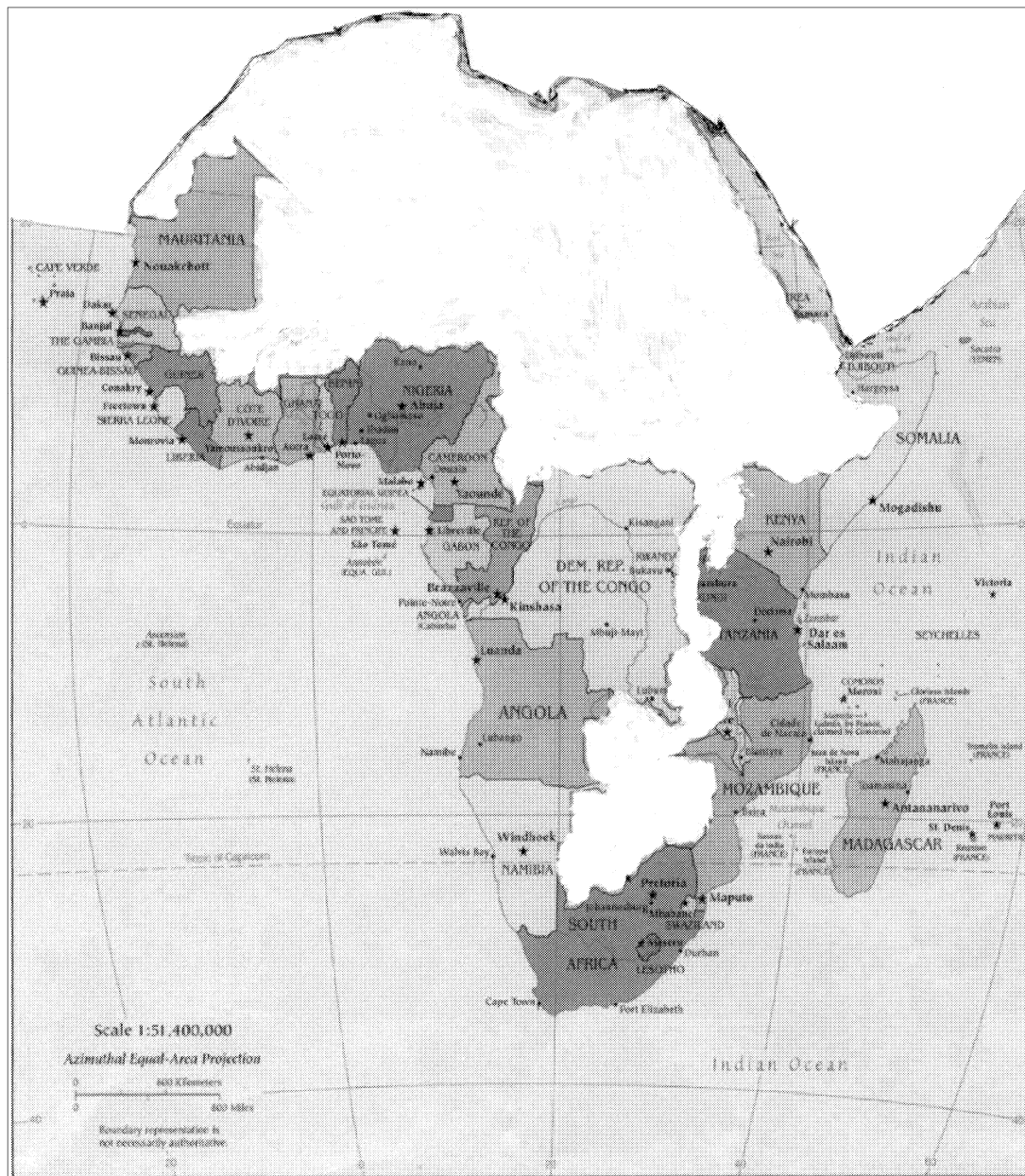


Figure 1. Coastal states of sub-Saharan Africa.

The East African sub Saharan countries include: South Africa, Mozambique, Tanzania, Kenya, Somalia, Madagascar, Comoros, Mauritius and Seychelles. The landward extent of the coastal zone in these regions is not well defined. However, the shelf break is regarded as the ocean seaward. The width of the shelf break varies from about 10 km to about 200 km. Table 1 shows coastal length and marine areas of sub-Saharan Africa. The large marine ecosystems in these coastal regions consist of the Canary Current, Guinea, Benguela, Agulhas, Somali and Mascarene ecosystems (Figure 2).

Coastal morphology

The major geomorphic features of the Eastern Atlantic Shelf in West Africa are bathymetric undulations consisting of sand shoals in the inner shelf, submarine canyons like Cayar Canyon in Senegal, Trou San Fonds in Côte d'Ivoire, Avon, Mahin and Calabar Canyons in Nigeria, and Congo Canyon in the Congo as well as other smaller gullies.

Table 1. Coastal length and marine area of sub-Saharan Africa states (compiled from World Resources 1994-95).

Country	Length of coastline (km)	Maritime area (x10 ³ km ²)	
		Shelf width to 200 m depth	EEZ
Angola	1,600	66.9	605.7
Benin	121	7.0	27.1
Cameroon	402	10.6	15.4
Cape Verde	965	X	789.4
Congo	169	8.9	24.7
Côte d'Ivoire	515	10.3	104.8
Equatorial Guinea	296	X	283.2
Gabon	885	46.0	213.8
Gambia	80	X	19.5
Ghana	539	20.9	218.1
Guinea	346	38.4	71.0
Guinea Bissau	274	X	156.5
Liberia	579	19.6	229.7
Mauritania	754	44.3	154.3
Namibia	1,489	X	X
Nigeria	853	46.3	210.9
Sao Tome and Principe	215	X	X
Senegal	531	31.6	205.6
Sierra Leone	402	26.4	165.7
Togo	50	1.0	2.1
Zaire	37	1.0	1.0
Comoros	340	X	249
Kenya	536	14.4	118
Madagascar	4,828	180.4	1,292
Mauritius	117	91.6	1,183
Mozambique	2,470	104.3	562
Reunion*	201	X	X
Seychelles	491	50	1,349.3
Somalia	3,025	60.7	782.8
Tanzania	1,424	41.2	223.2
South Africa	2,881	143.3	1,553.4

X - No available data

* Reunion is geographically in Africa but politically part of France

Sedimentary fans, especially off the mouths of major rivers like the Niger Delta, dead Holocene coral banks (Allen and Wells 1962; Awosika 1990) and rocky bottom especially off Cape Three Points in Ghana, are other features of the shelf. A chain of narrow volcanic islands lies off Cameroon while the Guinea and Walvis (off Namibia) ridges emanating from the mid-Atlantic ridge constitute other sea-bed topographic and geomorphic highs in the shelf.

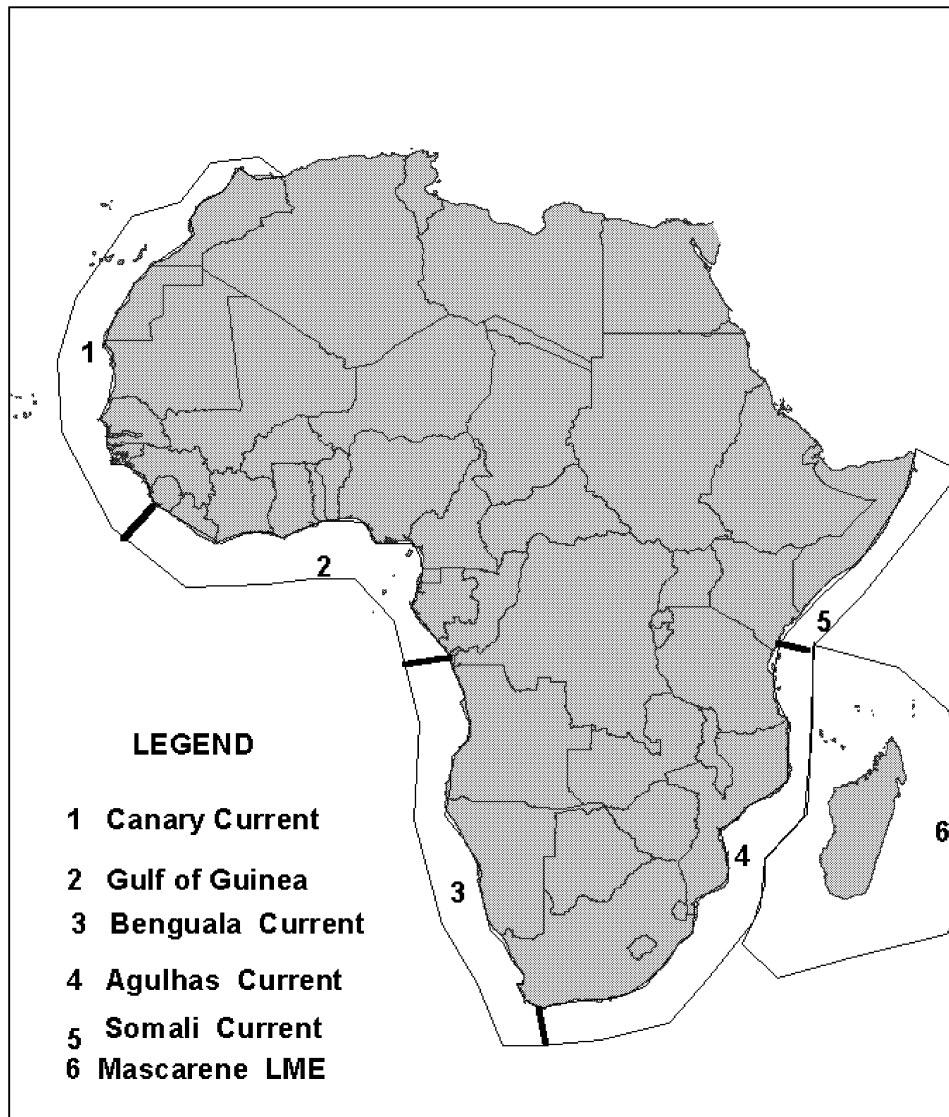


Figure 2. Large marine ecosystems of Africa.

Between Morocco and Senegal the coast is relatively unindented, while south-east of Monrovia the coast becomes indented with some offshore islands. Farther east, low-lying sandy deltaic/lagoonal ecosystems are very prominent. The coast between Monrovia and Cape Palmas in Ghana is interspersed with rocky headlands. Still farther east is the barrier-lagoon and deltaic coast between west of Abidjan and the Niger Delta. The Niger Delta is the largest delta in Africa with an area of 36,260 km² (Hughes and Hughes 1992). The Cameroon coast east of the Niger Delta is composed of rocky headlands interspersed with sandy low-lying coast with isolated lagoons.

The origin of the Seychelles Islands and other East African islands in the Western Indian Ocean can be traced back to the Cretaceous period when Madagascar and India were breaking away from Africa and drifting apart. The association of the Seychelles with Africa is confirmed by the existence of granitic rocks in most of the islands, which are of the same origin and date back to the pre-Cambrian era. However, the majority of the Seychelles islands are of limestone origin (fossil coral rock). Comoros and Mayote islands are believed to have appeared as a result of volcanic activity which occurred about 15 million years ago in the northern Mozambique Channel. Other islands which have a similar origin and originate from the same geologic period are Réunion, Mauritius, Rodriguez and Tromelin. The sporadic rocks bordering the continental margin of continental East Africa are mostly of Mesozoic origin (225 million years old). However, most of the coastal intertidal zone in Tanzania and Kenya is bordered by limestone cliffs and

these have originated from coral reefs during the Pleistocene era (about 1.6 million years ago). The main cause of their formation is the long-term variation in sea level.

The western and northern coasts of Madagascar have a wide continental shelf. Comoros and Mauritius are surrounded by deep waters that begin at a few hundred metres to several kilometres offshore. There are some shallow banks around the Rodriguez Islands and other dependencies of Mauritius. The coral islands in the Seychelles are characterised by the absence of extensive shelves.

Major ecosystems on the East African coast include mangrove forests, both in estuaries and in non-estuarine areas, fringing coral reefs and patch reefs, sandy and rocky beaches, and extensive intertidal flats.

Socio-economic activities and developments

The sub-Saharan African coastal zone is the socio-economic nerve centre of the continent. The coastal region harbours the largest population density, industries and other commercial activities. The population of Africa is approximately 650 million (World Bank 1995b). According to the World Bank, Africa's coastal population will continue to grow at a rate of no less than 3% per year. With this growth rate the population in the coastal urban area is expected to double within the next 30 years and by the year 2025, urban coastal population will increase from a mean of 200 inhabitants/km² to 500 inhabitants/km².

In West Africa, a large percentage of the urban population lives in coastal cities (Table 2). In Nigeria, for example, about 20 million people (22.5% of the national population) live along the coastal zone while in Senegal about 4.5 million people (66.6% of the national population) live in the Dakar coastal area. In Guinea-Bissau 79% of the national population is concentrated in the coastal areas of the capital. Most capitals and industrial cities, e.g., Dakar, Abidjan, Accra, Lagos, Dar es Salaam and Maputo, are located in the coastal zone. In 1994, the combined population residing in the coastal zone of East Africa was estimated at 19 million, of which Kenya, Tanzania, Mozambique and Madagascar constituted 95%. It is estimated that 30% of South Africa's population live within 60 km of the coast. The population growth rates of mainland states of East Africa are generally high, ranging from 2.8% to 3.3%. However, the urban population growth rate is much higher than the observed national average ranging from 5.0% (Mombasa) to 7.2% (Maputo) per annum.

In some countries, marine resources form the main economic life wire of the GDP. For example, oil and gas are the main foreign exchange earners for Nigeria, Gabon and Angola, while coastal fisheries constitute a large percentage of the GDP of Ghana, Senegal, Cape Verde and Equatorial Guinea. Coastal tourism is also responsible for a large part of the economy of Gambia, Senegal, Côte d'Ivoire, Kenya, Tanzania, the Seychelles and South Africa.

Most of the industries are located in the coastal zone due to accessibility to the sea. About 60% of the industries in the Gulf of Guinea states are located within the coastal zone (UNDP/GEF 1993). About 27 oil refineries and associated oil-related industries are in the Gulf of Guinea region.

About 90% of the industries in Senegal are located within the Dakar coastal zone. In Ghana as well as Benin, Togo and Sierra-Leone most of the economic activities that form the backbone of the economy are located within the coastal zone. There are also many local-scale industries consisting of textiles, pharmaceutical and plastic industries dotting the coastal zone. The coastal areas also form the main import export centres and food supplies for the landlocked countries of Africa.

Resources

Sub-Saharan African coastal areas are blessed with a variety of both living and non-living resources, which include:

- fisheries and faunal resources;
- oil and gas, non-fuel minerals such as sand, heavy minerals;

- natural habitats such as wetlands, mangroves, estuaries;
- coastal agricultural land; and
- recreational and scenic resources including beaches, coastal lagoons and estuaries.

Table 2. Populations in the coastal zone in relation to country population and area (from Africa: A framework for ICZM 1996).

Country	Country pop. 1994 (millions)	Coastal pop. 1994 (millions)	Coastal pop. as % of country pop.	Country area (km ²)	Coastal area (km ²)	Coastal area as % of country area
West Africa						
Angola	11.53	2.89	25.07%	1,245,828	95,410	7.66%
Benin	5.18	1.86	35.91%	116,266	7,248	6.23%
Cameroon	13.22	1.57	11.88%	465,425	29,378	6.31%
Cape Verde	0.41	0.41	100.00%	4,288	4,288	100.00%
Congo	2.32	0.35	15.09%	345,196	11,538	3.34%
Côte d'Ivoire	13.5	3.74	27.70%	322,770	32,843	10.18%
Eq. Guinea	0.39	0.21	53.85%	27,207	13,414	49.30%
Gabon	1.56	0.65	41.67%	261,764	53,060	20.27%
Gambia	0.94	0.5	53.19%	11,373	4,147	36.46%
Ghana	16.7	5.47	32.75%	239,312	27,644	11.55%
Guinea	6.24	1.35	21.63%	245,156	25,175	10.27%
Guinea-Bissau	1.09	0.87	79.82%	33,101	22,351	67.52%
Liberia	2.9	1.3	44.83%	96,826	31,477	32.51%
Mauritania	2.2	0.22	10.00%	1,041,970	39,291	3.77%
Namibia	1.55	0.04	2.58%	818,346	87,802	10.73%
Nigeria	97.23	19.29	19.84%	913,612	65,880	7.21%
Sao Tome & Principe	0.13	0.13	100.00%	856	856	100.00%
Senegal	8.12	4.37	53.82%	197,836	35,058	17.72%
Sierra Leone	4.55	2.15	47.25%	71,706	25,802	35.98%
Togo	4.05	1.37	33.83%	57,334	4,570	7.97%
East Africa						
Comoros	0.63	0.63	100.00%	2,030	2,030	100.00%
Kenya	25.84	1.66	6.42%	588,045	32,447	5.52%
Madagascar	13.05	4.8	36.78%	592,797	242,745	40.95%
Mauritius	1.1	1.1	100.00%	1,328	1,328	100.00%
Mozambique	16.6	5.62	33.86%	789,508	162,938	20.64%
Reunion	0.64	0.64	100.00%	2,036	2,036	100.00%
Seychelles	0.07	0.07	100.00%	210	210	100.00%
Somalia	9.65	3.79	1.88%	2,507,302	46,217	1.84%
Tanzania	28.39	4.61	16.24	942,654	57,225	6.07%
South Africa	40.72	12.4	30.45%	1,216,919	152,734	12.55%

Fishery resources

Fish is the most important source of dietary animal protein in Africa. FAO estimated (FAO 1996) the total fish harvest potential at about 7.8 million in salt water fisheries and 2.7 million in fresh water fisheries. The total salt-water fish harvested by countries of the region amounted to 3.9 million tonnes in 1994 (this figure excludes the production of foreign fleet that does not land in the region). Off the eastern coast of Africa catches represent less than 10% of the total regional harvest (foreign and domestic catches combined). The coastal and marine areas provide about 90% of the fish production in the majority of countries in the region. Fishing is one of the largest industries in the East African islands of the Seychelles, Mauritius, Madagascar and Comoro. A large part of this fishing industry is composed of artisanal fishermen. For

example, artisanal fisheries in the Seychelles exported an estimated 367.13 tonnes of fish in 1994, representing approximately one-third of total export of fresh and frozen fish from the Seychelles. The South African commercial fishing industry is worth about USD 10.2 billion annually. Table 3 shows some fishery statistics of some countries in the region. Targeted fish species in the East Central Atlantic include herrings, sardines, red fish, and tuna and jack mullet.

Increased and uncontrolled fishing methods employing unethical harvesting methods are leading to a decline in fisheries. Fish catches in many African states have shown a systematic decline since 1974. The infection of coastal waterways by floating weeds has led to a decline in fishery activities due to clogged waterways, estuaries and lagoons, for example in Abidjan, Lakou Lagoon in Benin and Lagos Lagoon in Nigeria. Uncontrolled exploitation of the fisheries by foreign vessels is also leading to depletion of some fish stocks.

Table 3. Average annual marine fish catch and percentage change of coastal states in sub-Saharan Africa (World Resources 1998-99).

Country	Average 1993-95 (10 ³ mT)	Percent change 1983-85
Angola	77.5	(1)
Benin	13.5	192
Cameroon	41.9	25
Cape Verde	11	248
Congo	17.5	8
Côte d'Ivoire	57.5	(22)
Equatorial Guinea	3.3	15
Gabon	240	28
Gambia	19.5	124
Ghana	299.6	34
Guinea	60.3	130
Guinea Bissau	5.3	75
Kenya	107.6	86
Liberia	3.8	(61)
Madagascar	85.1	180
Mauritania	86.6	(0)
Mauritius	19.0	74
Mozambique	24.8	(27)
Namibia	304.5	2,336
Nigeria	187	14
Senegal	329.7	41
Sierra Leone	47.1	34
Somalia	15.4	(3)
South Africa	552	(32)
Tanzania	243.4	68
Togo	8.7	(23)

Negative numbers are in parentheses

Oil and gas

Though oil and gas are found mainly in a few countries of the region, they constitute probably the most important coastal resource in the region (Table 4). Oil and gas form the main source of foreign exchange earner for Nigeria representing almost 90% of income for the country. In 1990, production of oil from the coastal zone averaged approximately 1,800,000 barrels per day. In the same year, the proven reserve base rose from an estimated 16.5 billion barrels to almost 18 billion barrels. In addition, the country has 85 TCF of proven gas reserves and a further 15 TCF of probable gas reserves. Other countries with oil and gas reserves include Cameroon with about 65 million metric tons of crude oil and 60 billion cubic metres of natural gas, Côte d'Ivoire with 15 billion cubic metres of crude oil and 60 million cubic metres of natural

gas. Other countries in the region have intensified exploration for crude oil and natural gas in their coastal zone. As at 1984, Ghana has been able to strike a reserve estimated at about 1 million cubic metres of crude oil in the coastal zone.

The only gas deposits in East Africa are found on the Tanzanian coast. These deposits are found in Songo Songo and Mnazi Bay in southern Tanzania and steps for their exploitation are under way.

Non-fuel minerals

Although oil and gas form the most important mineral resources in the coastal zone, other non-fuel minerals like sand, heavy minerals (hematite, goethite, illmenite, magnetite, and zircon), limestone, and diamond exist both on land and offshore. However, due to the lack of adequate technology, only sand is presently being exploited mainly for beach nourishment and construction. The nearshore environment and the lagoons have abundant sand usually mined for construction, block moulding and beach nourishment. In Nigeria for example, over 14×10^6 m³ of sand were dredged from offshore borrow pits between 1960 and 1990 to nourish the fast-eroding Victoria Beach. About 13×10^6 m³ of sand were dredged from the Lagos Lagoon between 1990 and 1991 to nourish the Lekki scheme development project area (Awosika and Dublin-Green, 1994).

Quarrying for sand and limestone occurs in all countries of the East Africa. For example, the annual demand for fine aggregates in Mauritius is 1.5×10^6 tonnes and approximately 800,000 tonnes of sand are extracted from the lagoon areas. Sand mining in lagoons, beaches and coastal dunes is causing extensive beach erosion in the region. Titanium deposits are found in the estuarine areas of the Zambezi River and the coastal area north of Dar es Salaam.

Along the west coast of South Africa and in Namibia are rich diamond deposits. These diamond deposits were first discovered in 1908 by an ex-Kimberley labourer. By 1925, prospecting for diamonds covered the 80 km strip from Port Nolloth to the Orange River. The land-based diamond reserves are nearing depletion and decommissioning of the mines is being considered.

Table 4. Oil and gas reserves of some countries in sub-Sahara Africa (compiled from World Resources 1994-95).

Country	Crude oil (1992) thousand tonnes	Natural gas (1992) million tonnes
Benin	117	10
Cameroon	65	95
Cape Verde	0	0
Côte d' Ivoire	3	100
Equatorial Guinea	1	3
Gabon	190	11
Gambia	0	0
Ghana	0	0
Guinea	0	0
Guinea Bissau	0	0
Liberia	X	X
Madagascar	0	0
Mauritania	X	X
Mauritius	0	0
Mozambique	0	0
Nigeria	2,040	3,398
Senegal	136	0
Sierra Leone	0	0
Tanzania	0	28
Togo	X	X
Zaire	11	28

Freshwater resources: surface and groundwater

Most of the largest river catchment basins in Africa are found in West Africa. The coastal zone of eastern Africa is comparatively dry. Table 5 shows statistics of the 10 largest surface river bodies in the sub-Saharan African region. These rivers form major catchment basins which drain the African pre-Cambrian craton. These rivers cut across international boundaries and provide fresh water for millions of Africans along the banks and even beyond the riverbanks. This results in heavy pressures on surface water resources. Many of these rivers have also been dammed for hydroelectric generation as well as for irrigation. The groundwater resources of the coastal areas consist of unconfined aquifers with high water tables. This makes most of the water resources susceptible to saltwater intrusion and contamination from raw sewers and other pollutants.

Surface water supply is an important resource both for domestic and industrial uses. About two thirds of the urban population in coastal areas of Africa are without safe drinking water even though there are river networks and creeks, as well as abundant groundwater resources. By the year 2000 about 300 million Africans risk living in a water scarce environment, and by 2025, the number of countries experiencing water stress will rise to about 18, and more than 600 million people will be affected (World Bank 1995a).

Many of the rivers entering the Indian Ocean from continental East Africa have been dammed for generating electricity, irrigation and in some cases flood control. These projects have modified river flows and have led to increased surface water runoff, soil erosion, transportation of pollutants and aggravation of water shortage. The island states in both West and East Africa depend mostly on groundwater for both domestic and industrial uses due to lack of large, all-season-flowing rivers.

Table 5. The ten largest surface water bodies in sub-Saharan Africa with drainage areas more than 350,000 km² (Rangeley *et al.* 1994).

Basin	No. of countries	Basin area (1,000 km ²)	Basin countries
Congo	9	3,720	Zaire, Central African Republic, Angola, Congo, Zambia, Tanzania, Cameroon, Burundi, Rwanda, Sudan
Niger	9	2,220	Burkina Faso, Benin Côte d'Ivoire, Chad, Niger, Central African Republic, Nigeria, Sudan, Cameroon
Zambezi	8	1,420	Zambia, Angola, Zimbabwe, Mozambique, Malawi, Botswana, Tanzania, Namibia
Orange	4	950	South Africa, Namibia, Botswana, Lesotho
Okavango	4	529	Botswana, Angola, Namibia, Zimbabwe
Limpopo	4	385	South Africa, Botswana, Mozambique, Zimbabwe
Volta	6	379	Burkina Faso, Ghana, Togo, Côte d'Ivoire, Benin, Mali
Senegal	4	353	Mali, Mauritania, Senegal, Guinea

Major environmental changes

Coastal areas of sub-Saharan Africa are presently experiencing coastal degradation in the form of coastal erosion, siltation, flooding, pollution, deforestation, salt water intrusion and subsidence. Many of these problems are caused or exacerbated through exploitation of coastal resources. Major environmental changes are the result of the following:

- pollution;
- coastal erosion, flooding, siltation, deforestation;
- over-exploitation and degradation of marine resources; and
- deteriorating water quality and sanitation with impact on environment and public health.

All these coastal problems cut across national boundaries in both western and eastern Africa.

Pollution

The main sources of pollution in coastal areas are domestic wastes and industrial effluents. Most of the domestic wastes are solid wastes from coastal inhabitants. Much of this waste is not treated but is disposed

indiscriminately. Many large cities in sub-Sahara Africa lack centralised systems for collecting and treating domestic waste. Individual households use septic tanks, so the population generates more waste than industry. This results in pollution of groundwater. In Mombassa (Kenya), domestic sewage and storm water runoff account for 18% (4,566 t yr⁻¹) and 37% (12,802 t yr⁻¹) of the total BOD and suspended solids. The cities of Mogadishu (Somalia) and Majunga (Madagascar) have no centralised sewage systems, while those of Dar es Salaam (Tanzania), Maputo (Mozambique) and Mombasa (Kenya) can handle only 20% of the existing sewage load. The sewage systems do not have pre-treatment before they are discharged into the sea. For example in Port Louis (Mauritius) the sewage system serves 75% of the population but is dumped directly into the sea as raw sewage. This has led to sanitation and health problems in most metropolises in the Western Indian Ocean region. Maputo, the only city in the East African region with a central sewage system, is only able to treat about 50% of the sewage generated. The remaining 50% is emptied into rivers that flow into the Maputo Bay. This has led to an increase in the levels of total and faecal coliforms in Maputo Bay, making the bay area unsafe for tourism.

Because oil and gas industries are the most important economic activities in West Africa, oil spills and industrial effluence are the dominant sources of pollution in the region. In Nigeria, oil exploration, exploitation and disposal of raw sewers and industrial effluent have led to pollution of large areas of the coast especially in the Lagos area and the Niger Delta. Pollution of water, sediment and biota as a result of heavy metals and pesticides has been documented in the region (Portman *et al.*, 1989).

Domestic and industrial pollutants are generally associated with mega-cities like Lagos, Abidjan, Dakar and Port Harcourt (Table 6). About 70% of Nigeria's industries are located in the coastal zone and about 80% of the effluents and emissions are discharged without treatment. These industries consist of oil refineries, petrochemical, pharmaceuticals, textile, food and beverage and plastic industries. Mining operations produce large residues that are discharged into coastal waters, for example, large quantities of phosphate residues in Côte d'Ivoire and residues from diamond mining in Namibia. Oil tankers in coastal waters in the region, especially in oil-producing countries create an important pollution source through accidental oil spills and ballast discharge.

Since most of the industries in East Africa are agro-based, the wastes are organic and nutrient-rich and are commonly discharged to sewers or directly into the ocean or rivers. Msimbazi Creek in Dar es Salaam is heavily polluted by industrial effluents. Other areas of heavy pollution include Tudor and Kilindini Creeks in Mombassa, Mogadishu Harbour, the Matola River in Maputo and St. Louis in Mauritius. Oil pollution is significant in waters adjacent to oil refineries in Mombassa, Dar Es Salaam, Maputo and Tamatave.

Table 6. Domestic water and waste statistics of some coastal cities in Africa.

City – Country	Per capita water used/day	Wastewater treated %	Per capita solid waste generated %
Lunda – Angola	50	0	-
Porto Novo – Benin	22	-	0.5
Douala – Cameroon	33	5	0.7
Younde – Cameroon	61	20	0.8
Abidjan – Côte d'Ivoire	111	58	1.0
Libreville – Gabon	100	0	-
Banjul – The Gambia	106	0	0.3
Accra – Ghana	4	0	0.4
Conakry – Guinea	50	0	0.7
Antananarivo – Madagascar	40	0	0.3
Novakcht – Mauritania	35	10	0.9
Maputo – Mozambique	80	-	-
Lagos – Nigeria	80	-	1.1
Dakar – Senegal	64	69	4
Dar Es Salaam – Tanzania	50	2	1.0
Lomé – Togo	35	-	1.9

The ocean and beaches are used as dumping grounds for a variety of wastes from ships, tourists and even industries. Plastics are the most common debris on the beaches along the West African coast, most of which are brought in by tourists who litter the beaches with their left-over plastics and food containers. Table 7 shows the volume of debris collected in some African countries' international beach cleanup exercise in 1996. Results of the 1995 beach cleanup along Victoria Beach in Lagos (Table 8) revealed that plastics and foamed plastics constituted the most abundant debris category amounting to 31.86% of total pieces of debris collected. This was followed by paper and metal categories constituting 16.67% and 10.45% respectively. Rubber and glass categories constituted 7.36% and 6.88% respectively while cloth category amounted to only 4.06% of the total.

Table 7. 1996 international coastal clean-up results for selected countries in Africa.

Country	Debris Collected (pounds)	Debris collected (kg)	Length of beach cleaned (miles)	Length of beach cleaned (km)
Cameroon	16,328	7,422	1.2	0.7
Ivory Coast	5,005	2,275	1.4	0.9
Kenya	23,844	10,838	54.4	33.7
Nigeria	3,121	1,419	2.5	1.6
South Africa	9,005	4,093	33.5	20.8
Tanzania	8,360	3,800	0.3	0.1

Table 8. List of categories of debris collected during the 1995 beach clean-up at Victoria Beach, Lagos. Total weight of debris collected: 1,260.9kg.

Categories of debris	No. of pieces	% Composition of total
Plastics	6,768	31.86
foamed plastics	2,161	10.17
Glass	1,462	6.88
Rubbers	1,563	7.36
Metal	2,664	12.54
Paper	3,542	16.67
Wood	2,219	10.45
cloth pieces	862	4.06
TOTAL	21,241	99.99

Coastal erosion

Coastal erosion is the most prevalent coastal hazard in West and East Africa. Though 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. Typical areas of erosion include:

- **Senegal:** Niang (1990) reported annual erosion rates of 5.8 cm at Cape de Naze cliff, 32.9 cm at Cape des Biches and 29.3 cm at Fann Cliffs. For sandy coasts this rate is about 1 to 1.5 m per year.
- **Guinea:** Murdy and Sexton (1986) reported erosion phenomena in the northern part of the Camagienne Peninsula. Widespread erosion has also been reported along the Koba area especially at the mouth of the canals dug to drain excess water from the rice fields to the ocean.
- **Sierra Leone:** Collins *et al.* (1983) reported widespread erosion between Freetown and the eastern border especially off Sherbro Island.

- **Liberia:** Coastal erosion along the Liberian coast has been reported along cities like Buchaner, Greenville, Harper and Robertsport. Around the Organisation of African Unity (OAU) Beach, Shannon (1990) reported erosion rates of 3 m annually.
- **Côte d'Ivoire:** The La Vigie area with its coastal residential area of "Les Tourelles" and Adjoufun suffered extensive damage from erosion and flooding during the summer storms of 1984. Koffi *et al* (1990) reported coastal erosion rates of 1-2 m annually along the south-eastern coast (Fresco, Vridi, Port Bouet to Ghana border). High erosion rates have been reported in the areas off the Abidjan harbour.
- **Ghana:** Along Labadi Beach, an erosion rate of 3 m per year was reported between 1966 to 1975. At Ada near the Volta estuary erosion rates of 2.2 to 2.4 m annually have been reported between 1939 and 1976. Along the Keta coast, erosion rates of 4 m to 6 m per year between 1923 to 1975 have also been reported.
- **Togo:** East of the Lomé harbour an erosion rate of 20 m per year has been reported while the updrift western side has accreted so much that it is threatening to silt up the entrance to the Lomé port. The coastal road at Anneho has also been washed away as a result of the erosion.
- **Benin:** Erosion is very prevalent along Grand Popo, Seme and east of the Cotonou harbour. According to Adams (1990) erosion was sparked off with the construction of piers around the coastal areas of Kpeme factory, Aneho town, L. M. Hotel and Hotel da Silva. The New Town scheme, which was supposed to be a residential 'Hollywood' of Benin, has been devastated by erosion. Many of the roads, houses and other facilities constructed for the residents now lie under the sea.
- **Nigeria:** Erosion rates of 25 to 30 m annually have been documented along Victoria Beach in Lagos (Ibe *et al.* 1984). Although about six sand nourishment projects have been implemented on the beach since 1958, erosion continues to wash off large parts of the coast. Other areas where erosion has been very devastating along the Nigerian coast include Forcados 20 m per year, Brass 16-19 m per year, Eket 10-13 m per year and Awoye along the Mahin mud beach 20-30 m per year.
- **Kenya:** Coastal erosion is very prevalent along the cliffed beaches at Kanamai, Shanzu, Iwetine, Nyali, Likoni, Black Cliff Point and Tiwi. High rates of erosion have also been reported along the sandy beaches north of Mtwapa Creek and north of Tudor creek at Bamburi-Kenyatta.
- **Mauritius:** Erosion has been reported along the coast of Cape Malheureux to Flic en Flac. Beach erosion rates of 10 m was reported along near the Le Morne Brabant Hotel in the past 15 years.
- **Tanzania:** Erosion is very prevalent along Kunduchi Beach north of Dar es Salaam. Hotels on tourist beaches like Hotel Africana, Kundichi Beach Hotel, Silver Sand Hotel, Rubgwe Oceanic Hotel and Bahari Hotel are threatened by beach erosion causing extensive damage. In Zanzibar, high erosion rates have threatened the coralline reefs in Ras Numgwi and the Maruhubi area in Zanzibar town.

Several activities in the hinterland have also caused adverse changes in the coastal zone. The need to generate cheap and abundant electricity, water for irrigating dry land and development of inland fisheries have led to the damming of many of the major rivers in the region. The construction of the Akosombo dam on the Volta in Ghana has led to a 60% reduction in the sediment load reaching the coastline (Collins *et al.* 1983). Several dams built on the River Niger in Nigeria have also led to a drastic reduction of sediments reaching the coastline. The Mono River in Togo with a pre-dam sediment discharge of about 21,000 cubic metres of sand now has a post-dam discharge of close to zero. Trapping of sediments behind the dams is depriving the coastal areas of sand. Such deprivation of sediments along the coastline is exacerbating coastal erosion and flooding. Excessive generation of sediments from upland areas also causes sedimentation downstream. The silting up of Korle Lagoon in Ghana is a classic example. The Koba coastal rice field in Guinea is also suffering from excessive siltation by sediments generated from the upland areas.

Land reclamation is extensive in the intertidal areas especially in the islands. In Victoria, Mahé, Seychelles, the airport, residential area and the port were built on reclaimed land. The extensive dunes in Mozambique are mined for construction materials causing significant beach erosion. Most of the rivers of the region have been dammed for water supply and irrigation. The damming of the Zambezi River (Mozambique) and Rufiji River (Tanzania) have resulted in significant adverse impacts on the ecological, and socio-economics at the Rufiji Delta.

Flooding

The low nature of the coastal zone makes the area susceptible to flooding especially during the rainy months of May to September. Storm surges are prevalent during April and August - September in West Africa (Awosika *et al.* 1995). These storms are usually associated with astronomical high tides exceeding 2 m above the normal high tide levels. These high waters result in flooding of the low-lying areas in the coastal zone. Poor drainage channels and clogged drainage channels with solid domestic wastes contribute immensely to flooding of coastal areas. The seasonal flooding of the Victoria Island during the rainy months and storm surges usually result in the dislocation of socio-economic activities of the economic nerve centre of Nigeria (Awosika *et al.* 1995). Seasonal flooding of the low-lying fringing coastal plains in East Africa is also prevalent.

Deforestation

Rapid urban growth and industries in the region have contributed to the clearing of large virgin forest. Table 9 shows the rate of deforestation in the region. A large part of coastal vegetation is composed of mangroves, palms, trees and scrubs. Large areas of the coastal forest areas are being destroyed to make room for industries, residential and commercial houses. The net deforestation rate for tropical Africa is estimated at 3.6m ha/year representing about 0.67% of total forest reserves of tropical Africa.

The coastal zone, though not densely forested due to its sandy nature, is known to have a variety of flora species. The fern, *Acrostichum aureum*, often grows among the mangroves. The grass, *Paspalum vaginatum*, a variety of which is used for mat-making is rapidly replacing virgin forest. The succulent herb, *Portulaca sp.*, is an important plant species in the coastal areas. Table 9 shows the forestry statistics for African coastal countries and rates of depletion. Between 1990 and 1995 African forest was depleted by about 3.5%.

Table 9. Forest areas, deforestation rate and loss of mangroves in selected sub-Sahara African countries.

Country	Closed forest (000 ha)	Deforestation rate (% per year)	Current extent of mangrove (000 ha)	Loss of mangroves (% of total)
Côte d'Ivoire	4,458	6.5	3	60
Nigeria	5,950	5.0	1052	50
Benin	47	2.6	7	x
Guinea-Bissau	660	2.6	315	70
Liberia	2,000	2.3	36	70
Guinea	2,050	1.8	120	60
Kenya	1,105	1.7	93	70
Madagascar	10,300	1.5	130	40
Angola	2,900	1.5	110	50
Ghana	1,718	1.3	2	70
Mozambique	935	1.1	276	60
Sierra Leone	740	0.8		50
Cameroon	17,920	0.4	486	40
Zaire	105,750	0.2	125	50
Gabon	20,500	0.1	115	50
Congo	21,340	0.1	2	0

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. In Senegal for example, it is estimated that about 40% of the mangroves had been lost by 1980 (Table 9) and there are now extensive barren areas with acid-sulphate soils. As at 1980 about 60% of the mangroves in Guinea were reported to have been lost. In Liberia, nearly 70% of the mangrove vegetation had been lost as at 1980. In Ghana about 70% of the primary mangrove vegetation have been lost mainly through human activities. Most of the forest wood is used for fuel-wood. The original mangrove vegetation in these countries has now been replaced by the hardy grass *Paspalum vaginatum*. The once flourishing coconut and

palm groves along many beaches have either been cut down or uprooted by erosion, leaving the beaches bare of vegetation.

Climate change and emerging coastal hazards

Global climate change and associated impacts such as sea-level rise and flooding have been documented to have serious impacts on socio-economic activities in the West African region. The coastal nations of West and Central Africa (e.g., Senegal, Gambia, Sierra Leone, Nigeria, Cameroon, Gabon and Angola) have low-lying lagoonal, erosive coasts, and hence are likely to be threatened by sea-level rise. Most countries in the coastal belt of the African region including Cape Verde, Sao Tome and Principe, Comoros, Mauritius, Reunion and Seychelles, where coastal areas represent 100% of the country (WRI 1994) would be affected by different IPCC (1995) scenarios of 0.5-1.0 m sea-level rise by the end of the 21st century.

Sea-level rise, combined with localised subsidence, is also expected to exacerbate coastal erosion and inundation in the region. Awosika *et al.* (1992) estimated that about 18,120-18,396 km² of Nigerian coastal areas could be at risk by the end of the twenty first century with a one meter sea-level rise (Table 10). This is expected to put about 3.18 million people at risk. Values at risk could amount to \$18,134 million. Nicholls *et al.* (1993) also estimated that a one meter sea-level rise could put about 6,042 to 6,073 km² of the Senegalese coast at risk. This could again risk the lives of 109,000 to 178,000 coastal dwellers while risking values worth between \$494 to \$707 million. Productive wetlands and other ecosystems like the Niger Delta would be adversely affected by sea-level rise (Table 11). In Tanzania, sea-level scenarios of 0.5 and 1.0m sea-level rise per century will result in inundation of about 2,090 and 2,117 km² respectively. A one meter sea-level rise will lead to erosion of about 9 km² along the Tanzanian coastline (Mwaipopo 1997).

Table 10. Summary of Impacts and Response costs for a one meter sea level rise (after French and Awosika 1993).

	Senegal	Nigeria
Land at risk (km ²)	6,042 to 6,073	18,120 to 18,396
Population at risk	109,000 to 178,000	3,180,000
Value at risk *million)	US\$494 to 707	US\$18,134
Important area protection	US\$255 to 845	US\$558 to 688
Total protection	US\$973 to 2,156	US\$1,424 to 1,766

Table 11. Niger Delta (Nigeria) ASLR I and II physical effects and natural system projection to 21st century (from Awosika *et al.* 1995).

	Units	Presently no ASLR	ASLR I	ASLR II
1. Erosion rate	m/y	10 – 15	16-19 55-	20-25
2. Erosion-area lost **	km ²	26 - 45	120	130-330
3. Inundation and erosion**	km ²	3,000	7,000	15000
4. % of total area lost due to inundation and erosion	%	15%	35%	75%
5. Subsidence	*	*	*	*
6. Salinity				
(i) Salt wedge intrusion	*	*	*	*
(ii) Seepage rate	*	*	*	*
(iii) Seepage salinity	*	*	*	*
7. Natural System Responses	km ²	794	2,779	5,955
(I) Agriculture (7,940 km ²)				
8. No. of villages impacted	No	50	200	350
9. No. of people displaced	No	150,000	1-2m	2-3m

Conclusion

The economic loss due to degradation of the coastal areas will have serious consequences on the development of sub-Saharan Africa. It is estimated that decreased fishing has led to loss of income of many coastal states and local fishermen. Coastal erosion has led to destruction of buildings, tourist facilities, and valuable real estate. Changed hydrological regimes and inavailability of adequate fresh water has led to unsafe sanitary conditions and health problems leading to increase in medical bills. Sea-level rise and flooding would also have deleterious impacts on the economy of coastal States in the region.

On the socio-economic side, Africa's tourism industry could be adversely affected by the destruction of coastal infrastructure, sandy beaches, barrier bars and other marine ecosystems. Sea level rise adaptation or mitigating options will involve heavy costs, which the developing African states will find difficult to bear.

Environmental problems facing the sub-Saharan African areas are of high magnitude and need urgent and holistic approach. Although local and regional approaches may be necessary in some areas, many of the problems cut across international boundaries. In many places like Conakry Guinea, hard structures like sea walls have been constructed to control coastal erosion. Many of these structures have failed to solve the problem. Rather, they have resulted in the transfer of the problem down drift.

A holistic approach to all environmental problems calls for an Integrated Coastal Management (ICM) that will have a regional approach. In the drive by many governments to revamp their economy and provide social facilities there is a tendency to neglect sound and holistic environmental management plans. Many of the countries for example, Senegal, Côte d'Ivoire, Benin, Nigeria, Kenya, South Africa, Mauritius and Seychelles already have agencies or ministries of environment which have mandate for ensuring sustainable management of the environment. These governmental agencies have existing legislation with ingredients for effective management plans. However, these management plans are ineffective because of the following:

- lack of co-ordination and interactions between agencies with coastal zone mandates;
- lack of trained personnel and infrastructure for implementing ICM;
- inadequate data and information on coastal zone processes and activities; and
- Lack of adequate communication facilities for exchange of data and information.

Capacity (human and infrastructure) building is an essential element for effective implementation of ICM. Hence any regional ICM programme should include a well-articulated capacity building programme.

In conclusion a regional programme that takes onboard the following is urgently required:

- A regional database using geographic information system for analysis and evaluation of coastal indicators should be established in regional centres of excellence in the region. Data from such must be made accessible to planners and researchers as well as coastal zone stakeholders;
- tools for monitoring, assessment and decision-making must be standardised and made available to African countries, together with technical support;
- development of reliable regional climate change scenarios, impact assessments and policy development in the coastal zone and the entire marine environment will be needed; and
- Building capacity for coastal zone management through training, infrastructural development and upgrading population awareness will constitute important strategies.

A regional compilation of environmental problems, root causes and possible remedial options must be embarked upon. This process will identify “environmentally degraded hot spots” Identification of these “hot spots” will ensure a clearer understanding of the problems and help in the implementation of sustainable remedial measures.

References

- Adams, K.S. 1990 Implications of sea level rise for Togo and Benin. Pg 13-24 in: *Changing climate and the coast*, Vol. 2. *Report to IPCC from the Miami Conference on Adaptive Responses to sea level rise and other impacts of Global Climate Change*.
- Allen, J.R. and Wells, J.W. 1962 Holocene coral banks and subsidence in the Niger Delta. *Journal of Geology* **70**:381-397.
- Awosika, L.F. 1990 Coral bank obstruction to trawling in the middle to outer continental shelf east and west of Lagos, Nigeria. *NIOMR Pub.* No **57**, 13 pages.
- Awosika, L.F., French, G.T., Nicholls, R. and Ibe, C.E. 1992 The Impacts of Sea Level Rise on the Coastlines of Nigeria. *IPCC CZMS Workshop*, Venezuela, March 1992.
- Awosika, L.F. and Dublin-Green, C.O. 1994 Sand Mining in the Lagos and Lekki lagoons and strategies for effective management. *Journal of Mining Geology* **30 (11)**: 137-139.
- Awosika, L.F., Ibe, A.C., Ojo, A., Ajayi, T.O., Niang-Diop, I. and Nai, T. 1995 Impacts of climate change on the Niger Delta. *A special report for UNEP*.
- Collins, M.B., Rowlands, G.L. and Harris, P.T. 1983 Coastal erosion in West and Central Africa; literature review and data analysis (U.K. contribution) *UNESCO Project WACAF/3*, 1983.
- FAO 1996 *The State of World Fisheries and Aquaculture*. Rome, FAO.
- French, G.T. and Awosika, L.F. 1993 Sea-level rise in Nigeria: Potential Impacts and responses. *Journal of Coastal Research SI#14*.
- Hughes, R.H. and Hughes, J.S. 1992 *A directory of African Wetlands*. IUCN Gland, Switzerland and Cambridge, UK; Nairobi:UNEP; Cambridge, UK: WMCM.
- Ibe, A.C., Awosika, L.F. and Antia, E.E. 1984 Progress report No.2 Coastal Erosion project. *NIOMR Special Pub.* 106 pages.
- IPCC 1995 *Climate Change: The scientific assessment - The impacts assessment - The response strategies. Reports of the working groups 1, 2 and 3*. Cambridge University Press.
- Koffi, P.K., Kaba, N. and Zabi, S.G. 1990 Response to expected impact of climate change on the lagoonal and marine sectors of Cote d'Ivoire. Pages 89-92 in Titus, J. (ed): *Changing climate and the coast*, Vol. 2. Environmental Protection Agency, Washington, D.C.
- Murdy M. and Sexton, W.J. 1994 The morphology and sediment of the coastline of Nigeria: The Niger Delta. *Journal of Coastal Research* **10 (4)**:959-977.
- Niang, I. 1990 Responses to the impacts of greenhouse-induced sea level rise in Senegal. Pages 67-87 in: *Changing Climate and the Coast, Vol. 2. Report to IPCC from the Miami Conf. on Adaptive responses to sea level rise and other impacts of Global Climate Change*.
- Nicholls, R.J., Awosika, L.F., Niang-Diop, I., Dennis, K.C. and French, G.T 1993 Vulnerability of West Africa to accelerated sea level rise. In Awosika, L.F. *et al.* (eds): *Proc. Coastal Zone special volume "Coastlines of Western Africa"*, American Society of Civil Engineers, 1993.
- Portman, J.E., Biney, C., Ibe, A.C. and Zabi, S. 1989 State of the Marine Environment in the West and Central African region. *UNEP Regional Seas Report and Studies No 108*, UNEP 1989.
- Rangeley, R.B.A., Thiam, R.A. and Lyle, C.A. 1994 International River Basin Organisation in Sub-Saharan Africa. *Tech. Paper No 250*, The World Bank, Washington USA, 70 pages.
- Shannon E.H. 1990 Coastal erosion and management along the coast of Liberia. Pages 25-42 in *Changing Climate and the Coast, Vol. 2. Report to IPCC from the Miami conference on Adaptive responses to sea level rise and other impacts of Global Climate Change*.
- UNDP/GEF 1993 Water pollution control and biodiversity conservation in the Gulf of Guinea Large Marine Ecosystem Project Proposal to the GEF.
- World Bank 1995a Nigeria: *Strategic options for redressing industrial pollution*. February 1995, Industry and Energy Division, West Central Africa Department, 45 pages.
- World Bank 1995b Towards environmentally sustainable development in Sub-Saharan Africa. A Framework for Integrated Coastal Zone Management. Building Blocks for Africa 2025. *Environmentally Sustainable Development Division. Africa Technical Department. Post UNCED Series*, Paper No **4** April 1995, 56 pages.
- World Resources 1994-95 *A Guide to the Global Environment*. Report by the World Resources Institute in collaboration with UNEP and UNDP, 1994.
- World Resources Institute 1998-99 *A Guide to the Global Environment. Environment Change and Human Health*. Report by the World Resources Institute in collaboration with UNEP and UNDP 1998.