Transboundary Diagnostic Analysis of Land-based Sources and Activities in the Western Indian Ocean

First published in Kenya in 2009 by the United Nations Environment Programme (UNEP)/Nairobi Convention Secretariat and Western Indian Ocean Marine Sciences Association (WIOMSA).

ISBN 9987 - 8977-3-8
UNEP/GEF WIO-LaB Technical Report Series 2009/1

For additional information please contact:

UNEP/Nairobi Convention Secretariat
United Nations Environment Programme
United Nations Avenue, Gigiri,
P.O Box 47074, Nairobi, Kenya
Tel: +254 20 7621250/7622025
E-mail: Nairobi.convention@unep.org

Western Indian Ocean Marine Science Association (WIOMSA)
P.O. Box 3298
Zanzibar, Tanzania
Tel: +255 24 2234597
Fax: +255 24 2233852
E-mail: secretary@wiomsa.org

Principal Authors: Dr. Salomao Bandeira (University of Eduardo Mondlane, Mozambique), Mr. Jude Bijoux (Centre for Marine Research & Technology - Marine Parks Authority, Seychelles), Mr. Anton Earle (African Centre for Water Research, South Africa), Prof. Jan Glazewski (University of Cape Town, South Africa), Dr. Narriman Jiddawi (Institute of Marine Sciences, Zanzibar, Tanzania), Dr. James Kairo and Mr. Jacob Ochiewo (Kenya Marine and Fisheries Research Institute, Kenya), Dr. Sixtus Kayombo (University of Dar es Salaam, Tanzania), Mr. Daniel Malzbender (African Centre for Water Research, South Africa), Mr. Akunga Momanyi (University of Nairobi, Kenya) and Ms. Susan Taljaard

(Council for Scientific and Industrial Research, South Africa).

Technical Editors: Dr. Mathew Richmond, Prof. Rudy van der Elst, Dr. Michael Schleyer, Ms. Bernadine Everett and Ms. Fiona MacKay (Oceanographic Research Institute, South Africa), and Dr. Peter Scheren and Dr. Johnson Kitheka (WIO-LaB Project Management Unit, Kenya).

For citation purposes this document may be cited as:

UNEP/Nairobi Convention Secretariat, 2009. Transboundary Diagnostic Analysis of Land-based Sources and Activities Affecting the Western Indian Ocean Coastal and Marine Environment, UNEP Nairobi, Kenya 378P

Table of contents

Acronyms

ACEP	African Coelacanths Ecosystems Project
ACP	African Caribbean Pacific group of countries
AEIN	Africa Environmental Information Network
AEO	African Environment Outlook
AGOA	African Growth and Opportunity Act
ACLME	Agulhas Current Large Marine Ecosystem
AMCEN	African Ministerial Conference on the Environment
AMCOW	African Ministerial Conference on Water
ANGAP	Association Nationale pour la Gestion des Aires Protégés, Madagascar
ASCLMEs	Agulhas and Somali Current LMEs
BCC	Benguela Current Commission
BCLME	Benguela Current LME
BMU	BEACH Management Unit
BOD	Biochemical Oxygen Demand
CDA	Coast Development Authority of Kenya
CEAS	Coastal Environment Award Scheme
CHM	Clearinghouse Mechanism
CITES	Convention on the International Trade in Endangered Species
COD	Chemical Oxygen Demand
COMESA	Common Market for Eastern and Southern Africa
COSMAR	Coastal and Marine Secretariat
COP	Conference of the Parties
CORDIO	Coral Reef Degradation in the Indian Ocean
CSIR	Council for Scientific and Industrial Research, South Africa
CSO	Civil Society Organizations
DEAT	Department of Environmental Affairs and Tourism (South Africa)
DNE	Direction Nationale de l'Environnement, des Forets et des Stratégies Agricoles (Comores)
DOE	Department of Environment (Seychelles)
DWAF	Department of Water Affairs and Forestry (South Africa)
EA	Environmental Assessment
EAC	East African Community
EACC	East African Coastal Current
EAF/RCU	Eastern African Regional Coordination Center for the Nairobi Convention
EAME	East Africa Marine Ecoregion
EAMS	East Africa Marine Systems
EARO	East Africa Regional Office (IUCN)
EARPO	Eastern Africa Regional Programme Office (WWF)
EC	European Community
EIA	Environmental Impact Assessment
EIS	Environmental Information System
EEZ	Exclusive Economic Zone
EHN	Empresa Nacional de Hidrocabonatos
EJ	Equatorial Jet
ELVs	Effluent Limit Values

EMPS	Environmental Management Plan of Seychelles
EPZ	Export Processing Zone
EQO	Environmental Quality Objectives
EQO/Ts	Environmental Quality Objectives and Targets
EQS	Environmental Quality Standards (also referred to as Quality Guideline Values)
EPA	Environment Protection Act 1994
EU	European Union
FARI	Forum for Academic and Research Institutions in the WIO-Region
FAO	Food and Agricultural Organisation of the United Nations
FPSO	Floating, production, storage and offloading (of cargo from vessel)
GEF	Global Environment Facility
GEMPA-EA	Group of Experts for Marine Protected Areas in Eastern Africa
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution
GDP	Gross Domestic Product
GIS	Geographical Information System
GIWA	Global International Waters Assessment
GNI	Gross National Income
GNP	Gross National Product
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP)
GWP	Global Water Partnership
HDI	Human Development Index
IAEA	International Atomic Energy Agency
IAEA-MESL	International Atomic Energy Agency Marine Environmental Studies Laboratory
IAIA	International Association for Impact Assessment
ICAM	Integrated Coastal Area Management
ICARM	Integrated Coastal Area and River Basin Management
ICZM	Integrated Coastal Zone Management
IFIs	International Financial Institutions
IMO	International Maritime Organisation
IMS	Institute of Marine Sciences, Tanzania
IOC	Indian Ocean Commission
IOC-UNESCO	Inter-governmental Oceanographic Commission of UNESCO
ISO	International Standards Organization
IT	Information Technology
IOTC	Indian Ocean Tuna Commission
IUCN	The World Conservation Union
IW	International Waters
IWMI	International Water Management Institute of the Consultative Group on International Agricultural Research
IWRM	Integrated Water Resources Management
KMF	Kenya Marine Forum
KMFRI	Kenya Marine and Fisheries Research Institute
KOBWA	Komati Basin Water Authority
LBSA	Land-based Sources and Activities
LME	Large Marine Ecosystem
MAP	Mean Annual Precipitation

MAR	Mean Annual Runoff
MBREMP	Mnazi Bay-Ruvuma Estuary Marine Park
MCEN	Marine and Coastal Educator's Network
MCM	Marine and Coastal Management
MENRT	Ministry of Environment, Natural Resources and Transport, Seychelles
MDG	Millennium Development Goals
MICOA	Ministério de Coordenaçao Ambiental, Mozambique
MOE	Ministry of Environment and National Development Unit, Mauritius
MPA	Marine Protected Area
MSP	Medium Sized Project
MWW	Municipal Wastewater
NCS	Nairobi Convention Secretariat
NEMA	National Environmental Management Authority (Kenya)
NEMC	National Environmental Management Council (Tanzania)
NEPAD	New Partnership for Africa's Development
NFP	National Focal Point
NFPI	National Focal Point Institution
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration (United States)
NORAD	Norwegian Development Agency
NPA	National Programme of Action
OMNIS	Office des Mines Nationales et des Industries Stratégiques
ONE	Organisation Nationale pour l'Environnement (Madagascar)
ORI	Oceanographic Research Institute, South Africa
PADH	Physical Alteration and Destruction of Habitats
PAH	Polyaromatic hydrocarbon
PACSICOM	Pan African Conference on Sustainable Integrated Coastal Management
PCB	Polychlorinated biphenyl
PDF-B	Project Development Facility Block B Grant
PMU	Project Management Unit
POPs	Persistent Organic Pollutants
PPP	Public Private Partnership
PSA	Product Sharing Agreement
PSC	Project Steering Committee
PSU	Practical Salinity Unity
RAC	Regional Activity Centre
RCU	Regional Coordinating Unit (of Nairobi Convention)
RSP	Regional Sea Programme
RSA	Republic of South Africa
RWQO	Receiving Water Quality Objectives
SADC	Southern African Development Community
SAIEA	Southern African Institute for Environmental Assessment
SAMSA	South African Maritime Authority
SAP	Strategic Action Programme
SAREC	Swedish Agency for Research Cooperation with developing countries
SANBI	South African National Biodiversity Institute
SCLME	Somali Current Large Marine Ecosystem
SEA	Strategic Environmental Assessment
SEACAM	Secretariat for East African Coastal Area Management

SIDS	Small Island development State
STAC	Scientific and Technical Advisory Committee
SWCI	Shared Watercourse Institutions
SWIOFC	South-Western Indian Ocean Fisheries Commission
SWIOFP	South-Western Indian Ocean Fisheries Project
STAC	Scientific and Technical Advisory Committee
TCMP	Tanzania Coast Management Partnership
TDA	Transboundary Diagnostic Assessment
TIA	Transboundary Impact Assessment
TOR	Terms of References
TPDC	Tanzania Petroleum Development Corporation
TTT	TDA Task Team
UCD	Urbanization and Coastal Development
UDSM	University of Dar es Salaam
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Scientific and Cultural Organization
UNWTO	United Nations World Tourism Organisation
USAID	United States Agency for International Development
WCS	World Conservation Society
WHO	World Health Organisation
WIO	Western Indian Ocean
WIO-C	Consortium for the Conservation of the Coastal and Marine Ecosystems in the Western Indian Ocean
WIO-LaB	Addressing Land-based Activities in the West Indian Ocean
WIOMSA	Western Indian Ocean Marine Sciences Association
WSSD	World Summit for Sustainable Development
WWF	World Wildlife Fund for Nature
ZAMCOM	Zambezi River Basin Commission
ZRA	Zambezi River Authority

Acknowledgements

Many regional and national institutions and organizations, as well as individual experts, participated in the preparation of this Transboundary Diagnostic Analysis (TDA) of land-based sources and activities affecting the Western Indian Ocean (WIO) coastal and marine environment. In this regard, we would like to extend our appreciation for the valuable contributions made by participating institutions and organisations, as well as by individual experts. In particular, we would like to thank the principal authors of this TDA, the members of the Scientific and Technical Advisory Committee established under the auspices of the Forum of Academic and Research Institutions in the WIO region, which scrutinized the various sections of the TDA, as well as the members of the various Regional and National Task Forces established under the auspices of the Nairobi Convention WIO-LaB Project: the Municipal Wastewater Management Task Force, the Physical Alteration and Destruction of Habitats Task Force, the Environmental Impact Assessment Task Force, the Legal and Technical Review Task Force and the Regional Working Group on Water, Sediment and Biota Quality. We would also like to thank the valuable contributions received from numerous national, regional and international governmental and non-governmental organisation in the process, either through the provision of relevant background information and documentation, or through their facilitation of the intensive stakeholder involvement processes that took place on both national and regional level. Last but not least, we thank the Global Environment Facility (GEF) and the Government of Norway for providing funds that enabled the successful development of this TDA.

While it would be quite impossible to thank all individuals of the above-mentioned organisations for their contributions, a list of persons who played a key role in the development of this TDA is presented in Annex 1.

Photo courtesy of Peter Scheren

Executive Summary

This document presents the results of a series of investigations and expert analyses relating to land-based sources of pollution and other activities that cause the degradation of the coastal and marine environment in the West Indian Ocean (WIO). More specifically, it identifies those elements that may induce impacts beyond national boundaries or that are problems common to several countries of the region. Collectively, this represents a Transboundary Analysis (TDA); a decision support tool intended to inform countries in the WIO region with regard to priority issues and problems to be addressed within the context of immediate and long-term sustainable management of the WIO coastal and marine ecosystems. In this regard, the TDA forms the basis for the development of a comprehensive Strategic Action Programme (SAP) for addressing land-based sources and activities.

The Western Indian Ocean: a region of global and local significance

The WIO region extends from approximately latitude 12°N to 34°S and longitude 30°E to 80°E, an area of some 30 million km^2, equivalent to 8.1% of the global ocean surface. Its combined coastline exceeds 15,000 km^2 and a total continental shelf area of approximately 450,000 km^2. Water circulation patterns in the WIO are determined by prevailing winds and ocean currents, especially the westward-flowing South Equatorial Current, the northward Somali Current, the East Madagascar Current, the strong western Agulhas Boundary Current and a series of slow-moving gyres or eddies that constitute the Mozambique Current. The WIO encompasses a large array of marine and coastal settings, ranging from small volcanic and coral islands to large continental countries with extensive coastlines and tropical and subtropical climates; the African mainland states are Somalia, Kenya, Tanzania, Mozambique and South Africa, while the island states are Mauritius, Comoros, Seychelles, Madagascar and La Réunion (France).

The WIO's diverse coastal and marine ecosystems, which include coastal lowland forests, mangroves, seagrass beds and coral reef, support the productivity of the large marine ecosystems, including fisheries. The region features a high level of biodiversity, including more than 2,200 species of fish, over 300 species of hard coral, 10 species of mangrove, 12 species of seagrass, over 1,000 species of seaweed, several hundred types of sponge, 3,000 species of molluscs, 300 species of crabs and more than 400 echinoderms. The region also sustains unique taxonomic groups, zones of high endemism as well as a suite of highly vulnerable and unusual species such as coelacanths, whale sharks and sawfishes, five of the world's seven species of marine turtle and more than 38 cetacean species. The total coral reef area is estimated at 13,000 km^2, mangrove forests covering 10,000 km^2 as well as large areas of other coastal habitats such as seagrass beds, coastal forests, sandy beaches and rocky shores.

The many river basins in the region, among which 12 major ones, have highly variable flow rates and sediment loads. Freshwater discharges from these rivers have a profound effect on the marine ecosystems in the region, driving various ecological processes and providing nutrients to sustain living marine resources, their coastal estuaries serving as habitat and nursery grounds for numerous fish and crustaceans.

The coastal and marine ecosystems provide essential sources of livelihood and income for numerous coastal inhabitants, and contribute to the growing economies of countries in the region. Over 60 million people, or more than 1/3 of the total population of the countries bordering the WIO inhabit the coastal areas of the WIO region, many of them dependent on the goods and services provided by the coastal and marine environment for their livelihood. A basic socio-economic valuation study undertaken as part of the TDA estimates the total value of the goods and services provided by the WIO coastal and marine habitats at 25 billion US dollars per year, but potentially more. It is estimated that the direct benefits obtained from coastal goods and services in South Africa, the largest economy in the region, are equivalent to about 35% of the country's gross domestic product.

Tourism is the largest source of income that is directly linked to the coastal and marine environment; the region's beautiful sandy beaches, mangrove forests, lagoons and coral reefs attract over 20 million tourists from all over the world every year, injecting more than 6 billion US dollars per year into the economies of the countries of the WIO region. In general, tourism arrivals in sub-Saharan Africa have increased by 8% over the past 15 years, therefore providing an important economic growth sector.

The coastal and marine waters of the WIO, and in particular its coastal waters, lagoons, estuaries and continental shelves are also important fishing grounds. According to official statistics, the region generates about 4.8 % of the global fish catch, equivalent to about 4.5 million tonnes of fish per year, although this is likely to be an underestimate due to the under-reporting of catches by some of the countries. While not as productive as some other well known fishing grounds in the world, the WIO fisheries sector is still of high importance in terms of food security, employment, and income generation for the growing coastal population. Furthermore, mangroves, seagrass meadows and coral reefs provide coastal protection, as well as food and shelter for fishes, crustaceans, molluscs and other organisms of immense ecological and commercial value.

The need for action

The WIO region's rapidly growing population is exerting large pressure on the marine environment, through pollution, degradation of critical coastal habitats and changes in the freshwater flow and sediment loads from rivers draining into the western Indian Ocean. Today, the coastal zone of the region hosts major cities, harbours, industries and other development infrastructure that is increasingly posing a threat to the integrity of the coastal and marine ecosystems. Other pressures are associated with high volumes of tourism and poorly regulated inshore and offshore fishing, activities that have increased considerably in the recent past. Recognising the enormous development needs of countries around the WIO and noting the growing natural and anthropogenic pressure imposed on the region, presents not only challenges but also an opportunity to avoid serious degradation in one of the world's unique and highly biodiverse oceans.

Recognizing that the threats to the productivity and integrity of the coastal and marine environment due to pollution and habitat degradation are not confined to national boundaries, the governments of the WIO region, in 1985, signed the Nairobi Convention. This Convention offers a vital regional platform for the protection, management and development of the marine and coastal environment in the Eastern and Southern African region. The United Nations Environment Programme (UNEP), hosting the Secretariat of the Nairobi Convention, has actively supported the efforts of the governments in Eastern and Southern Africa to develop more sustainable approaches for the management of their common marine and coastal ecosystems. One initiative in this endeavour is a project entitled "Addressing land-based Activities in the Western Indian Ocean," widely known as the "WIO-LaB Project". The project was funded by the Global Environment Facility (GEF), the Government of Norway and UNEP, participating countries, and implemented within the framework of Nairobi Convention in the period 2005 to 2010. The broad vision of this project was to assist governments in the WIO region to build the necessary capacity for addressing the challenges faced by countries in the management and protection of their marine and coastal environment from impacts originating from land[1].

As part of the WIO-LaB project, a region-wide assessment of transboundary problems and issues affecting the marine environment in the WIO region was undertaken. The outputs of these assessments led to the formulation of a Transboundary Diagnostic Analysis (TDA), detailing key problems and causes of degradation of the coastal and marine environment in the WIO region, with a special emphasis on land-based sources and activities (LBSA). The TDA, in turn, is intended to provide the basis for the formulation of a Strategic Action Programme (SAP) for addressing the challenges faced by governments in the region.

The TDA development process

Between 2005 and 2009, within the context of the WIO-LaB project, a comprehensive, region-wide analysis of priority transboundary problems related to land-based activities and sources of degradation of the coastal and marine environment was undertaken. The development of the TDA was led by a multi-disciplinary team of experts drawn from leading institutions in the WIO region, with specialization in relevant fields, such as marine pollution, coastal habitats, fisheries, river–coast interactions, governance and socio-economics. The TDA development process followed five main steps:

1. Establishment of the multi-disciplinary TDA task team;
2. Initial identification of transboundary problems;
3. Fact finding (data collection and analysis);
4. Causal chain and governance analysis; and
5. Review and validation of the TDA.

The data and information used in the preparation of the TDA was derived from various thematic assessment studies undertaken under the auspices of the WIO-LaB Project. A total of 12 regional and 48 national thematic assessment studies were undertaken between 2004 and 2009, focusing on 7 thematic areas, namely: (i) Legal, Policy and Institutional Frameworks; (ii) Water, Sediment and Biota Quality; (iii) Physical Alteration and Destruction of Habitats; (iv) Municipal Wastewater Management; (v) Marine Litter; (vi) Alteration in Freshwater Flows and Sediment Loads in Key River Basins; and (vii) Environmental Impact Assessment.

In addition, the project made use of a huge body of relevant literature, including over 550 published and unpublished reports, journal papers, and others, generated through other studies and regional processes. Also, a total of 15 regional technical workshops on various thematic areas were held with the objective of providing a comprehensive analysis of transboundary problems in the WIO region, including their root causes. During the process, over 500 experts and stakeholders were consulted, drawn mainly from key academic and research institutions, government agencies and regional organizations, as well as NGOs that are active in coastal and marine development and conservation. The review and validation of the TDA was undertaken by

---

1 It should be noted that Somalia and La Réunion (France) did not officially participate in the WIO-LaB project. Although information gathered on these countries is presented in the TDA, a detailed analysis of hotspots in Somalia and La Réunion was not part of the assessment.

a Scientific and Technical Review Committee established within the framework of the Forum for Academic and Research Institutions in the WIO-Region (FARI).

Overview of findings of the TDA

The TDA identifies three main clusters of land-based transboundary pressures on coastal and marine ecosystems:

1. Water and sediment quality degeneration due to pollution;
2. Physical alteration and destruction of habitats; and
3. Alteration in freshwater flows and sediment loads from river basins.

In addition, the TDA presents a detailed analysis of governance and awareness related aspects of land-based sources and activities management. The following sections present a summary of the findings of the TDA with regard to each of these problem areas.

Problem Area 1: Water and sediment quality degeneration due to pollution

A significant amount of the pollution load to the WIO emanates from land-based activities, such as domestic and industrial effluents, and contaminated surface and sub-surface runoff from urban and agricultural areas[2]

. The TDA found that the highest pollutant loads entering the WIO originate from the mainland states and Madagascar, with South Africa and Tanzania contributing approximately 80% of the overall loading of nutrients and organic matter.

The estimated loads of organic material (BOD), suspended solids, nitrogen and phosphorous generated from municipal wastewater in coastal areas of the WIO region are 70,000, 97,000, 18,000 and 4,000 tonnes per year, respectively. Pollution is mainly concentrated around specific hot spot areas (the TDA identifies 39 principal hotspots[1]) located in and around the main urban centres such as Mombasa, Dar es Salaam, Maputo, Durban, Tuléar, Port Louis, and Port Victoria, where they affect some of the most productive areas of the coastal and marine environment, such as estuaries and near-shore waters.

Photo courtesy of UNEP

2 Detailed analyses are presented in the national and regional Pollution Status Report prepared under the auspices of the WIO-LaB project: Anon Madagascar, 2009, Anon Mozambique, 2007; Anon Mauritius, 2009; Munga et al., 2009; Mohammed et al., 2009; Abdallah et al., 2009; Dubula et al., 2009; Antoine et al., 2009; and UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a.

The TDA identifies five pollution categories:

Microbial contamination	The TDA found that microbial contamination is the most widespread type of pollution in the region, and has most impact in terms of health risk to the population (through both direct contact with seawater and consumption of seafood products). Microbial contamination is typically associated with inappropriate disposal of municipal wastewater, contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing and industrial effluents (mainly from food-processing industries).
High suspended solids	High suspended solid loads from land-based sources enter WIO coastal waters mainly through municipal and industrial wastewater discharges, river discharges and surface runoff, particularly during rainy seasons. Dredging activities (usually associated with ports and harbours) can also significantly contribute to this problem. High levels of suspended solids in the WIO region are particularly found around urban areas, river outlets and ports.
Chemical pollution	Chemical pollutants in the WIO region are typically linked to agrochemical discharges (accidental or intentional), industrial discharges, dredging activities in ports and harbours (re-suspending sediment-bound heavy metals and hydrocarbons), and leachate from solid waste dumpsites. The highest levels of chemical contaminants in the region have been detected around some of the major urban areas, in particular in and around ports.
Marine litter/solid waste	Most of the major cities and towns found in the WIO region generate significant amounts of solid wastes, some of which reach the sea to contribute to marine litter problem, as well as discharges through rivers (transporting solid waste/debris from urban areas located in their watersheds). Marine litter is a common feature along the coasts of the WIO region, especially Comoros, Mozambique, Kenya and Tanzania.
Eutrophication	Eutrophication - or enhanced algal and phytoplankton growth - is a result of the increased availability or supply of nutrients, usually related to inappropriate disposal of municipal wastewater or nutrient-enriched agricultural return flows. In the WIO region, elevated levels of nutrients have been recorded in many hotspots, with cases of eutrophication noted in few cases, in particular in Seychelles and Mauritius.

Problem Area 2: Physical alteration and destruction of habitats (PADH)

The TDA found that one of the priority transboundary problems for the WIO region is rapid and unmanaged transformation of the coastal land- and seascape and consequent loss of critical habitats that provide essential ecosystem goods and services. This transformation is often driven by increased economic activities such as construction of beach hotels, resorts, marinas and ports. Dredging, sand winning, beach reclamation, mining, extraction of minerals, laying of pipelines (oil, water and gas) and wastewater outfalls all add to a long list of anthropogenic activities that lead to the alteration of shorelines and habitats in the WIO region.

In addition, excessive exploitation of living resources such as coastal forests, mangroves, seagrass meadows and coral reefs further degrade critical habitats that are already stressed by global climate change. Also, land reclamation for agriculture, aquaculture and coastal development, as well as extensive deforestation of catchment areas (watersheds), is causing changes in the flow of freshwater and sediments to the coast. Finally, invasive species are increasingly claiming their place in the ecosystem structure. The cumulative impacts of these transformations and losses have led to significant physical and ecological changes and an overall deterioration in many ecosystem goods and services. The TDA identifies 25 principal hotspots in the WIO region[1].

Photo courtesy of Rudy v.d. Elst/ORI

The impacts of habitat transformation in the WIO can be grouped into five categories:

Degradation of mangrove forests	Mangrove wetlands are controlled by several interacting factors such as tides, periodicity of freshwater and sediment fluxes, topography, soil and water salinity, temperature and sedimentation patterns, factors that are closely related to land- and water-use practices in the areas adjacent to and upstream of mangrove forests. Human-induced stresses range from diversion of freshwater flow, poor land use in and around mangrove forests to over-exploitation of mangrove resources. These stresses disrupt the natural equilibrium, ultimately leading to the degradation of the mangrove wetlands, which in turn not only depletes the resources within their boundaries, but also affects the productivity of adjacent coastal and marine ecosystems. It is estimated that the region has lost 50% of its mangrove cover over the past century.
Degradation of seagrass beds	Seagrass degradation in the WIO region is generally evidenced by continued destruction and/or reduction of seagrass habitats in shallow inter-tidal and sub-tidal areas. This degradation is usually as a result of physical action (e.g. dragging of nets, or clearing), pollution or by climate change through increased discharge of sediment-laden low-salinity water derived from flooded river systems. Seagrass degradation has negative impacts on the system's productivity, biodiversity and hence food security, ultimately leading to loss of livelihood and increased poverty among coastal populations.
Degradation of coral reefs	Coral reef ecosystems face various types and levels of impact across the WIO region. In addition to anthropogenic threats such as destructive fishing activities, there is climate change, which led to severe coral bleaching during the 1998 El Niño/Southern Oscillation phenomenon, damaging reefs throughout the region, in some areas causing up to 95% bleaching. Continuous degradation of coral reef biodiversity lowers fisheries productivity and leaves shorelines unprotected, impacting on livelihood and incomes of local communities, thereby increasing poverty levels.
Degradation of coastal forests	Degradation of coastal forests occurs mainly in the form of land transformation through intense clearing for agriculture, mining, human settlement and coastal development, including tourism. There is also destruction associated with an increased demand for forest products such as timber and firewood. Transformation of coastal forests has a significant impact on the coastal environment through reduction of plant and faunal diversity, loss of fertile soils, increased soil erosion, and a reduction in the recharge of groundwater aquifers. Ultimately, these impacts change the dynamics of both sediment and water exchange in the coastal zone.
Shoreline changes	Erosion and accretion of coastlines can result in significant shoreline change. Sea level rise, as well as episodic storm events (in part driven by climate change), have an impact on critical habitats, coastal infrastructure, agricultural land and human settlements. As many WIO shores are dominated by rapidly eroding sediments and low-lying wetlands, the impact of sea level rise and storms are accentuated. Changes in accretion of the coast originate from two main sources: changes in sediment loads from rivers and the re-suspension of benthic sediments by rough seas. In addition, increased water turbidity, due to re-suspended sediments, can result in smothering of corals, seagrasses and mangroves, hence further contributing to shoreline change.

Problem Area 3: Alteration in freshwater flows and sediment loads from rivers

The WIO region is endowed with a number of important rivers, including some transboundary rivers such as the Zambezi, Incomati and Ruvuma. These rivers are important not only in terms of provision of freshwater to both rural and urban areas, but also for their role in sustaining the riverine, estuarine and marine physico-chemical and ecological processes and productivity. Throughout much of the region, and particularly in continental states, important transformations of the coastal and marine environment can be attributed to human activities and climatic variability occurring in the river basins. The impacts from human activities on the river basins, such as impeded flow of freshwater, terrigenous sediment and increased organic matter, have altered the nature of the interaction between river systems and coastal processes. Also, nutrients and pollutants from domestic sewage and industrial and agricultural chemicals have led to water quality degradation in some of the major river systems that drain into the WIO.

According to the TDA, the most affected river basins are Pangani (Kenya and Tanzania); Athi-Sabaki (Kenya); Incomati (South Africa, Swaziland and Mozambique); Zambezi (Angola, Botswana, Democratic Republic of Congo (DRC), Malawi, Namibia, Tanzania, Zambia, Zimbabwe and Mozambique); and Betsiboka (Madagascar). In addition, the numerous smaller rivers found throughout the region have not escaped human influences, although the extent of alteration strongly varies.


Photo courtesy of Rudy v.d. Elst/ORI

The TDA distinguishes the two main categories of river–coast interaction:

Alteration of river flows and water quality	The alteration of the natural river flow (and consequent possible change in water quality) is found to some degree in many of the major river basins in the WIO region. The four most frequent reasons for flow alterations are: (i) overall reduced flow due to consumptive uses of water, (ii) increase of river surface area along sections of the river due to impoundment/damming, (iii) changed seasonal flow patterns (e.g. releases for hydropower-generation during the dry season), and (iv) increased floods due to wetland losses (loss of water retention capacity). These are coupled with the large-scale realities and uncertainties brought about as a consequence of climatic change, as a result of which some basins are predicted to receive more rainfall than the historic mean and others less.
Alteration of sediment loads	Although less common than flow alteration, a number of factors, such as changing climate, land-use practices and dam construction, have led to changes in the sediment load transported by some of the rivers in the WIO region. The alteration of sediment loads in the WIO region rivers broadly manifests itself in three ways: • Increased sediment loads – this has a negative impact on the coastal and marine environment, through for example the degradation (smothering) of mangroves, coral reefs and seagrass beds, as in the case of Athi-Sabaki and Mwache river in Kenya, and the Betsiboka river in Mozambique. • Decreased sediment loads – has a negative impact on the marine environment through increased erosion of the delta mouth, and through increased salt-water intrusion, leading to a reduction of downstream habitats for mangroves and other species, as in the case of the Tana River in Kenya, and the Zambezi and Incomati rivers in Mozambique. • Variable sediment loads in different parts of the basin - in some ivers, there is both increased sediment loads from erosion in upstream areas, and reduced sediment transport downstream of dams due to trapping of the sediments behind the dam wall.

Cross-cutting theme: Problems related to governance and awareness

Despite the creation of national institutions and the enactment of national laws, supported by international conventions, the management of the coastal and marine environment in the WIO region is still challenging. While most countries in the region have put in place policy, legal, regulatory and institutional frameworks that are relevant to the protection and management of the coastal and marine environment, many have not succeeded in reversing the trend of degradation of coastal and marine ecosystems.

A key recommendation from the governance analysis undertaken as part of the TDA process is that crosscutting governance instruments and tools need to be developed and promoted to meet the unique challenges in the coastal zone. Such instruments and tools are based on the application of Ecosystem-Based Management Approaches (EBM), including Integrated Coastal Zone Management (ICZM), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), and Marine Protected Areas (MPAs). A positive development is that virtually all WIO countries have to a certain extent commenced, or at least considered the application of such instruments and tools in their areas of jurisdiction. However, there is still need to build capacity at the country level in these areas.

Other recommendations for the TDA focus on the development and harmonization of legislative and regulatory instruments at the regional level, including the strengthening of coordination between relevant regional institutions for the implementation of the same. Finally, in light of the fact that the socio-economic importance of the coastal and marine environment in the WIO region is often inadequately considered in national policy formulation and planning processes, there is a strong need for awareness raising and capacity building at the level of policy makers.

An overview of the main limitations in LBSA governance identified in the TDA is presented below.

Policy and legislative inadequacies	• Inadequate updating, implementation, enforcement and monitoring of relevant legislation • Inadequate ratification and domestication of relevant international and regional instruments
Limited institutional capacity	• Lack of mechanisms for effective coordination and inter-sectoral governance • Inadequate human resources and technical capacity in institutions charged with the responsibility of addressing LBSA-related issues
Inadequate awareness	• Inadequate awareness, understanding and appreciation of the economic value of coastal/marine ecosystem goods and services among policy makers and legislators, the civil society and the private sector
Inadequate financial mechanisms	• Inadequate financial mechanisms and resources for dealing with LBSA-related issues
Poor knowledge management	• Lack of adequate scientific and socio-economic data and information to support policy making, monitoring and enforcement

Root causes and stakeholder sectors related to transboundary problems

The WIO LaB TDA identified the root causes of the transboundary problems related to the coastal and marine environment in the WIO region. An overview of the main root causes of degradation from land-based sources and activities is presented below:

Generic Root -Causes
A. Population pressure Rapid population growth and associated urbanization in the WIO region has increased the generation of waste and concentration of waste streams. Also, population growth has led to increased demand for ecosystem goods and services.
B. Poverty and inequality The WIO region is characterized by high poverty levels, which result in increased reliance on the exploitation of natural resources. The consequent lack of financial resources has led to problems such as inadequate sanitation infrastructure, and institutions and regulatory bodies lacking capacity.
C. Inadequate governance In the countries of the WIO region there exists a weakness in policy, legal and institutional structures and building blocks for effective management of the coastal and marine environment.
D. Inadequate financial resources Most countries in the WIO region do not have adequate financial resources, whether in absolute terms or through inadequate priority setting, for effective management of the coastal and marine environment.
E. Inadequate knowledge and awareness Gaps in the knowledge base and inadequate awareness of the value of ecosystem goods and services provided by a healthy coastal and marine environment are a major cause of management inefficiencies by coastal communities and policy makers in the WIO region.

F. Climate change and natural variability
Climate change and variability in the WIO region is already influencing rainfall patterns, evidenced by the frequency and intensity of extreme weather events, changing the flow patterns of rivers (causing floods and impacting on floodplains, deltas and coastal ecosystems) and other events such as the bleaching of corals.

G. Economic drivers
The demand for ecosystem goods and services, including from export markets, is exceeding the availability and regeneration capacity of elements of the ecosystems in the WIO region.

The TDA furthermore identifies the main stakeholder groups that are relevant within the context land-based sources and activities management. It was found that most economic sectors (fisheries, agriculture, tourism, industry, mining, transportation, energy production) as well as urbanization in general, are attributable to pressures related to most if not all of the problem areas. This reinforces the need, as earlier mentioned, for adequate cross-sectoral management.

At the receiving end, those that are being affected by the problems, stands mostly the coastal communities, either as 'passive' victims (e.g. affected by pollution or more indirectly by economic development restraints) or as 'active' resource users (e.g. fishermen, coastal tourism operators). In this regard, the 1/3 of the population of the countries bordering the WIO region living within the larger coastal zone (<100 km from the coast), as well as arguably the economies of the countries as a whole, are all somehow affected by the negative impacts of land-based sources and activities in the coastal zone.


THE RED DEVILS
MANCHESTER UNITED
TAYSEER

Chapter 1 - Introduction

Figure 1-1: Map of the Western Indian Ocean Region

1. Introduction

1.1 The Western Indian Ocean setting

The Western Indian Ocean (WIO) region extends from approximately latitude 12° N to 34° S and longitude 30o E to 80o E, an area of some 30 million km2, equivalent to 8.1% of the global ocean surface (FAO, 2007) (Figure 1-1). The region has distinct ocean circulation patterns with two large western boundary currents: the seasonal Somali Current that runs northwards, approximately from the equator; and the large meandering Agulhas Current that flows poleward and exhibits many outstanding oceanographic features. Monsoonal circulation, gyres, current retroflections, rings and eddies are all oceanographic features that characterise the uniqueness of the region (Lutjeharms, 2006). The WIO encompasses a large array of marine and coastal settings, ranging from small volcanic and coral islands to large continental countries with extensive coastlines and tropical and subtropical climates; the African mainland states are Somalia, Kenya, Tanzania, Mozambique and South Africa, while the island states are Mauritius, Comoros, Seychelles, Madagascar and Réunion (France).

In addition to the larger islands and landmasses, there are a number of smaller islands and atolls, many uninhabited, that have unique biota and act as biodiversity hotspots and refugia. Though remote, their protection from pollution, alteration of habitat and non-sustainable development should equally be seen as an essential element of WIO protection. In particular, nesting turtles, endangered seabirds and vulnerable fish species are key biota on islands such as Europa, Glorieuses. Juan de Nova, Bassas de India, Tromalin, and the smaller islands of the Seychelles group.

The WIO countries not only share an ocean with common biological resources and climatic features but also many historical, cultural and economic ties. Despite these commonalities, the countries in the region are at different stages of both political and economic development, reflected among others by the individual economic indicators for countries in the region ranging from those with a *per capita* gross national product (GNP) of over $ 8,000 per annum (Seychelles and Reunion), to those with less than $1,000 GNP (Comoros, Tanzania, and Madagascar) (UNDP, 2007; World Bank, 2009a).

Over 60 million people inhabit the coastal areas of the region although the overall coastal population density of the region is not exceptionally high. However, while large areas may lack coastal populations, such as much of the Somali coastline, certain areas are densely populated. Urbanization pressures appear most marked in the mainland states, where coastal cities such as Mombasa (Kenya), Dar es Salaam (Tanzania), Maputo (Mozambique) and Durban (South Africa) are supporting populations of 2 to 4 million each. However, island states do not escape urbanization pressures as seen in Port Louis (Mauritius), Moroni (Comoros) and Victoria (Seychelles).

These same coastal settlements are centres of economic activities in the WIO region, sheltering internationally important harbours that handle most of the region's incoming and outward-bound ship-borne cargo. Mainland countries are rich in mineral deposits, with most mining activities taking place inland, but increasingly, coastal mining is becoming a significant activity in South Africa, Kenya, Mozambique, Tanzania and Madagascar (SEACAM, 2003). Recently, extensive oil and gas exploration and development in the coastal zone has begun in Tanzania and Mozambique, with increased activity in Kenya, including deep-water exploration well-drilling. Similar exploration is taking place off Madagascar and Seychelles.

During the last three decades, the tourism industry played an important role in the economic development of most of the countries of the WIO region. Tourism expansion has been actively pursued by national governments because of its positive effects on national income, high levels of employment and diversification of the economic structure. Much of the tourism activity takes place in coastal areas, often associated with Marine Protected Areas (MPAs).

1.2 Global and regional significance of the WIO region

The marine and coastal environment in the WIO is recognized for its high ecological and economic value. The region is considered a distinct division of the tropical Indo-West Pacific, the world's largest marine bio-geographic province (Sheppard, 1987; 2000). The WIO region sustains a high level of biodiversity, including more than 2,200 species of fish, over 300 species of hard coral, 10 species of mangrove, 12 species of seagrass, over 1,000 species of seaweed, several hundred types of sponge, 3,000 species of molluscs, 300 species of crabs and more than 400 echinoderms (Richmond, 2001). The WIO region also has several unique taxonomic groups and certain zones with high levels of endemism. Some invertebrate groups are more than 20% endemic, while the subtraction zone of southern Mozambique and KwaZulu-Natal have high fish endemicity – up to 13%. Highly vulnerable and unusual species occur, such as coelacanths, whale sharks and sawfishes, while five of the world's seven turtle species nest on beaches of the region. The cetacean fauna is also rich with more than 38 cetacean species found here and especially diverse towards higher latitudes (Best 2007; Berggren, 2009).

The biological richness and natural beauty of the WIO region, including its beaches, mangrove forests, lagoons and coral reefs, represent a basis for the region's important tourism sector, attracting visitors from all over the world. Its marine waters, and in particular its continental shelves, coastal margins, lagoons and estuaries are important fishing grounds for a great diversity of fishers, ranging from artisanal fishers using traditional gear to industrial fisheries generating food, employment and foreign exchange. The WIO Region generates about 4.8 % of the global fish catch, equivalent to about 4.5 million tonnes of fish per year (FAO, 2007), although this is likely to be an underestimate due to the under-reporting of catches by some of the countries (Van der Elst *et al*, 2005). Besides biological productivity, the various diverse coastal habitats of the WIO also provide coastal protection, food, shelter and safety for fishes, crustaceans, molluscs and other organisms of ecological and commercial value.

Although the WIO is still considered to be one of the least ecologically disturbed areas of global oceans, it cannot escape the impacts of global change and human development, so that the region is increasingly threatened by natural and anthropogenic events. In the recent past, coastal and marine environments have started showing signs of degradation, attributed to both natural factors (Lindén and Sporrong, 1999) and a variety of human activities, acting at different intensities and in various combinations. The coastal zone of the WIO region is the site of major cities, harbours, industries and other socio-economic infrastructure, which affect the environment. Pollution from domestic, industrial and agricultural sources increasingly degrade water and sediment quality, resulting in loss of biological diversity, problems for human health, a reduction in fish stocks and associated threats to food security. Human activities also cause physical alteration of the coastal zone which can induce or accelerate coastal erosion and further lead to the destruction of vital habitats such as mangrove forests, seagrass meadows and coral reefs. Recognising the enormous development needs of countries around the WIO and noting the growing natural and anthropogenic pressure imposed on the region, presents not only challenges but also an opportunity to avoid serious degradation in one of the world's unique and highly biodiverse oceans.

The Western Indian Ocean: home of the coelacanth and many other vulnerable species

1.3 A call for action

Most countries in the region currently lack sufficient capacity and regulatory frameworks to adequately manage threats to their coastal zone. Moreover, it is generally recognised that the protection, management and development of the shared ecosystems of the WIO would be enhanced through a regional approach, because the impacts of many sources and activities are not confined to national borders. The dynamic components of the WIO, such as winds, currents, rivers and tides exist on scales larger than geopolitical entities, and over-exploitation, habitat destruction or degeneration in water quality in one part of the WIO may adversely impact on one or more neighbouring countries. Furthermore, problems identified in one country may be similar to those in others, so that a common approach to solving shared problems can strengthen the region's overall response to land based sources and activities that cause degradation.

Recognizing these facts, the First Meeting of the Contracting Parties to the Convention for the Protection, Management and Development of the Marine and Coastal Environment in the Eastern African Region (The Nairobi Convention) in March 1997 called for concerted action to address the increasing impact of human activities on the WIO coastal and marine environment. Based upon this call, UNEP, as the host for the Secretariat of the Nairobi Convention, took the lead in developing a preliminary Transboundary Diagnostic Analysis (TDA) and Strategic Action Plan (SAP) for the WIO region, facilitated through a Global Environment Facility (GEF) Project Development Facility Block B (PDF-B) Grant.

The preliminary TDA and SAP (UNEP 2002a), which were finalized in 2002, defined a number of priority areas for intervention and further identified gaps in information that needed to be filled in order to make better-founded management decisions. These documents built strongly on the outcome of the GEF Medium-sized Project (MSP) "Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa" (often referred to as "The African Process"). Subsequently, three regional projects were developed within the GEF framework in order to undertake strategic data collection and analysis and to define and demonstrate appropriate strategies that would address priority problems in the WIO region. These projects, and their respective implementation agencies, are as follows:

1. **The Project "Addressing Land-based Sources and Activities of Degradation in the Western Indian Ocean" (WIO-LaB)**, with a mandate primarily focused on the issues relating to land-based sources of pollution and other activities that impact on the marine and coastal environment (UNEP);

2. **Agulhas and Somali Current Large Marine Ecosystems (ASCLMEs) Project,** focused on issues relating to ocean dynamics, productivity, artisanal (subsistence) fisheries and to a certain extent marine pollution (heavy metals and Persistent Organic Pollutants or POPs (UNDP); and

3. **South West Indian Ocean Fisheries Project (SWIOFP)**, which concentrates on the issue relating to assessment and shared management of the region's continental shelf and offshore fisheries (World Bank).

The WIO-LaB, first of these three projects to be initiated, was officially launched in Madagascar in July 2004, during the Fourth meeting of the Contracting Parties to the Nairobi Convention. The project is a direct follow-on to the 2002 World Summit for Sustainable Development (WSSD) and the related Johannesburg Plan of Implementation, which calls for "advanced implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)".

One of the key outputs of the WIO-LaB Project is a TDA and SAP focusing on land-based activities and sources of pollution. The WIO-LaB TDA-SAP process is designed to be closely coordinated with similar processes in the ASCLMEs and SWIOFP projects, and their results will eventually be integrated into an overall TDA and SAP for the WIO region.

The Western Indian Ocean: a global treasure (photo courtesy of Farid Anasse, DNE)

1.4 Purpose of the TDA and its relationship to the Nairobi Convention and other regional initiatives

The main purpose of this TDA is to provide Contracting Parties with a scientific/technical basis and decision-support tool for the identification and prioritization of key issues concerning the degradation of the coastal and marine ecosystems in the WIO region. The TDA further identifies critical habitats or ecosystems that are important for the threatened or endangered species of wild flora and fauna, besides defining the areas requiring management intervention to address developmental pressures in a comprehensive and regionally-agreed and implementable plan: the SAP.

The TDA and SAP resulting from the WIO-LaB Project will provide the basis for further reviewing and defining new priority areas for the Nairobi Convention's work programme in the WIO region, as well as contribute to the goals and objectives of other global and regional conventions and policy frameworks including:

- Millennium Development Goals;
- Regional and global priorities identified under Agenda 21 (Chapter 17);
- Convention on Biological Diversity and especially the Jakarta Mandate;
- Durban Accord; IUCN - World Parks Congress September, 2003
- Programme of Action for the Sustainable Development of Small Island Developing States (Barbados, 1994);
- Pan-African Conference on Sustainable Integrated Coastal Management (Mozambique, 1998);
- Arusha Resolution on Integrated Coastal Zone Management (ICZM) in Eastern Africa including the Island States (April, 1993);
- Seychelles Conference Statement on ICZM (October, 1996); and,
- WIO Marine Turtle Task Force of the Indian Ocean-South-East Asian Marine Turtle MOU.
- Convention on Wetlands of international Importance especially as Waterfowl Habitats, 1971. (Ramsar Convention, 1971).
- Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1973 (CITES, 1973).

The TDA and SAP also complement the commitments and priorities identified within the Environmental Component of the New Partnership for Africa's Development (NEPAD).

1.5 Boundaries and conditions of the TDA

In terms of geographical scope, this TDA covers the territorial waters (including river basins and catchments) of the eight Nairobi Convention countries that participated in the implementation of the UNEP-GEF WIO-Lab Project, namely: Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, the East Coast of South Africa and Tanzania. Although not formally part of the WIO-LaB Project, information and data from La Réunion (France) and Somalia have been included in the analysis as far as possible.

In terms of thematic scope, this TDA is confined to issues related to land-based sources and activities affecting the environmental health of the coastal and marine environment of the participating countries. The three main thematic areas of this TDA are therefore:

1. Water and sediment quality degeneration due to pollution from land-based sources;
2. Physical alteration and destruction of habitats due to human activities; and,
3. Alteration of river flows, quality and sediment loads.

1.6 Description of the TDA Process

A schematic presentation of the TDA process is shown in Figure 1.2. The five main steps in the TDA development process may be distinguished as:

1. Establishment of the TDA task team
2. Initial identification of transboundary problems
3. Fact finding (data collection and analysis)
4. Causal chain and governance analysis
5. Review and validation

Each of these steps is further defined in the sections that follow:

Establishment of the TDA Task Team

The TDA development was led by a regional TDA Task Team (TTT) consisting of scientific and institutional experts from the WIO region, covering the following fields of expertise:

1. Marine Pollution
2. Coastal Habitats (including aspects of fisheries)
3. River-coast Interactions
4. Governance
5. Socio-economic Issues

Details on the members of the TTT are presented in Annex 1.

In order to facilitate seamless and close interaction with the other elements of the Project workplan, the function of coordination of this TDA Task Team was undertaken by the WIO-LaB Project Management Unit (PMU) based at the Nairobi Convention Secretariat in Nairobi, Kenya. Members of the Unit and contributors to the TTT are presented in Annex 1.

Initial identification of transboundary problems

Based upon the "major perceived issues and problems" identified by the African Process and as part of the Preliminary TDA (2002), supported by available documentation and expert advice where necessary, the TTT embarked on an initial review of transboundary problems within the WIO region. The findings of this exercise enabled the team to establish a clear workplan with division of responsibilities for each of the team members. This also led to the formulation of activities and mechanisms for consultation with national and regional stakeholder groups on the issues and problems identified.

As a next step in the process, the TTT facilitated a regional TDA/SAP workshop, in order to:

- identify and validate the perceived priority transboundary problems;
- undertake an initial root-cause analysis of the identified transboundary problems;
- identify data sources and gaps related to each of the transboundary problems and establish mechanisms to fill such gaps;
- undertake an initial analysis of governance and socio-economic aspects related to the identified transboundary problems;
- establish criteria for the prioritization of transboundary problems and undertake a preliminary prioritization of the identified problems based upon expert opinion; and

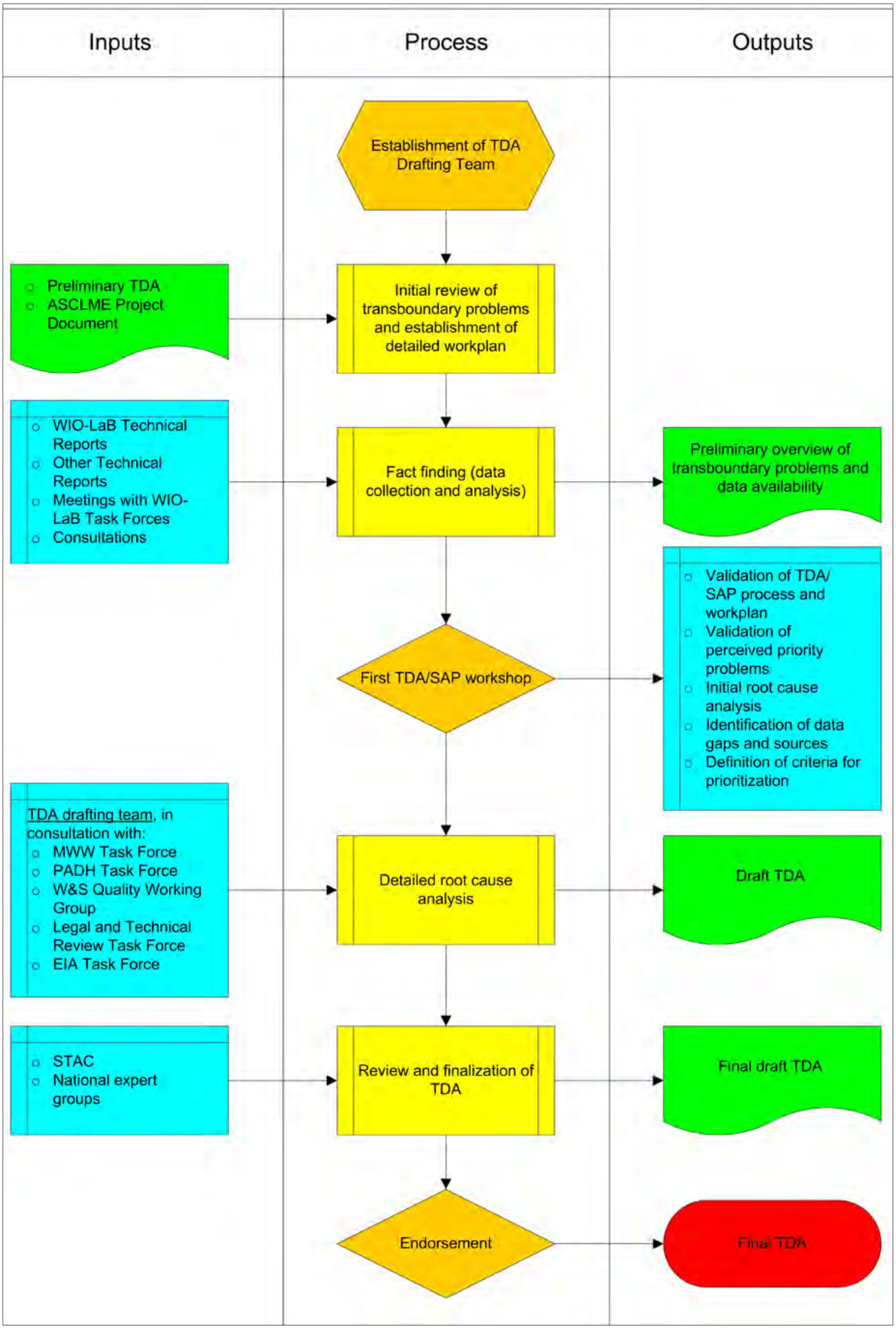


Figure 1-2: Schematic presentation of the TDA development process

- identify key areas for intervention to provide solutions to the identified transboundary problems.

The first TDA/SAP workshop gathered over 40 experts from the various technical fields, who were then grouped into four Technical Task Forces established by the WIO-LaB Project:

- Regional Task Force on Municipal Wastewater Management
- Regional Task Force on Physical Alteration and Destruction of Habitats
- Regional Task Force on Water, Sediment and Biota Quality
- Regional Legal and Technical Review Task Force

Representatives of key academic and research institutions in the region, other regional organizations, including NGOs, active in marine ecosystem conservation in the WIO region also attended.

Stakeholders gathered for the first Regional TDA Stakeholder Conference held in Nairobi, Kenya, in April 2007

Fact finding, data collection and analysis

On the basis of the outcomes of this initial regional TDA/SAP workshop, the TTT embarked on a detailed analysis of documented and perceived priority transboundary problems, based upon available scientific and technical information. Much of these data were collected as part of WIO-LaB thematic assessment studies, or through other initiatives[1]. The results of these detailed studies represent the main technical supporting documents for this TDA:

1. Regional Overview of Physical Alteration and Destruction of Habitats in the WIO Region (UNEP/Nairobi Convention Secretariat, 2004a)
2. Regional Assessment of the State of Pollution in the WIO Region (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009)
3. Regional Overview and Assessment of Marine Litter Related Activities in the WIO Region (UNEP/Regional Seas Programme and WIOMSA, 2008)
4. The Status of Municipal Wastewater (MWW) Management in the WIO Region (UNEP/ Nairobi Convention Secretariat and WIOMSA, 2009a)
5. Regional Overview and Assessment of River-coast Interactions in the WIO Region (UNEP/ Nairobi Convention Secretariat, ACWR and WIOMSA, 2009)
6. Regional Review of Policy, Legal and Institutional Frameworks for Addressing Land-based Sources and Activities in the WIO Region (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009b)
7. Regional Review of the Status of Ratification of International Conventions related to Land-based Sources and Activities Management in the WIO Region (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009c)

Causal Chain and Governance Analysis

Based upon these detailed studies and in consultation with other specific experts, the TTT undertook a comprehensive causal-chain analysis of the priority transboundary problems. Detailed consultations on the various topics were also held within the context of the WIO-LaB Technical Task Forces, specifically at a series of meetings held throughout the region[2].

The final step involved a detailed governance analysis which, within the context of the WIO-LaB Project, was embarked on through the regional legal, policy and institutional review process undertaken by the Legal and Technical Review Task Force. More detail on this process is presented in Chapter 5.

---

1. Such as the African Process, the Global International Waters Assessment (GIWA) programme, the Eastern African Marine Systems (EAMS) programme, GESAMP, TransMap and various reports prepared by the UNEP Nairobi Convention Secretariat, the UNEP Global programme of Action for the Protection of the Marine Environment from land-based Activities (UNEP/ GPA)

2 The 2nd meeting of the Regional PADH Task Force (Toliara, Madagascar, 3-5 June 2007); and, the 3rd meeting of the Regional Working Group on Water, Sediment and Biota Quality (Maputo, Mozambique, 19-20 July 2007). The 3rd meeting of the Regional Legal and Technical

Review and validation of the TDA

An important step in the development of this TDA involved validation of the results by acknowledged experts and institutions in the region to provide credence and authenticity to the process. The principal mechanism for validation of the WIO-LaB TDA report was the Scientific and Technical Advisory Committee (STAC) established by the Project. The STAC comprised selected heads of academic and research institutions (or their delegates) as represented in the Forum for Academic and Research Institutions in the WIO-Region (FARI), as well as selected independent experts. As part of the review process, the draft TDA was presented to a FARI[3] workshop during which the modalities of operation of the STAC were also agreed upon. Subsequently, members of FARI we requested to nominate experts to participate in the TDA review process. The selection of 12 STAC members took place on the basis of review the CVs of nominees by the Chair and Secretariat of FARI, Nairobi Convention Secretariat and the WIO-LaB PMU. The draft TDA was subsequently circulated to the members of the STAC, resulting in a meeting of the STAC, together with a selected number of representatives of the TTT[4]. Following updating of the TDA, the second draft TDA was subsequently circulated for endorsement by the STAC and subsequently put forward for endorsement by the WIO-LaB Project Steering Committee in May 2009.

3 On 27 November 2007 at ORI in Durban, South Africa.
4 On 25th and 26th August 2008

CHAPTER 2 - BIOPHYSICAL SETTING OF THE WIO REGION

2. Biophysical Setting of the WIO Region

2.1 Physical setting

2.1.1 Geographical location and setting

The WIO region has a combined coastline exceeding 15,000 km (including those of the island states) and a total continental shelf area of about 450,000 km² (GEO, 2003) as detailed in Table 2-1. The region is characterized by a wide diversity of habitats including sandy beaches, sand dunes, coral reefs, estuarine systems, mangroves and seagrass beds. The region also has several major river basins that drain into the Indian Ocean (Van den Bosche and Bernacsek, 1990; Hatziolos et al., 1996; Hirji et al., 1996; FAO, 2001; UNEP, 2001). Some of the coastal-marine ecosystems and river basins are transboundary in nature as they extend across more than one country.

Table 2-1 Key geographical characteristics of the WIO region Countries

Countries	Land area (km²)	Coastline (km)	Territorial waters (km²)	Continental Shelf (km²)	EEZ (million km²)
Comoros	2,230	340	12,684	1,416	0.161
Madagascar	581,540	4,828	124,938	96,653	1.079
Mauritius	2,040	372	16,840	27,373	1.900
Seychelles	450	491	45,411	31,479	1.288
Kenya	569,140	536	12,832	8,460	0.104
Mozambique	784,090	2,470	70,894	73,300	0.493
Somalia	62,734	3,025	68,849	40,392	1.200
South Africa	1,214,470	2,881	74,699	160,938	1.016
Tanzania	883,590	1,424	36,578	17,903	0.204
TOTAL	4,100,274	15,141	463,725	457,914	6.819

Note: Data extracted from the GEO Data Portal, 2003

2.1.2 Climatic conditions

The climate in the WIO region can be characterised as ranging from sub-tropical to tropical (FAO, 2005). Mean daily temperatures in the northern parts range from 25°C-29°C, while the hottest summers reach 35°C, usually recorded in the months of December through February (Carbone and Accordi, 2000). In the coastal regions of Kenya, the mean annual temperature range between summer and winter is the smallest, ranging from 26°C to 30°C (Hughes *et al.*., 1992). In Tanzania and northern Mozambique, mean annual temperature ranges between 18°C and 36°C (Hughes *et al.*, 1992), while average annual temperature on the east coast of South Africa are 21°C, reaching an annual maximum mean of 29°C (AFRISCO, 1994; IUCN 2003; FAO, 2005; Preston-Whyte, 1980). Lower temperatures, between 8-10°C, can occur from June to August in the southern extreme of the region (FAO, 2002).

1 Data for Mauritius confirmed and updated by the Ministry of Housing and Lands, Mauritius (2008).

The prevailing wind regimes in the WIO region can be divided into two distinct systems: the monsoon regime that dominates the Somali Current Large Marine Ecosystem (SCLME), and the subtropical high-pressure system that dominates the southern region (the Agulhas Current LME, or ACLME) (Beckley, 1998, Okemwa, 1998). The Northeast Monsoon affects the climate of the northwest Indian Ocean from November to March and is characterized by north-easterly winds over the tropics and northern subtropics (Ngusaru, 1997). The Northeast Monsoon has winds of moderate strength, with dry terrestrially-derived air blowing from Arabia to Madagascar (Weller *et al.,* 1998). In contrast, during the Southwest Monsoon (June to October), wind direction reverses and the winds then tend to be much stronger, with an intense wind stream developing along the high Eastern African highlands (Ethiopian highlands, Kenya highlands, highlands of northern and southern Tanzania, etc.) (Ngusaru, 1997; Slingo *et al.,* 2005).

The rainfall pattern in the region decreases northwards from Mozambique with a range of 530-1,140 mm, to Somalia with 250-375 mm per year. On average, the island states receive more rainfall than the mainland states of eastern and southern Africa (FAO, 2005a). For instance, along the west coast of Madagascar, the annual rainfall is in the range of 400-800 mm while the east coast receives an annual rainfall of about 1,500 mm (FAO, 2005a). The annual rainfall in Seychelles, Mauritius and Comoros is in the range of 2,000–4,000 mm (FAO 2005a). On the other hand, in the coastal regions of continental states such as South Africa, Mozambique, Tanzania and Kenya, the maximum annual rainfall does not exceed 1,500 mm and in most cases is in the range of 500 to 1,000 mm (FAO, 2005a).

The rainfall seasons in the WIO are strongly influenced by monsoon winds. The northern part of Mozambique, Tanzania, Kenya and the southern parts of Somalia receive heavy and extended rains in the period March through May, before the Southeast Monsoon sets in (FAO, 2005a). In the same region, short rains are experienced in October through December during the Northeast Monsoon (AFRISCO, 1997; Kitheka *et al.*, 2004). The islands of the Seychelles receive heavy and extended rains during the Northeast Monsoon, while the rainfall pattern in other island states is strongly influenced by the Southeast Monsoon (FAO, 2005a).

The volume of river discharge into the Indian Ocean to a certain extent reflects the rainfall patterns in the region; rivers draining high rainfall areas thus have relatively higher discharges (Alemaw and Chaoko, 2006). In the northern parts of the WIO region (e.g. Somalia and Kenya), the total annual river discharge has been estimated to be in the range 1.8 - 4.95 km^3/yr, and in the central and southern parts (e.g. Tanzania, Mozambique and South Africa), the annual river discharge is in the range of 2.9 - 106 km^3 (Hatziolos *et al.*, 1996; Hirji *et al.*, 1996; FAO, 2001; UNEP, 2001). Consequently, the southern parts of the WIO region, and in particular Mozambique, are characterized by the presence of large estuaries supporting extensive mangrove forests (Taylor *et al.,* 2003).

2.1.3 Geology and geomorphology

In terms of its geological structure, the coastline of eastern Africa represents a passive continental margin from which, continental fragments have separated and migrated across the adjoining oceanic crust through geological time, creating what is now the Indian Ocean (Kairu and Nyandwi, 2000). This 200-million-year process is reflected today in the heterogeneity of the geological formations in the WIO. The coastal sediments of Tanzania, Kenya and Mozambique, for instance, vary in age from the Jurassic through the Cretaceous to the Tertiary and Quaternary; and are composed of both marine and terrestrial sedimentary rocks (see Kent *et al.*, 1971). Some of the detached continental fragments comprise the granitic islands of the main Seychelles group and the island of Madagascar (see Figure 2-1). The more recent outer islands of the Seychelles

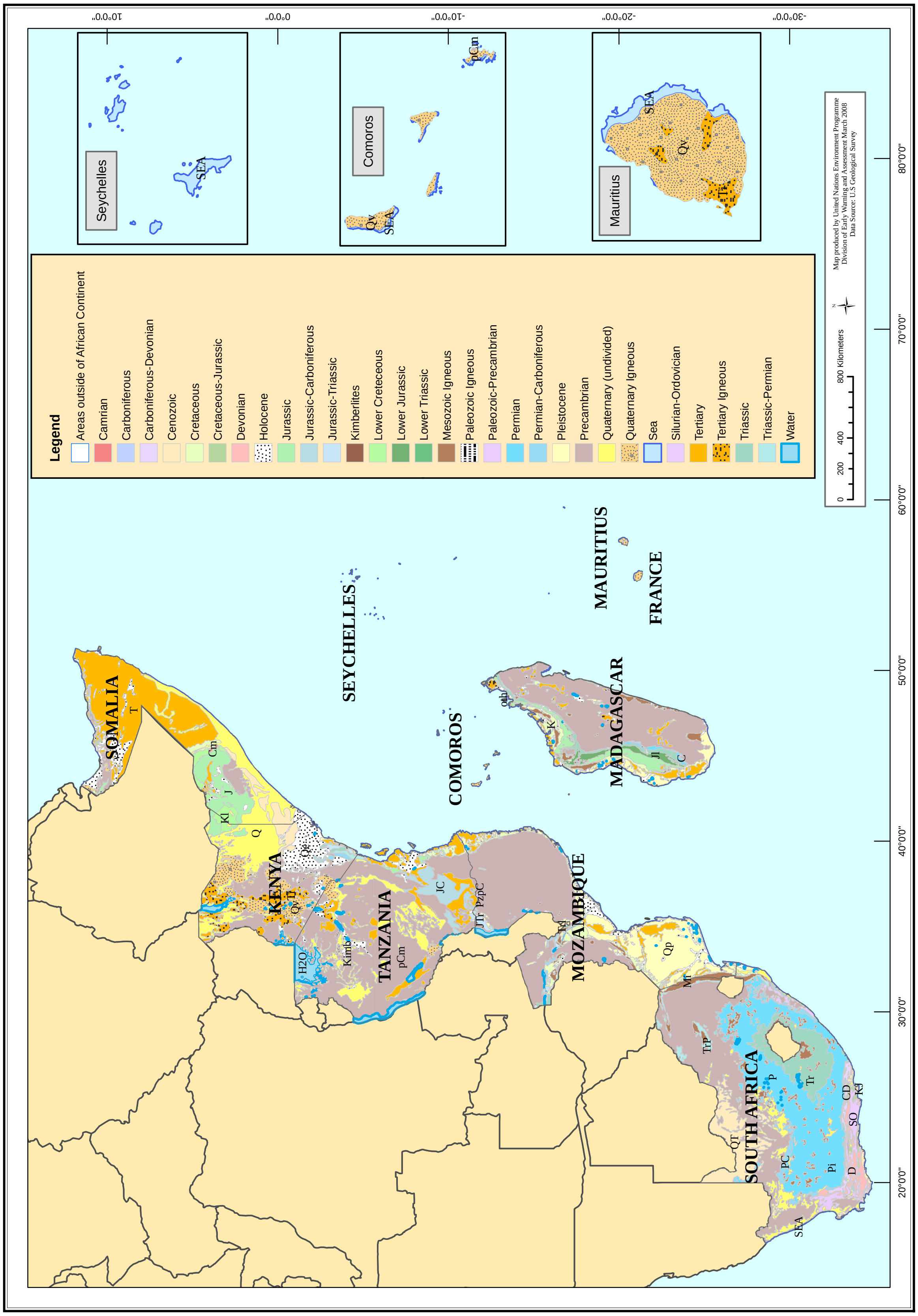


Figure 2-1 Geology of the WIO region

Archipelago (e.g. Aldabra, Cosmoledo), and the islands of Réunion, Comoros, Mauritius and Rodrigues are essentially of volcanic origin (Stoddard, 1984).

This structural history has left the mainland states with generally narrow continental shelves (Ngusaru, 1997), exceptions being the central parts of the coasts of Mozambique at Sofala, central Tanzania in the vicinity of Unguja and Mafia islands, the sedimentary river banks off the major rivers in the south, e.g. Maputo Bay in Mozambique and the Thukela Banks in South Africa. Similar wide continental shelves are found along western Madagascar. Although of different geological origin, the Seychelles Bank and Mascarene Plateau also represent extensive shelf areas (Kairu and Nyandwi, 2000). The WIO region also harbours a variety of submerged geomorphologic features, including abyssal plains, basins, mid-ocean ridges, seamounts and ocean trenches. Some of the deep ocean trenches range from 6,000 to 7,000 meters in depth.

Pleistocene coral limestone overlays older rock along much of the mainland coastline and on some of the islands, in places forming extensive coastal terraces, cliffs, and fringing intertidal platforms (Arthurton, 1992). The intertidal platforms, eroded from Pleistocene limestone cliffs, dominate the coastal geomorphology in much of the region, extending seawards generally from 100 to 2,000 meters. Their seaward edges form reef crests and offshore breaker zones. Terraces and platforms alike are incised by major creeks draining the hinterland, as at Dar es Salaam and Mombasa.

The Mascarene Plateau is one of the most notable physical influences behind climatologic and oceanographic boundary changes in the WIO. It extends as a fault-composite arc for 2,300 kilometres from the Equator southward, with water depths ranging mostly from 8-150 meters. As such, this mid-oceanic geographical feature interrupts the westward flow of the South Equatorial Current and consequently determines the fluxes of water and nutrients – the essential controls of ocean and shallow-sea productivity (Gallienne and Smythe-Wright, 2005; New *et al.*, 2005). The Plateau extends from the Seychelles in the north to Réunion in the south and covers an area of approximately 115,000 km^2. In addition to the two Large Marine Ecosystems (LMEs) of the WIO region already mentioned, the ACLME and SCLME, the entire marine zone around the Mascarene Plateau might also be considered as large marine ecosystem.

2.1.5 Watersheds, hydrological conditions and estuaries

There are twelve main river basins within the WIO region, including the largest in Madagascar. A map of the main river basins in the WIO region is presented in Figure 2-2. Table 2-2 provides an overview of the size of each river basin, the individual length of the main stem of each river, and values for mean annual precipitation (MAP) and mean annual runoff (MAR), the months of the highest and the lowest flows respectively, and the sediment load transported to each river mouth. As can be seen, there is considerable spatial variation in all of these factors. Not shown is the fact that there is also considerable temporal variation in these variables in most of the basins especially rainfall, runoff and sediment transport. Very few years can be considered 'average', the norm being variability and change. While Somalia is generally a water scarce country with many of its rivers as dry and occasional "waddies", the extensive river system in the southern Jubbaland region is important. Comprising the Juba and Shebelle rivers, these catchments drain part of Ethiopia and create a large estuarine system with offshore shrimp fishing grounds in southern Somalia. The delta also provides significant agricultural potential, especially in banana production.

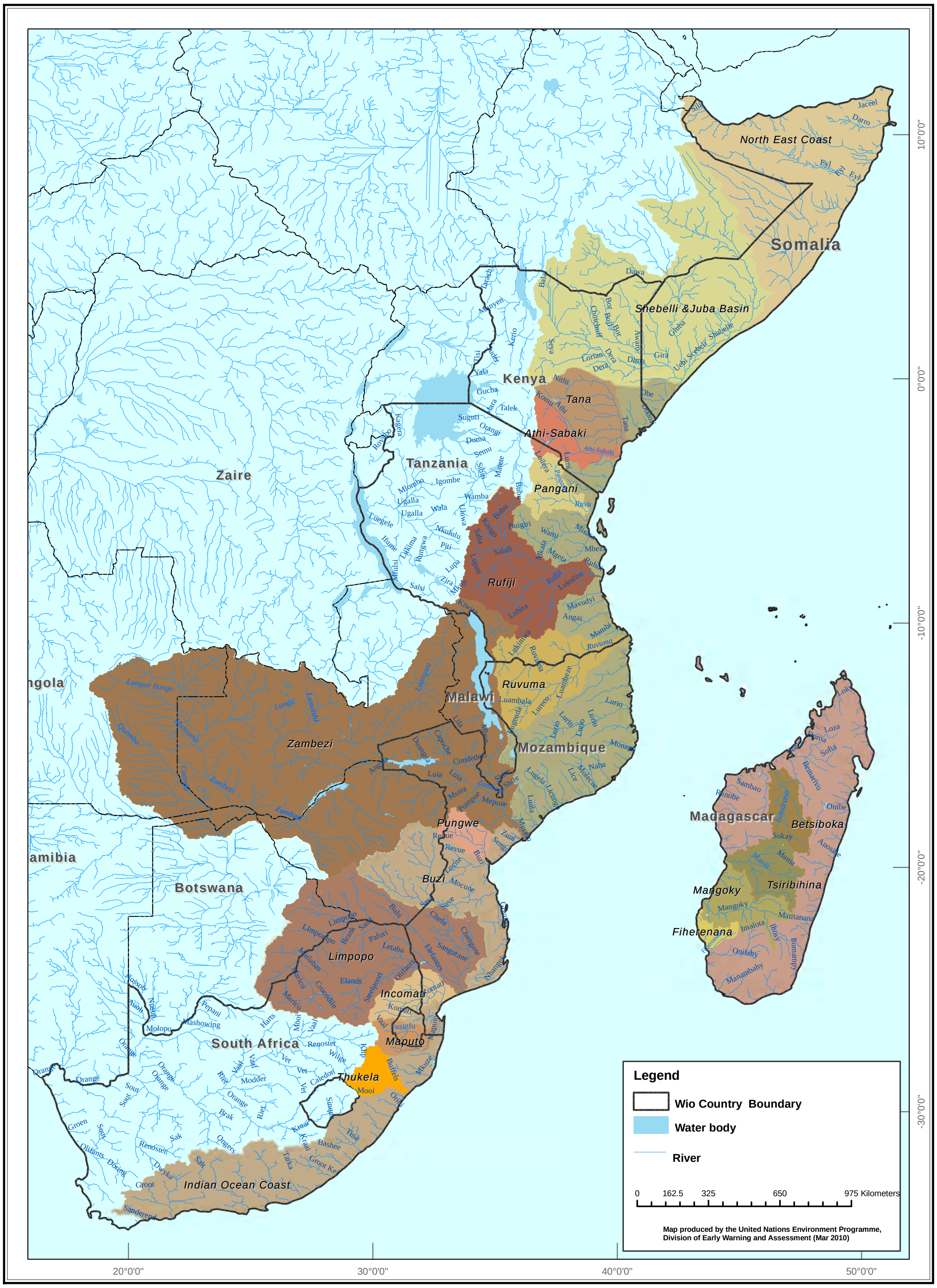


Figure 2-2 Map of the main river basins in the WIO

Table 2-2 Overview of the main rivers in the WIO region

River	Area (km²)	Length (km)	MAP[1] (mm)	MAR[2] (mm)	Average flow (mm³/y)	Highest flow month	Lowest flow Month	Sediment Load (Mt/yr)
Tana	126,828[a]	1,102[b]	566a,[c]	38[a]	7,200[d]	May[d]	Aug[d]	6.8[a]
Athi-Sabaki	69,930[e] 66,800[f]	650[g]	585[a]	35[h]	2,302[a] 1,539[f]	April[f]	Septi,[f]	5.7[a] 7.5-14.3[i],[j]
Pangani	43,650[k]	432[k]	1,079[k, l]	20[m]	850[m]	May[m]	Sept[m]	No data
Rufiji	177,000	±600	1,000	No data	35,000[n] 30,000[o]	April[p,o]	Novp,[o]	16.5[n] ; 15-25[o]; 17[q]
Ruvumaz	155,400[p,r]	800[p,s]	1,160[s]	96[t]	28,000t, [u]	Feb[t]	Aug[t]	No data
Zambezi	1,300,000[s] 1,200,000[t]	2,650[s]	1,000[x]	67[t] 190[v]	106,000[t]	Feb[t]	Sept[t]	43[q] 22[v]
Pungwe	31,000[w] 29,500[t]	395w	1,100[w]	115[t]	6,600[t]	Feb[w]	Octw	No data
Limpopo	415,500[y] 412,000[t]	1,750[z]	530[v]	13[t]	5,200[t]	Feb[z]	Sep[z]	10[z] 34[q]
Incomati	46,800[ii, iii]	480[s]	736[ii]	46[t]	3,587[ii]	Feb[v]	Sepv	7[ii]
Maputo	28,500[t]	380[t]	630[t]	102[t]	2,900t	Febt	Sept[t]	
Thukela	30,000 [vi]	405[viii]	840[vii]	133[vii]	3,800[vi] 4,600[viii]	Feb[vii]	Sept[vii]	9.3[vi] 10.5[q]
Betsiboka	49,000 [ix]	525[ix]				Feb[x]	Sept[x]	

Sources: a. Kitheka et al., 2003; a b. Kitheka, et al., 2003; b, c. GOK, 1979; d. Kitheka et al., 2004b; e. Kitheka et al., 2003d; f. Fleitmann et al., 2007; g. UNEP, 1998; b,h. Kitheka et al., 2003c; i. van Katwijk et al., 1993; j. Watermeyer et al., 1981; k. PBWO/IUCN, 2007; l. Røhr et al., 2002; m. PBWO/IUCN, 2006a; n. Temple and Sundborg, 1973; o. Shaghude, 2004 citing Euroconsult, 1980; p. Anon Tanzania, 2006; q. Arthurton et al., 2002; r. GoT, 2006; s. Pallet, 1997; t. DNA, 1994; u. Kaponda, 2005; v. Hirji et al., 2002 ; w. Van der Zaag, 2000; x. FAO, 1997; y. CP, 2004; z. Louw and Gichuki, 2003; ii. TPTC, 2001; iii. Hoguane, 2007; iv. UNEP, 2005; v. Van der Zaag and Carmo Vaz, 2003; vi. DWAF, 2004a; vii. DWAF, 2004b; viii. Forbes et al., 2002 ; ix. Shahin, 2003; x. IWMI, 2006.

The freshwater flows from the various rivers have a profound effect on the marine ecosystems in the region, driving various ecological processes and providing nutrients for many biota (Kairu and Nyandwi, 2000; Crossland *et al.*, 2005). Rivers draining the central highlands, the Maputo, Incomati, Limpopo, Save, Tana, Athi-Sabaki, Rufiji, Zambezi and Ruvuma, discharge large volumes of siliclastic sediment to the sea (Kairu and Nyandwi, 2000).

The zone of interaction between the freshwater and the saltwater ecosystems- the estuaries - is of significance to this study. According to the South African National Water Act (No. 36 of 1998), an estuary can be defined as "a partially or fully enclosed body of water, which is open to the sea permanently or periodically; and within which the sea water can be diluted, to an extent that is measurable, with freshwater drained from land" (RSA, 1998). According to the DWAF (South Africa) report "Methodology for the Determination of the Ecological Water Requirements for Estuaries", patterns of river inflow to estuaries manifest strong correlations with important hydrodynamic and sediment characteristics, such as state of the mouth, amplitude of tidal variation, water circulation patterns and sediment deposition/erosion. However, the relationships between these characteristics and river inflow are generally difficult to interpret, owing to the influence of the sea, i.e. state of the tide and associated seawater intrusion. The manner in which these

1. MAP: Mean Annual Precipitation
2. MAR: Mean annual Runoff

characteristics are influenced by river flow is often not the result of a single flow event, but rather that of characteristic flow patterns occurring over weeks or months. In estuaries, there is also a large buffer or delay-effect between river inflow patterns and their effect on abiotic parameters (DWAF, 2004c).

Many of the rivers terminate in important estuaries or deltas that serve as habitat and rich nursery and spawning grounds for various species of fish, crustaceans and other marine life. Table 2-3 provides an overview of the main estuaries and deltas in the WIO region, also listing some of their key ecological functions. Several of the estuaries in the WIO region are known to be experiencing stress due to land-based activities upstream and are thus less able to provide the ecosystem services upon which communities depend (Arthurton *et al.*, 2002; UNEP, 2006a). In addition to climatic variability and/or change, the principal drivers of environmental change in basins in the region include agricultural development, urbanisation, deforestation, river damming and industrialisation (Crossland *et al.*, 2005; UNEP, 2006b).

The small, island nations of Comoros, Seychelles and those in the Mascarene Group (Mauritius, Réunion) have very small, usually seasonal rivers, of low volume and flow rates. These are not described further, whereas the countries with significant river basins constitute the focus of the remainder of this section.

Kenya - The two river basins included in this study are the Tana and Athi-Sabaki. Both are medium-sized basins, seasonally flushed by rainfall mainly during the transitions between the Northeast and Southeast monsoons (Kitheka *et al.*, 2004; Crossland, 2005). Both these river basins have been subject to diversions and changes in land use (UNEP, 2006b), as they originate in the highly populated and heavily cultivated Central Kenyan highlands (Kitheka *et al.*, 2004; Dominik *et al.*, 2007; WRI, 2007). Hydropower generated by dams in the Upper Tana Basin provides the principal source of electricity for the country (WRI, 2007), but dam construction has had a major influence on the river's downstream flow and physical characteristics, most notably by regulating water flow and decreasing the frequency and magnitude of flooding (IUCN, 2003; UNEP, 2006a).

Table 2-3 Summary of the features of the main estuaries and deltas of the WIO region

River	Key facts	Key ecological functions
Athi-Sabaki	The estuary at Malindi is small and narrow (0.58 km^2 and 2.5 km long), shallow, with an average depth of 2 m (Kitheka, 2004a) and a small section is colonised by mangroves and associated plants. Accretion is associated with the deposition of high sediment load.	Habitat and nursery ground for shrimps and feeding ground for birds, (UNEP, 1998 and Kitheka, 2004a). Plays an important role in sustaining the productivity of Ungwana Bay (see above).
Betsiboka	The estuary is large, but shallow; highly deltaic and experiences significant tidal incursions during spring tide. Accretion associated with heavy deposition of sediments. Mangroves cover 420 km^2 (IWMI, 2006)	Mangroves act as nursery and feeding grounds for shrimp, crab and finfish (Shahin, 2003). Also, a source of building materials to the local communities.
Incomati	The estuary is of limited spatial extent, but with significant sea water intrusion. There are 5,000 ha of mangroves. Lower parts of the estuary are eroding.	Mangroves act as a nursery ground for fish and shrimp and provide building materials and charcoal to local communities.

Limpopo	Limpopo estuary is small, about 6 km in length (Louw and Gichuki, 2003).	Nursery ground for fish and shrimp, provides building materials to local communities from limited mangroves (Louw and Gichuki, 2003).
Maputo	Maputo Bay is 70,000 ha in extent and incorporates estuarine, mangrove and marine components (Hoguane et al., 2002).	Has a large mangrove forest and is important in terms of fisheries. It acts as a shrimp spawning ground (Hoguane *et al.*, 2002; Arthurton, 2002).
Pangani	The estuary is about 3 km^2 in extent. Due to a reduction in sediment load, the estuary is eroding. There is also a large fringing mangrove forest.	Contains 753 ha of mangroves (Kijazi, 2002). Also important for fishing (crabs and prawns) (PBWO/IUCN, 2007).
Pungwe	The estuary is located 20 km north-west of the city of Beira (Van der Zaag, 2000).	Used for aquaculture, targeting prawns; the farms also prevent saltwater intrusion into Beira's freshwater supply intake (Van der Zaag, 2000).
Rufiji	Large delta area (65 km across, 23 km long and 1,200 km^2 in size) with 53,000 ha of mangroves (Richmond *et al.*, 2002; Shaghude, 2004).	Mangroves (largest estuarine forest in East Africa), fishing and aquaculture (Mwalyosi, 2004; Shaghude, 2004).
Ruvuma	Northern portion of 650 km^2 estuary declared a marine park - Mnazi Bay-Ruvuma Estuary Marine Park (Lerise, 2006).	Mangroves, seagrass beds, nursery ground for fish and shrimp (Francis *et al.*, 2002; Richmond and Mohamed, 2005).
Tana	Tana Delta consists of several estuaries such as Kipini (27 km^2), Mto Kilifi, Mto Moni and Mto Tana. The estuaries extend inland up to 10 km and are relatively deep with a mean depth of about 5 m. Accretion is limited and some sections of the delta are already eroding. The delta is colonized by mangroves (4,100 ha) and associated plants.	Large mangrove forests act as an important habitat and nursery ground for juvenile fish and shrimps (Munga et al., 2006). Play an important role in sustaining the productivity of Ungwana Bay - Kenya's most productive coastal fishing ground.
Thukela	Size 0.6 km^2 during low flows (DWAF, 2004b) with estimated axial length of 800 m, shore line length of 2 km, and a maximum width 350 m, with a channel width of 50 m, increasing to over 1,000 m during floods (DWAF, 2004b)	Extensive areas of mud-flats interspersed with submerged aeolianite reef, providing significant fishing grounds and the only shallow water penaeid prawn trawling ground in South Africa (Forbes et al., 2002).
Zambezi	The delta is about 100 km long and 120 km wide at the coast, covering 15,000 km^2 (Pallet, 1997; ZRA, 1998; Chenje, 2000) or 1.4 million ha (Turpie, 2006).	Sustains rich offshore Sofala Bank with its fisheries, key nursery ground for fish and offshore shrimp resources (ZRA, 1998; Masundire and Mackay, 2002). Provides mangrove building materials to local communities.

The Tana River Delta consists of four main estuaries – Kipini, Mto Kilifi, Mto Tana and Mto Moni (Kitheka *et al.*, 2003; Kitheka *et al.*, 2004) and is Kenya's only major ocean delta (UNEP, 1998a). The annual sediment load is currently estimated to be 6.8 x 10^6 tonnes year^{-1} (Kitheka *et al.*, 2004), which is lower than the estimated sediment load before the construction of dams in the Upper Tana Basin. The estuaries support artisanal and industrial fisheries, estimated to support around 50,000 people in 1991 (IUCN, 2003). However, construction of hydro-electric power (HEP) dams in the upper Tana Basin has led to some changes in the flow patterns of the river in the lower Tana Basin. There has been a reduction in the surface area and longevity of flood-supported riverine forests, wetlands and mangrove areas, as well as in the fish populations and diversity in the main river channel (Aboudha and Kairo, 2001; Hoff *et al.*, 2007; Kitheka *et al.*, 2005; Muchiri, 1998). It is thought that additional dam construction will rapidly exacerbate this decline in fishing area and catch (Turpie, 2006). A controversial sugar cane project that will cover several thousand hectares is being promoted by Nairobi-based business investors.

The Athi-Sabaki River comprises the second longest and the fourth largest catchment in Kenya, with an area that includes large urban centres such as Nairobi (UNEP, 1998; Kitheka *et al.*, 2004). Urbanisation in the headwaters region has led to reduced infiltration of rainfall – causing rapid, but short-lived, high flows and a much reduced base flow (van Katwijk *et al.*, 1993; Snoussi *et al.*, 2004). There are two main tributaries, namely the Tsavo and Athi rivers, which join to form the Sabaki River. The Athi River drains the lower parts of the Central Highlands of Kenya, including Nairobi, while the Tsavo receives flow from the slopes of Mount Kilimanjaro (Kitheka *et al.*, 2004). The flow, terminating in the Indian Ocean north of Malindi, displays great seasonal as well as inter-annual variability (Kitheka *et al.*, 2004). To-date there is no dam on the river (Snoussi *et al.*, 2004). However, major land-use changes within the basin, combined with climatic variability, have already affected the flow of the river.

Malindi Bay is where the Athi-Sabaki River flows into the Indian Ocean, via the Sabaki estuary (Kitheka *et al.*, 2004). This system is important in terms of the biodiversity and productivity of Malindi-Ungwana Bay which supports both artisanal and industrial fisheries targeting prawns (UNEP, 1998b). However, the estuary has experienced a large increase in sediment load, from an estimated 58,000 tonnes in the 1960s to a sediment load that ranged between 7.5 and 14.3 million tonnes in the 1980s (Watermeyer *et al.*, 1981; van Katwijk *et al.*, 1993). Recent studies by Kitheka *et al.*, (2004) have estimated the present annual total sediment load for the Sabaki River to be 4 million tonnes. The Athi-Sabaki River also experiences a high variability in sediment load that is partly governed by the rainfall patterns in the river basin. Rainfall variability affects river flow and hence the river capacity to transport sediments. The general increase in the sediment load of the Athi-Sabaki River has had a negative impact on coral reef ecosystems in Malindi Bay, particularly in Malindi Marine National Park and the Watamu Marine Reserve (van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007). One positive impact of the sediment accretion in the estuary has been an increase in the area colonised by mangroves in the Sabaki Estuary (Kitheka, 2004).

Tanzania - The Pangani River drains a transboundary river basin shared by Kenya and Tanzania, with the Ruvu, Weruweru, Kikuletwa, Rau and Kikafu Rivers being the main tributaries. Much of its catchment covers Tanzania, with the headwaters of the Pangani River located in the Kilimanjaro and Meru mountains (both in Tanzania), fed by cloud-forest precipitation and snowmelt from the glaciers respectively (PBWO/IUCN, 2007; Hamerlynck *et al.*, 2008.). The name Pangani is assumed after the confluence of Kikuletwa and Ruvu at Nyumba ya Mungu Dam. The river then successively flows across dry plains, through the extensive Kirua swamps, and is finally joined by the Mkomazi at Korogwe and the Luengera before traversing the Pangani Falls before entering the Indian Ocean (Akitanda, 2002).

The Pangani River flows into the Indian Ocean just south of the town of Pangani through the Pangani Estuary (PBWO/IUCN, 2007). Fishing is an important activity in the estuary, particularly for crabs and prawns (PBWO/IUCN, 2007) and local inhabitants also harvest aquatic plants such as reeds, sedges, mangroves and medicinal plants for household use or sale (Kijazi, 2002). In the Pangani Basin Water Office (PBWO) State of the Basin Report, the estuary is described as being in a "poor condition" (PBWO/IUCN, 2007). It has far fewer fish, birds and other animal species than comparable systems in Tanzania. Sea water is intruding ever further upstream as the river flow weakens because of upstream abstraction; this is eroding banks and affecting agriculture. Pollution associated with decomposing plants and fine silt from cultivated land, introduced by the river, are creating oxygen levels so low for much of the year that most fish and other aquatic animals cannot survive (PBWO/IUCN, 2007). A once-abundant estuarine fishery is now seriously depleted (PBWO/IUCN, 2007).

The Umba River basin is another transboundary river catchment shared between Kenya and Tanzania. This river drains northeast and crosses the Tanzania-Kenya border before it enters the Indian Ocean through a huge mangrove system at Vanga in southern Kenya. The river's main catchment lies in the Usambara Mountains of northeast Tanzania. The flow of the Umba River is characterised by high seasonal variability, attributed to changes in land-use (cultivation, deforestation, etc), and climatic variability within its upper catchment areas.

Tanzania's largest river basin is the Rufiji, comprised of three sub-basins – the Great Ruaha, the Little Ruaha and the Kilombero. The Great Ruaha originates in the Paroto Mountains and Njombe highlands, where numerous rivers flow into the Usangu Plains and the vast Utengule swamps. It then traverses the Great Ruaha National Park plains and later joins the Little Ruaha before entering the Kisigo River at Mtera. After Mtera, this joins with the Kilombero River system in the Kilombero Plains before entering the Rufiji River upstream of Stiegler's Gorge – the site of a proposed new hydro-power dam (Richmond *et al.*, 2002). At present, the river is not dammed, but its resources are used via direct abstraction and fishing (Shaghude, 2004). From Stiegler's Gorge, the river flows another 180 km across the floodplain and into the Rufiji Delta – flowing into the Indian Ocean opposite Mafia Island (Anon Tanzania, 2006). Sediments carried by the river have resulted in accretion, causing a substantial shift in the shoreline seaward over the millennia (Mwalyosi, 2004). Another important feature of the lower Rufiji floodplain is the presence of a permanent lake system comprising altogether 13 lakes (Shaghude, 2004 citing Hogan *et al.*, 1999).

The Rufiji Delta is characterised by the presence of a huge expanse of mangrove forests (about 50 km^2) that play an important role in supporting the productivity of the coastal fisheries. The delta is formed through the splitting of the river into seven main channels, interwoven by lesser channels (Shaghude, 2004 citing Kajia, 2000). The Rufiji Delta estuarine mangrove forests constitute around 46 percent of the total mangrove cover in Tanzania and support an extensive marine food web (Mwalyosi, 2004). The estuary serves as a nursery ground for shrimps, supporting a commercially important fishing industry; around 80 percent of Tanzania's prawn catch comes from the Rufiji Delta and the area to its north (Mwalyosi, 2004). Studies have shown the shrimp catch to be closely correlated with the extent of intertidal vegetation (particularly mangroves) and freshwater flows in the estuary (Mwalyosi, 2004 citing Turner, 1977). The delta is dynamic in terms of flux – with the present trend being an increase in water flow to the northern channels and a decrease to the south (Richmond *et al.*, 2002; Mwalyosi, 2004). Dynamism in the system is driven by changes in river flow and sediment load, through interplay between erosion and accretion. A change in this balance, e.g. through the construction of a dam upstream, could have negative impacts on the delta ecosystems (Mwalyosi, 2004).

Mozambique - Tanzania The Ruvuma River (Rovuma in Mozambique) forms the border between Tanzania and Mozambique for the final 650 km of its journey to the Indian Ocean (Pallet, 1997). A small part of the catchment is in Malawi – around 470 km^2. After rising in the Matogoro Mountains in southeast Tanzania, the river flows across the Makonde Plateau before dropping to the coastal plain (DNA, 1994; Anon Tanzania, 2006; GoT, 2006). The river basin includes ecologically important areas such as the Nyassa Nature Reserve and the Quirimbas National Park, both in northern Mozambique.

The Ruvuma estuary is famous for its beaches, mangroves and other tropical coastal marine resources. It is shared by Tanzania and Mozambique within the Mtwara Region and Cabo Delgado Province, respectively (Lerise, 2006) and is a dominant feature in the region, the estuary covering 15 % of the coastline (Lerise, 2006). In general, the coastline is made up of a stable substrate with deep sheltered bays that have fishing and recreational potential. The Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP) is on the Tanzanian side while the Qurimbas National Park is found on the Mozambique side. There are plans to link up these two marine reserves – providing a contiguous protected habitat (Anon. Tanzania, 2006). The estuary has a large mangrove forest as well as important stretches of seagrass beds (Francis *et al.*, 2002; Richmond and Mohamed, 2005).

Mozambique - The Zambezi River basin is the fourth largest in Africa after the Congo, Nile and the Niger. The River rises from the Kalene Hills in the North Western Province of Zambia and flows south and then eastwards for some 2,650 kilometres to the Indian Ocean. The Zambezi River is an exemplary transboundary river system since, before discharging into the Indian Ocean, it flows through nine riparian states, namely Angola, Botswana, Democratic Republic of Congo (DRC), Malawi, Namibia, Tanzania, Zambia, Zimbabwe and Mozambique. The main stem of the river forms the southern border of Zambia with Namibia, Botswana and Zimbabwe, before flowing through Mozambique, where it discharges into the Indian Ocean. One of the largest tributaries of the Zambezi, the Shire River, drains Lake Nyassa (Malawi), shared by Malawi, Mozambique and Tanzania (Pallet, 1997). There is no doubt that water resource developments have improved the economy of the riparian states. However, the construction and operation of large HEP dams, such as the Kariba and Cahora Bassa dams, have had environmental impacts downstream (Beilfuss, 1999). Proposals for the development of these dams did not seriously consider environmental impacts (Brown and King, 2002) and, as a result, adverse impacts of the dams were not effectively mitigated against and now include reduction in terrigenous sediment loads (thus increasing downstream scouring), changes to the riverine habitats and flora due to reduced natural variability in stream-flow, and the destruction of estuarine habitat (Hirji *et al.*, 2002).

The Zambezi River provides important functions in sustaining and maintaining the productivity of aquatic fauna and fisheries in the Indian Ocean directly off the Delta, through the transport of vital nutrients downstream which are discharged into the sea (ZRA, 1998; Brown and King, 2002). Coastal geography and the pattern of oceanic currents combine to restrict the availability of these nutrients to the near-shore marine environment along this stretch of the East Africa coastline (Hoguane, 1997a, b). Since the construction of the Cahora-Bassa dam in Mozambique, the flow regime at the delta has become much more constant – with higher low flows and lower high flows, and very few years of floods (Brown and King, 2002). This has had a negative impact on fisheries, prawn catch and mangrove forests in Mozambique (ZRA, 1998; Hirji *et al.*, 2002). The floodplain areas of the delta have shrunk and the reduction in sediment load has led to accelerated coastal erosion and incision of the channel (Brown and King, 2002). Studies carried out by Hoguane (2002) show that the northern part of the estuary, the Chinde outlet, is eroding by an average of 22 m/yr, while accretion is taking place at the southern outlet of Ponta Liberal at a rate of 58 m/yr (Anon., Mozambique, 2006).

The Pungwe River originates on the Zimbabwe Highveld (Inyangani Mountain system) at an altitude of more than 1,000 meters, then travels 395 kilometres eastwards into the Indian Ocean (van der Zaag, 2000). In the northern and eastern part of the basin, the climate can be described as tropical savannah, while the rest is characterised by a humid, subtropical climate (Maud, 1980). The river enters the Indian Ocean through Mozambique at an estuary located some 20 kilometres northeast of the city of Beira, at Bué Maria. Up-country, although there is no dam on the main stem of the river, a water pipeline transfers 22 million m^3 per year (60,273 m^3/day) of water from the Pungwe River to the Odzani catchment (a part of the Save River basin) to augment the water supply for the town of Mutare in Zimbabwe (Van der Zaag, 2000).

The estuary of the Pungwe River and its discharge has critical environmental implications by restricting seawater intrusion upstream, crucial for Beira's freshwater supply. A flow of 10 m^3/s is considered minimal to safeguard the intake of freshwater for Beira (Van der Zaag, 2000). The 10 % low flow (i.e. the flow with a 10 % chance of occurring; with a return period of 10 years) at Bué Maria has been established at 8.8 m^3/s (Van der Zaag, 2000 citing Zanting *et al.*, 1994). The large amount of sediment discharged by this river minimises the effects of coastal erosion in the area (Anon. Mozambique, 2006).

The Limpopo River drains parts of Botswana, South Africa and Zimbabwe, some of the most economically developed areas in the region, and flows into the Indian Ocean at the city of Xai-Xai in Mozambique (UNEP, 2005). The river experiences high streamflow variability, characterised by flooding after intense rainfall and extreme low flows during periods of severe drought. This creates great hardship for rural communities that rely on rain-fed subsistence agriculture (Ashton *et al.*, 2001). In Mozambique, three important tributaries join the Limpopo River: the Nuanedzi River in the north of the basin (rising entirely in Zimbabwe) and joining the Limpopo after flowing for about 60 kilometres through Mozambique; the Changane River (rising close to the Zimbabwe border) that joins the Limpopo close to its mouth on the coast near Xai-Xai (SARDC, 2003); and the Elephants River that joins the Limpopo after the Massingir Reservoir (Louw and Gichuki, 2003). Wetlands comprise two important water resources in the Limpopo River basin within Mozambique, these being the swamp ecosystems downstream of the confluence of the Limpopo River with the Elephant River, and riverine floodplains extending along the Limpopo River near its approaches to the confluence with the Changane River (Brito *et al.*, 2003). Although there are no large dams on the main stem of the river (the Massingir Dam being on the Elephants River tributary), the water resources of the basin are heavily utilised, mainly through direct abstraction (UNEP, 2005). The basin supports large urban settlements such as Francistown, Gaborone, parts of Pretoria, Polokwane and Johannesburg – all contributing a heavy pollution load to the river (Earle *et al.*, 2006).

Although the Limpopo River estuary is comparatively small, it plays an important role in supporting fisheries and providing a breeding ground for shrimp (Louw and Gichuki, 2003). Sea water intrusion into the river is regularly measured up to 55 km upstream and up to 80 km during droughts (Anon. Mozambique, 2006). Between 40,000 and 60,000 hectares of floodplain directly upstream of the estuary are, extensively cultivated by local farmers (Louw and Gichuki, 2003).

The Incomati River is shared by South Africa, Swaziland and Mozambique and its six tributaries support a large variety of ecosystems, including important conservation areas such as the Kruger National Park. The Incomati's water resources are heavily exploited and, with increasing demand, they are becoming insufficient (Hoguane, 2007). Population growth and urban and industrial development negatively affect the river basin, and the demand for land and water is increasing (van der Zaag and Carmo, 2003). Consequently, water quality has deteriorated (Hoguane, 2007) and upstream impoundments and abstractions have changed the flow regime with negative effects for the estuarine ecosystem, exacerbated by mangrove harvesting for construction, charcoal and firewood (Van der Zaag and Carmo Vaz, 2003). The estuary of the Incomati River extends approximately from Manhiça to where the river discharges into the Indian Ocean at Marracuene (Noble and Hemens, 1978). It comprises several inter-linked habitats, including a long narrow peninsula (the Macaneta Peninsula) and a series of inter-riverine islands. This estuarine ecosystem is important for aquatic birds and Palaearctic migrants and provides a variety of services such food security through harvesting and flood damage amelioration (TPTC, 2001).

The Maputo River has two principal tributaries, namely the Usutu and the Pongola. Most of the catchment of the Usutu River lies in Swaziland and that of the Pongola River in South Africa. Within Mozambique, the river passes through the Lebombo Range and there takes a northerly course until it discharges into Maputo Bay and the Indian Ocean. Although the Maputo River basin is small in terms of size as well as discharge, it, along with the Incomati River, is one of the two largest rivers flowing into Maputo Bay (DNA, 1994).

Maputo Bay supports one of Mozambique's most important fisheries (Arthurton *et al.*, 2002; Anon. Mozambique, 2006). The estuary and the adjacent mangrove forests serve as nursery grounds for fisheries which sustain a considerable proportion of the local population and fishing industry, contributing approximately 20 % to the overall shrimp catch of Maputo Bay (Anon., 2001). The high productivity of the Bay depends largely on freshwater input from the Maputo River and the Incomati as discussed above (Hoguane, 2007). However, this fishery is considered an environmental "hot spot" due to its continued degradation (Hoguane *et al.*, 2002), including the estuary's mangrove forests which have been significantly reduced by harvesting, particularly on Benguelene Island. Since 1996, a ban on mangrove harvesting has been enforced on the island (TPTC, 2001). Nevertheless, Maputo Bay is experiencing increasing stress from pollution, emanating from agricultural return flows, industrial waste and urban sewage (Hoguane *et al.*, 2002).

South Africa - The Thukela River catchment has a notably steep gradients, extending from sea-level to the Drakensberg Plateau with peaks of over 3,000 meters within a distance of 180 kilometres from the coast (Forbes *et al.*, 2002). Rainfall in the catchment is erratic and years of prolonged drought in the central and lower catchment alternate with very wet periods. The main economic activities in the Thukela catchment are manufacturing industry, trade, transport and agriculture, the latter an important source of livelihood, both in the form of commercial as well as subsistence agriculture (DWAF, 2004a). Most of the Thukela River system is comparatively undeveloped – there are, however, some dams in the upper catchment and infrastructure for four inter-basin transfers of water out of the basin. The feasibility of further development through the Thukela Water Project, consisting of two large dams, has been positively assessed, but no decision regarding construction has been made.

Turbid conditions are frequently associated with Thukela River outflow and extensive areas of muddy marine sediments contrast with the rest of the South African east coast, rendering the Thukela estuary and shelf a unique ecosystem in the South African context (Forbes *et al.*, 2002). The muddy sediments offshore from the Thukela River mouth, the Thukela Banks, are interspersed by submerged aeolianite reef and the combination of the two habitats provides significant fishing grounds and the only shallow water penaeid prawn trawling grounds in South Africa (Forbes *et al.*, 2002). It is believed that extreme flood events transport large quantities of suspended sediment from the Thukela River, making extreme events significant in the sediment dynamics of the adjoining continental shelf (Forbes, *et al.*, 2002). Two sub-catchments that would be affected by the proposed dams that form part of the Thukela Water Project provide 40 % of the total discharge and 25-30 % of the total sediment load (Forbes *et al.*, 2002). Although a DWAF (2004b) study contends that sediment dynamics in the estuary would remain in a dynamic equilibrium even after the construction of the dams, this remains to be proven, especially as the mouth to the sea has closed in recent years.

Madagascar - The Betsiboka River is one of the largest river systems in Madagascar, originating near Falaise de l'Angavo at 1,755 meter altitude (Shahin, 2003) and is navigable for about 140 kilometres upstream, making it important for shipping and local transport. It flows to the northwest and empties into Bombetoka Bay forming a large delta. Major tributaries are the Mahajamba, Isandrano and Ikopa Rivers. A well developed floodplain is found in the lower course containing some 150 small lakes (IWMI, 2006), including Amparihibe-South (12.5 km^2), Ambania (9.1 km^2), Amboromalandy (6.6 km^2) and Bondrony and Matsiabe (5.0 km^2 combined). The total area of the lakes is 80 km^2. The Ikopa tributary basin has large dams at Mantasoa and Tsiazompaniry.

The Betsiboka River estuary is one of the largest and most important in Madagascar, with distinctively red-coloured water caused by sediments emanating from highly eroded/degraded catchments associated with high rates of soil erosion, reaching up to 250 tonnes per hectare (IWMI, 2006).

2.1.5 Oceanographic characteristics

The oceanographic characteristics of the WIO are strongly influenced by prevailing winds and ocean currents, and the key physico-chemical parameters of salinity, temperature and oxygen, as well as productivity. Unless otherwise indicated, the following précis on the regional oceanography is extracted from Kanagev *et al.* (2009).

Zonal asymmetry is noted in the surface-water temperature distribution in summer in areas north of 20° S. Summer surface temperatures are higher in the eastern part of this region than in the west, where a minimum temperature of about 22°C is recorded in the area of Cape Gwardafuy (Guardafui) on the Horn of Africa, associated with seasonal upwelling. In more central areas, near the Equator, northern winter surface-water temperatures exceed 28°C, notably in the eastern part of the ocean.

The WIO generally is subject to large variations in salinity as a result of dramatic yet variable rainfall on the mainland that introduces fresh water into the marine environment through river discharge. Sea surface salinity is also affected by anomalous anti-cyclonic winds blowing in the southeast Indian Ocean that block the transport of saltier water out of the WIO (Perigaud *et al.*, 2003). Salinity and rainfall are both affected by winds in the region that are linked to El Niño events (Slingo *et al.*, 2005).

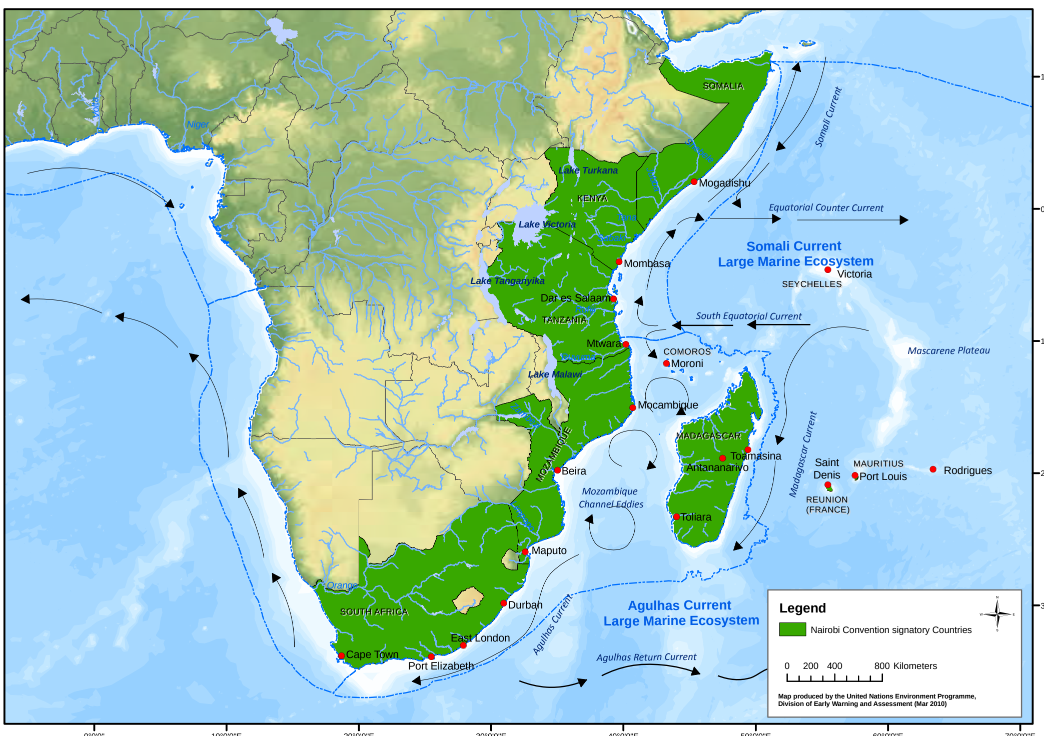


Figure 2-3 Ocean circulation in for the WIO region

Overall, the salinity of Indian Ocean surface waters varies between 32 and 37 practical salinity units (PSU) with large local differences. The northern parts of the WIO, especially the **Arabian Sea**, has a dense, high-salinity layer (37 PSU) to a depth of about 120 meters because of high evaporation rates at subtropical temperatures, with moderate seasonal variations. However, salinity in the eastern part of the WIO, particularly towards the **Bay of Bengal** is considerably lower, often less than 32 PSU because of the huge drainage of freshwater from Asiatic rivers. High surface salinity greater than 35 PSU is also found in the Southern Hemisphere subtropical zone between 25° and 35° S; while a low-salinity zone stretches along the hydrological boundary of 10° S from Indonesia to Madagascar. Antarctic surface-water salinity is generally below 34 PSU.

Ocean surface circulation in the WIO is wind-driven. In the northern monsoon zone, surface circulation reverses every half year and features two opposing **gyres** that are separated by the Indian subcontinent (see Figure 2-3). During the Northeast Monsoon, a weak counter-clockwise gyre develops in the Arabian Sea, and a strong clockwise gyre forms in the Bay of Bengal. During the Southwest Monsoon, the current reverses direction in both seas, with warm- and cold-core eddies forming in the Arabian Sea. During the Northeast Monsoon, the **North Equatorial** Current flows westward, turns south at the coast of Somalia, and returns east as the Equatorial Countercurrent between 2° and 10° S. An equatorial undercurrent flows eastward at a depth of 150 meters during this period. During the Southwest Monsoon, the North Equatorial Current reverses its flow and becomes the strong east-flowing Monsoon Current. Part of the **South Equatorial** Current turns north along the coast of Somalia to become the strong **Somali Current.** A pronounced front, a phenomenon unique to the Indian Ocean at 10° S, marks the limit of the monsoon influence (Kanagev *et al.*, 2009).

The Somali Current reverses direction with season (American meteorological society, 2000), and is the western boundary current of the northwest Indian Ocean when flowing northwards along the East African coast. During the Northeast Monsoon, the Somali Current flows south, meeting the north-flowing East African Coastal Current (EACC) which originates from the South Equatorial Current (Horrill *et al.*, 2000; American meteorological society, 2000; Okemwa, 1998). With the transition from northeast to southwest monsoons, an intense Indian Equatorial Jet (EJ) develops within these waters between April and June for short (one-month) periods (American meteorological society, 2000). This occurs when the EACC strengthens, causing the Somali Current to change direction and flow northward in an intense coastal jet that may reach velocities of 3.5 meters per second (American meteorological society, 2000; Okemwa, 1998). The EACC's geographical extent is thus seasonally determined and its interaction with the Somali Current shifts southward as the monsoon progresses (Horrill *et al.*, 2000). By the time the Southwest Monsoon peaks in August, the Somali Current is established as a continuous current running from the EACC to the East Arabian Current (American meteorological society, 2000). Nutrients and primary productivity in its surface waters are generally low, although this is seasonal, with higher values being associated with surface upwelling areas (McClanahan, 1988). During the Southwest Monsoon, upwelling occurs off the Somali and Arabian coasts (Bakun *et al.*, 1998, Kanagev *et al.*, 2009). It is most intense between 5° and 11° N, with replacement of warmer surface water by water of about 14 °C.

South of the monsoon region, there is a steady subtropical anti-cyclonic gyre, consisting of the westward-flowing South Equatorial Current between 10° and 20° S, which divides as it reaches Madagascar (Kanagev *et al.*, 2009; Lutjeharms, 2006). One branch passes to the north of Madagascar, turns south as a series of slow-moving gyres or eddies that constitute the **Mozambique Current** between mainland Africa and Madagascar (Lutjeharms, 2006). These drift southward along the shelf edge at speeds of about 5 cm/s (Schouten *et al.*, 2003) and can cause minor upwelling. The other branch, the East Madagascar Current, turns south to the east of Madagascar and then curves back to the east as the South Indian Current at about 40° to 45° S (Kanagev *et al.*, 2009; Lutjeharms, 2006). A strong, narrow, western boundary current, the **Agulhas Current**, is generated by the East Madagascar Current and, to the greatest extent, the southwest Indian Ocean subyre, with little inflow from the Mozambique Current (Gründlingh, 1983; Stramma and Lutjeharms, 1997; de Ruijter *et al.*, 1999; Lutjeharms, 2006). The Agulhas Current flows along South Africa before turning east and joining the **Antarctic Circumpolar Current** south of 45° S. It generates periodic gyres between its western boundary and mainland which are responsible for minor upwelling (Lutjeharms, 2006).

The current system at the eastern boundary of the ocean is not as developed, but the **West Australian** Current flowing north from the South Indian Current closes the gyre to a certain extent. Only the Antarctic Circumpolar Current reaches the ocean floor. The Agulhas Current extends down to about 1,200 meters and the Somali Current to about 800 meters; the other currents do not penetrate farther than 300 meters.

Below the influence of the surface currents, water movement is sluggish and irregular, and is derived from a number of oceanic sources apart from the Indian Ocean. These cold, dense layers creep slowly northward from their source in the Antarctic Circumpolar Region, becoming nearly anoxic (oxygen-deficient) *en route*.

The WIO region, particularly the area known as the Agulhas and Somali Current Large Marine Ecosystem (ASCLME), is considered to be oligotrophic and characterized by low nutrient concentrations, low phytoplankton biomass and a predominance of regenerated production during south-east and inter-monsoon periods (Mengesha *et al.,*. 1999). Ammonium is the major nitrogen substrate, supplying between 50-99% of the phytoplankton nitrogen requirements (Mengesha *et al.,*. 1999). Nutrient levels vary seasonally, especially between the monsoons (Mengesha *et al.,* 1999). The flow of the South Equatorial Current, on the other hand, delivers high levels of nutrients to the central and northern Mascarene Plateau regions, which may be responsible for higher levels of productivity in these areas (New *et al.,* 2005).

Examples of all three tidal types - **diurnal, semi-diurnal**, and mixed - can be found in the Indian Ocean, although semi-diurnal (i.e. twice daily) are the most widespread. Semi-diurnal tides prevail on the coast of eastern Africa as far north as the Equator (Hamilton and Brakel, 1984). Tides are mixed in the northern region of the WIO, particularly towards the Arabian Sea (Sheppard *et al.,* 2000). Tidal ranges vary considerably from place to place in the Indian Ocean and its adjacent seas. Mauritius, for example, has a spring tidal range of only 0.5 meter, while, along the eastern Africa coast, the spring tidal range is of the order of 3-4 meters (Alusa and Ogallo, 1992; Hamilton and Brakel, 1984, Kanagev *et al.*, 2009).

2.2 Ecological setting

2.2.1 Coastal ecosystems and habitats

The WIO region comprises the western extremity of the tropical Indo-West Pacific, the world's largest marine biogeographic province (Ekman, 1953; Sheppard, 1987; 2000). The region is characterized by diverse coastal and marine ecosystems such as coral reefs, seagrass beds, mangroves, sandy beaches, sand dunes and terrestrial coastal forests. Figure 2-4 presents a synopsis of the key habitats found in the WIO region. A further description of each of the types of ecosystems is presented in the following sections.

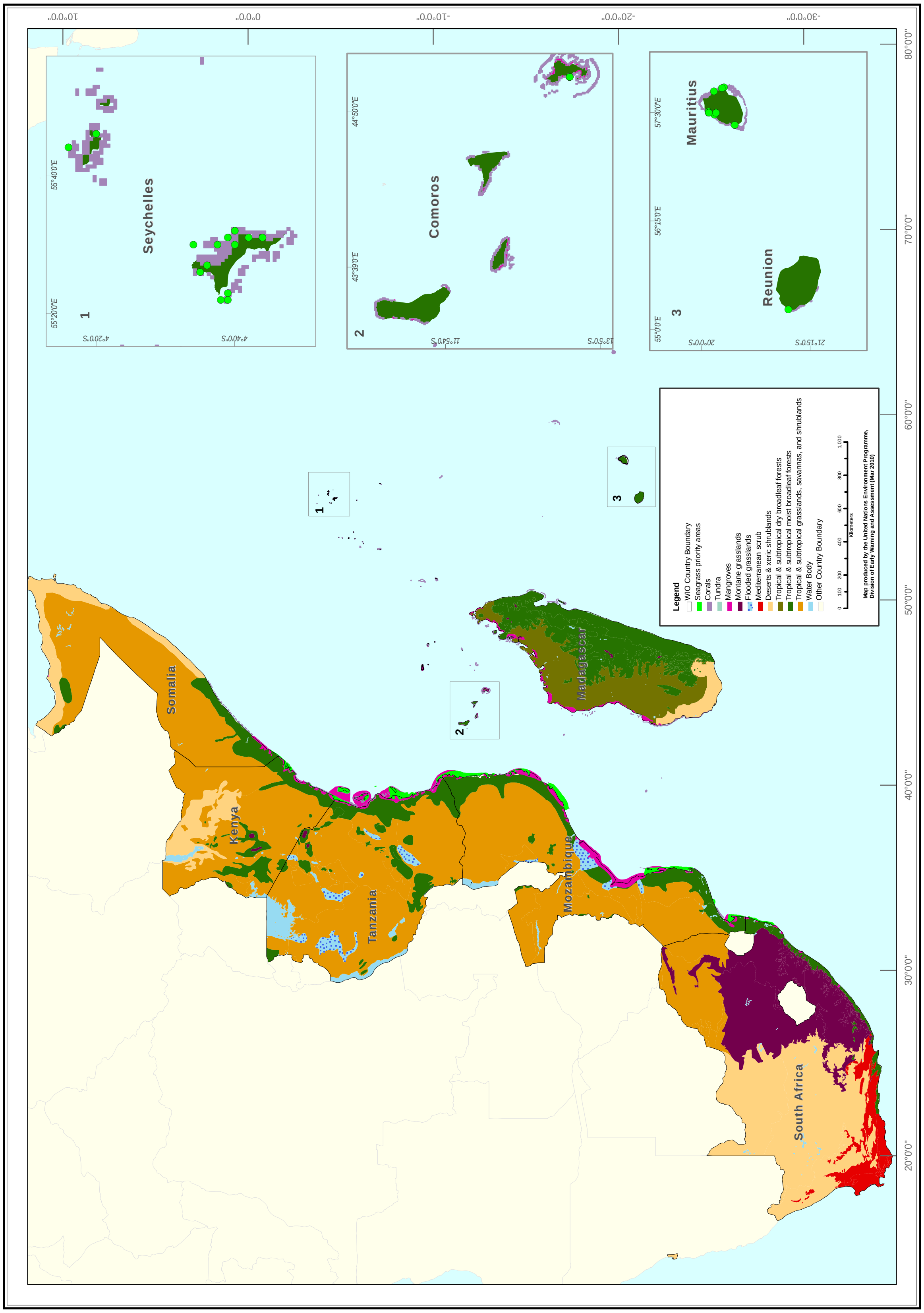


Figure 2-4 Map displaying key ecosystems and habitats in the WIO region

2.2.2 Coral reefs

The coral reefs in the WIO cover a surface area of approximately 12,913 km^2. Most coral reefs in the region are fringing carbonate reefs found along the length of the coastline, particularly in areas where there is no river drainage. Atolls and patch reefs are common in the island states and the offshore islands along the East African continental margin. In the WIO region, coral reefs play an important role in the socio-economic well-being of the people as many are dependent on them for work and subsistence. Coral reefs are probably the most biodiverse marine ecosystem in the WIO, having more than 300 coral species (see Table 2-4). While coral reefs in the WIO were severely affected by bleaching caused by elevated temperatures associated with the El Nino Southern Oscillation, this was followed by a measure of recovery (see CORDIO status reports by Souter *et al.*, 2000; Souter and Linden, 2005). This must nevertheless have adversely affected the coastal services provided by the coral reefs.

Table 2-4 Cover of coral reef and scleractinian coral species diversity by country in WIO.

Country	Reef area (km^2)	Recorded no. coral species
Comoros	430	314
Kenya	630	237
Madagascar	2,230	315
Mauritius	870	161-294
Mozambique	1,860	194-314
Seychelles	1,690	206-310
Somalia	710	59-308
South Africa	~50	99
Tanzania	3,580	314

Source: Spalding et al., 2001.

Somalia - Fringing reefs are well developed in the south and around the islands of the Bajuni Archipelago. However, north of the Archipelago, fossil carbonate reef structures are present but support reduced coral cover and biodiversity (Spalding *et al.*, 2001). This has been attributed to the upwelling of cold water within the Somali Current during the Southeast Monsoon. Somalia has 710 km^2 of coral reef which account for 5.5 % of the regional total. Despite this significant contribution to regional coral reef cover, very little is known today about the state of Somalia's coral reef due to political instability, especially after the 1998 coral bleaching event in which the neighbouring countries suffered coral mortality of between 50–95 % (Wilkinson, 1999; Wilkinson *et al.*, 1999).

Kenya - Coral reefs cover a surface area of about 630 km^2 comprising 4.9 % of the total regional reef area (Spalding *et al.*,2001). Better reef development is found in the fringing reefs in the southern part of the country (Spalding *et al.*, 2001). The northern coast of Kenya contains patchy reefs, within a system of barrier islands, mangroves and seagrass beds (Obura, 2002). Reef development is reduced in the northern part of the Kenya coast as it has large areas of mobile sediment and significant freshwater input from the Tana and Athi-Sabaki Rivers (Spalding *et al.*, 2001). Fringing reefs are also found off Lamu Island and along many of the barrier islands to the north.

Tanzania - This is the country with the largest area of coral reef in the region (3,580 km²), with fringing reefs being found along the coast of most of mainland Tanzania and the three main offshore islands: Pemba, Unguja (Zanzibar) and Mafia (Spalding *et al.*, 2001). In areas of high freshwater discharge, such as around the Rufiji Delta, there are breaks in the reef structure brought about by high sediment load and reduced salinity (Spalding *et al.*, 2001). The South Equatorial Current meets with the east African coast in southern Tanzania, rendering its reefs the most biodiverse in East Africa. Deflection of this current by the mainland further renders the Tanzanian coral reefs important in terms of connectivity with the other reef systems in East Africa, providing them with a source of larvae. Coral reefs are well-developed around the three main offshore islands, but the eastern shores of these islands have been reported to have a low cover of living hard coral, which is possibly due to high wave impact combined with anchor damage from decades of artisanal fishing (Spalding *et al.*,2001).

Mozambique - Coral reefs cover an area of about 1,860 km², about 14.4 % of the regional total, with most located within the provinces of Nampula and Cabo Delgado in northern Mozambique (Motta *et al.*, 2002, Spalding *et al.*, 2001). As a result of the remoteness of some of the northern areas, many Mozambican reefs have experienced less exploitation than elsewhere in East Africa. Though the country has the longest coastline on the east African coast, coral reefs are not as prolific as might be expected. This is partly due to the fact that over 24 rivers discharge into the Indian Ocean in the central part of the country, known as the 'swamp' coast, introducing sediment and reducing the salinity of coastal waters (Motta *et al.*, 2002, Spalding *et al.*, 2001).

South Africa – South Africa's only coral reefs are found along the north coast of KwaZulu-Natal, covering a surface area of just under 50 km² (Schleyer *et al.*, 2005). Here the coral communities represent the southernmost distribution of these biota on the African coast, and are reported to be of high coral cover though dominated by soft corals (Schleyer and Celliers, 2002). The coral reefs of South Africa are however not true accretive reefs as corals only grow as a thin cover over the limited sandstone substrata (Ramsay and Mason, 1990; Ramsay, 1996).

Seychelles - Coral reefs cover a surface area of about 1,690 km², equivalent to 13.1 % of the total coral reefs in the WIO region (Spalding *et al.*, 2001). The granitic islands on the Seychelles Bank are surrounded by widespread, discontinuous fringing reefs (Spalding *et al.*, 2001). The best developed reefs are found along the east coast of Mahe and the west coast of Praslin where the reef flats often reach 2 kilometres in width, with highly exposed, seaward algal ridges (Spalding *et al.*, 2001). Granite reefs are common in the shallow waters around the inner islands and comprise corals growing over granitic boulders. These coral communities were shown to be better able to recover from coral bleaching events (Engelhardt *et al.*, 2003; Payet *et al.*, 2005). The coralline islands to the south and south west of the Seychelles Bank form a number of geographic groups, the Amirantes Group being the largest and the Aldabra Groups the most distant (Spalding *et al.*, 2001). The reefs in these outer islands are highly varied and include true atolls, raised atolls, submerged or partially submerged atolls and platform or bank structures with coral cover varying considerably between localities (Spalding *et al.*, 2001). In the inner islands of the Seychelles Bank, coral cover is very low following the 1989 El Niño event and is taking a long time to recover (Payet *et al.*, 2005).

Comoros Archipelago - The three islands are surrounded by fringing reefs, with the exception of the main island of Grande Comoro, an island which is still volcanically active with steep and barren shores. Here fringing reefs are restricted to a only few parts of the coastline, mostly to the north and west (Spalding *et al.*, 2001). Moheli Island has the most extensive reef system with continuous fringing reefs all around the island (Spalding *et al.*, 2001).

Moray eel on a Sodwana reef (photo courtesy of Michael Schleyer, ORI)

Madagascar - Coral reefs are widely distributed along the west coast and the following account on them is derived from Spalding *et al*. (2001) except where indicated. The reefs cover a surface area of about 2,230 km^2 which is equivalent to 17.3 % of the regional total. Different types of reefs are present, including fringing reefs, barrier reefs, patch reefs and submerged coral banks and shoals (Cooke *et al.,* 2000). Extensive fringing reefs off the west coast of Madagascar are located between 500 meters and a few kilometres offshore and separated from the shore by generally shallow channels (Spalding *et al.,* 2001). A notable feature is the well developed barrier reef known as Grand Recif, which runs continuously for 18 kilometres. A fragmented barrier reef system is located in the area between Baie des Assassins and Morombe and north of the Mangoky Delta. Along most of the central section of the west coast, there is no reef development, which is probably caused by terrigenous sediment discharge from rivers and heavy input of freshwater. On the outer edge of the continental shelf in the far north there is a series of raised banks, forming a near continuous ridge which is thought to be the remains of a large barrier reef system. The east coast has less developed coral reefs.

Reefs on the east coast are not as well studied. However, those to the north and south of Tamatave were surveyed by Schleyer and Celliers (2004). Similar reef types to those found on the west coast were encountered but appear to be severely degraded.

Mascarene Islands - The Indian Ocean islands of Mauritius (including Rodrigues) and Réunion (France), located at the southern end of the Mascarene Ridge are all of volcanic origin (Pichon 1971). Réunion has the youngest reef in the region, while Mauritius is almost completely surrounded by fringing reefs with substantial lagoon and barrier reef development on the east and south west coast (Spalding *et al.,* 2001). Rodrigues, on the other hand has a highly developed reef structure, although a true barrier reef has not formed (Fenner *et al.*, 2004). The outer reef slopes in both Rodrigues and Mauritius are reported to have a high coral cover (Ahamada *et al.*, 2004). The islands of the Cargados Carajos Bank are also under the jurisdiction of Mauritius and are surrounded by large expanses of coral reefs (Spalding *et al.,* 2001). Réunion has only a few fringing reefs, restricted to the leeward western shore, while the French administered Iles Eparses, have reefs that account for about 1.9 % of the coral reefs in the region.

2.2.3 Mangrove forests

Mangroves trees and shrubs are a common sight on sheltered areas of tropical and subtropical shorelines in many parts of the world. They provide valuable resources to local communities, particularly the coastal service of protection of the shoreline from erosion and the provision of building materials. In view of the latter, they have been subjected to over-exploitation and degradation in many areas.

Mangrove forests form fringing coastal vegetation between the spring tide high mark and the mid-tide level. Consequently, their roots are exposed to air at least during each tidal cycle. The latitudinal limits of mangroves are about 31°22'N and 38°20'S (Tomlinson, 1986; Spalding *et al.*, 1997). Two main centres of mangrove diversity have been identified: the eastern group includes the Indo-West Pacific that stretches from the central Pacific to the mainland coastline of the WIO and the western group includes the mangroves of Atlantic-East Pacific, including those of West Africa, the Americas and the Caribbean Sea. The eastern group is more diverse and contains about five times the species diversity recorded in the western region (Duke, 1992).

The total area of mangroves in the WIO is estimated to be 10,000 km^2 (Spalding *et al.*, 1997), representing about 5.0 % of the total global mangrove coverage. The best developed mangroves in the region are found in the deltas of the Rufiji River (Tanzania), the Tana River (Kenya), the Zambezi and Limpopo Rivers (Mozambique) and along the west coast of Madagascar at Mahajanga, Nosy be and Hahavavy (Table 2-5).

Table 2-5 Distribution of mangroves in the WIO

Country	Area (ha) [1]	Species	Main mangrove areas
Mozambique	390,500	9	Zambezi Delta
Madagascar	314,000	9	West coast at Mahajanga bay, Nosy Be, and Hahavavy
Tanzania	164,200	9	Rufiji Delta, Tanga, Kilwa , Pangani.
Kenya	51,600	9	Lamu Archipelago, Tana Delta
Seychelles	1,900	7	Aldabra Atoll
South Africa	667	6	St Lucia
Comoros	670	5	Grande Comoro, Moheli
Mauritius	106	2	Mathurin Bay, Rodrigues
Somalia	9,100	6	Juba/Shebele Estuary

Data source: [1]FAO, 2002, Beentje and Bandeira 2007; Spalding *et al.*, 1997; Ministry of Environment and NDU, 2006

In the WIO region, nine species of mangroves are commonly encountered, with the most common species being *Rhizophora mucronata* and Ceriops tagal (see Table 2-6). The most common mangrove-associated tree species occurring within the mangrove ecosystem are *Barringtonia asiatica,* Barringtonia racemosa and *Pemphis acidula* (Beentje and Bandeira, 2007).

Table 2-6 Species of mangroves in WIO

Family	Species
Avicenniaceae	*Avicennia marina* (Forsk.) Vierh.
Combretaceae	*Lumnitzera racemosa* Willd.
Meliaceae	*Xylocarpus granatum* König
	Xylocarpus moluccensis (Lamk.) Roem.
Rhizophoraceae	*Bruguiera gymnorrhiza* (L.) Lam.
	Ceriops tagal (Perr.) C.B. Robinson
	Rhizophora mucronata Lamk.
Sonneratiaceae	*Sonneratia alba* J. Smith
Sterculiaceae	*Heritiera littoralis* Dryand.

Sources: Macnae, 1968; Semesi *et al.*, 1999

2.2.4 Seagrass beds

Twelve seagrass species, comprising about a fifth of the world's total, occur in the WIO region (Bandeira and Bjork, 2001; Gulström et al., 2002). These species are divided into three families namely, *Zostera capensis* of the Zosteraceae; *Thalassia hepmrichii, Halophila ovalis, H. minor, H. stipulacea* and *Enhalus acoroides*, all Hydrocharitaceae, and *Cymodocea rotundata*, C. serrulata, *Halodule uninervis, H. wrightii, Syringodium isoetifolium* and *Thalassodendron ciliatum* of the Cymodoceaceae family. Kenya, Tanzania and Mozambique support the highest diversity of seagrasses (see Table 2-7). *Ruppia maritima*, recently defined as a seagrass (Short *et al.*, 2001), is also a dominant species in the south-eastern Africa (Colloty, 2000).

Table 2-7 Seagrasses species in WIO counties

Species	Comoros	Kenya	Madagascar	Mauritius	Mozambique	Seychelles	Somalia	South Africa	Tanzania
Zostera capensis		√			√			√	√
Thalassia hemprichii	√	√	√		√	√	√	√	√
Thallassodendron ciliatum	√	√	√	√	√	√			√
Syringodim isoetifolium	√	√		√	√	√	√		√
Halodule wrightii	√	√	√	√	√		√		√
Halodule uninervis	√	√	√	√	√	√	√		√
Halphila stipulacea	√	√	√	√	√	√	√		√
Halphila minor		√			√				√
Halophila ovalis	√	√	√	√	√		√	√	√
Enhalus acoroides		√			√	√			√
Cymodocea serrulata	√	√	√	√	√	√	√	√	√
Cymodocea rotundata	√	√	√		√	√	√	√	√
Ruppia maritima								√	

Sources: Bandeira, 2000; Colloty, 2000; Bandeira and Bjork, 2001; Bandeira and Gell, 2003; Ochieng and Erftemeijer, 2003; Database of Marine Organisms of Mauritius, 2007.

The principal locations of seagrass beds in WIO countries are shown in Table 2-8, while the following sections describe the main characteristics of seagrass bed distribution within the relevant countries.

Table 2-8 Important sites of seagrass beds in the WIO mainland (and area covered).

Country	Key location	Area (km^2)
Kenya	Gazi Bay Diane-Chale Lagoon	8.00 4.50
Tanzania	Chwaka Bay (Zanzibar)	100.00
Mozambique	Inhaca Island and Maputo Bay Mecúfi-Pemba Quirimbas Archipelago	80.00 30.00 45.00
South Africa	St. Lucia estuary	1.81

Kenya - Seagrass beds cover a surface are of about 33.6 km^2, with the most important sites in the region between Lamu and Kiunga, Malindi, Mombasa, Gazi Bay (8 km^2), and Mida Creek and Diane-Chale lagoon (4.5 km^2) (Dahdouh-Guebas *et al.*, 1999; Ochieng and Erftemeijer, 2003). Twelve species of seagrass are present in Kenya. Some of the most common species are *Thalassodendon ciliatum, Halodule wrightii* and *Halophla minor* (see Obura, 2001; Gulstrom *et al.*, 2002). The pioneer seagrass association comprises *Halophila ovalis* and *Halodule wrightti*, while the climax vegetation of the intertidal zone is mainly composed of *Thallasia hemprichii* and some few macroalgae (e.g. *Halimeda opuntia, Gracilaria salicornia* and *G. corticata*). Monospecific patches of *Enhalus acoroides* also occur in deep water, while the lagoon is dominated by monospecific stands of *T. ciliatum* (Coppejans *et al.*, 1992). In the north of Kenya (Kiunga Marine Reserve), eleven of the total number of species was identified in estuary, bay and reef habitats (McMahon and Waycott, 2009). There has been significant loss of seagrass along the coast, initially attributed to human-related activities, but now also to sea urchin population growth. In the Diane-Chale lagoon for instance, preliminary studies indicate that *T. ciliatum* beds experienced a loss of more than 50 % of cover. These degraded sites were also found to have a density of the sea urchin *Tripneustes gratilla* of >37 individuals/m^2, while healthy sites had a density of 4 individuals/m^2 (Uku, 2006).

Tanzania - Major seagrass areas include Pemba, Unguja and Mafia Islands (Ochieng and Erftemeijer, 2001). One of the best studied sites for seagrasses in Tanzania is Chwaka Bay, Unguja Island, Zanzibar (de la Torre e Castro, 2000; Gultröm *et al.*, 2006). Here, two types of seagrass habitats are found: shallow beds in marine embayments, some distance from coral reefs but adjacent to mangroves and mud flats, and shallow seagrass beds situated on the shallow continental shelf adjacent to coral reefs but far away from mangroves and mud flats (Dorenbosch *et al.*, 2005). Seagrasses are present in most of the tidal zone, but are more abundant in the western part of the bay. There are about 11 species, the dominant include *T. hemprichii, E. accoroides* and *T. ciliatum* (de la Torre e Castro and Ronnback, 2004; Eklof *et al.*, 2005). Since 1990, the island has become an important site for seaweed farming, which is reported to negatively affect seagrass beds (de la Torre e Castro and Ronnback, 2004; Eklof *et al.*, 2005).

Mozambique - Seagrass beds are estimated to cover a total surface area of 439 km^2, with some 25 km^2 around Inhassoro and Bazaruto Island, 30 km^2 at Mecúfi-Pemba and 45 km^2 in the southern Quirimbas Archipelago (Bandeira and Gell, 2003). The largest seagrass beds occur at Fernão Veloso, Quirimbas and Inhaca-Ponta do Ouro (Bandeira and Gell, 2002). Pioneer species observed in Mozambique include *Halophila wrightii, H. ovalis* and *Cymodocea serrulata*. The first two species occur in exposed sandy areas close to the coastline (den Hartog, 1970), whereas *C. serrulata* is a pioneer species in silted channels (Bandeira, 2002). Seagrasses abound in the muddy and biogenic (calcareous) sediments of Mozambique with the three dominant mixed-seagrass communities on the sandy substrata of southern Mozambique comprised of *Thalassia hemprichii, Halodule wrightii, Zostera capensis, Thalassodendron ciliatum* and *C. serrulata* (Bandeira, 1995). In contrast, the seagrass communities of the more northerly limestone areas are quite different, with seagrasses tending to occur intermingled with seaweeds species (Bandeira and António, 1996). Macroalgae such as *Gracilaria salicornia*, *Halimeda* spp. and *Laurencia papillosa* occur mixed with *T. hemprichii*, and *Sargassum* spp. with *T. ciliatum* (Bandeira and Antonio, 1996; Bandeira, 2000). Elsewhere, *Zostera capensis* and *Haludule wrightii* also form mixed beds (Bandeira, 2000; Bandeira and Björk, 2001; Massingue and Bandeira, 2005). *Enhalus acoroides, Halophila stipulacea* and *H. minor* were only found in northern Mozambique.

South Africa - Seagrass beds, found only along the east coast of South Africa, cover about 7 km^2, with the largest concentration in the St. Lucia and Richards Bay estuaries. (Colloty, 2000). However, periodic droughts severely impact both the extent and the species composition of the seagrass systems in South Africa. The species *Zostera capensis* is the most widespread and dominant of the seagrasses in the country, occurring mostly in estuaries from KwaZulu-Natal to the Western Cape. Other important locations with seagrass species are the rocky promontories of KwaZulu-Natal, mostly dominated by *Thalassodendron ciliatum*, adapted to the rocky habitat, together with seaweeds (Barnabas, 1991). *Ruppia maritima* is another dominant seagrass species that occurs within estuaries, especially St Lucia (Short and Coles, 2003).

Seagrass farming in Zanzibar, Tanzania (photo courtesy of Rudy v.d. Elst, ORI)

Seychelles - A total of eight seagrass species occur in the Seychelles Archipelago, mixed with more than 300 species of macroalgae. The total area covered is not known, but in general, *Cymodocea serrulata, Syringodium isoetifolium* and *Thalassia hemprichii* dominate the soft bottoms (Ingram and Dawson, 2001). The clear waters of Seychelles have supported the deepest known seagrass distribution within WIO, with *Thalasodendron ciliatum* occurring up to 33 meter depth (Titlyanov, 1995). The structure of the Aldabra Atoll differs considerably from some of the other island groups, since its coasts are built primarily of dead consolidated corals and are steeply undercut with overhangs. Four seagrass species (*T. ciliatum, T. hemprichii, H. uninervis* and *S. isoetifolium*) and 119 algal species occur both on the reef slope and in the lagoon itself, with some of common algae genera in the atoll being *Halimeda, Turbinaria* and *Laurencia* (Kalugina-Gutnik *et al.*, 1992). Mahé Island supports the highest recorded seagrass diversity in the archipelago (seven species), with *C. rotundata* inhabiting a narrow band along the shore, which is then replaced by *T. ciliatum* occupying the entire area exposed at low waters. Kalugina-Gutnik *et al.* (1992) report that algae may be associated with seagrasses, these include *Sargassum cristaefolium, Gracilaria crassa, Cheilosporum spectabile, Jania* spp., *Hypnea* spp., *Laurencia parvipapillata, Amphiroa foliacea, Cladophoropsis sundanensis and Gelidiella acerosa.*

Comoros - These islands, being located less than 400 kilometres east of the coastline of Mozambique and sharing a similar climate, are likely to support similar seagrass meadows to those of northern Mozambique, with mixed seagrass species in intertidal areas and subtidal seagrass species dominated by broad-leafed species such as *Thalassodendron ciliatum* (see Bandeira and Gell, 2003).

Madagascar - Little is known about the relative dominance of seagrass species, though it is likely that in southwest Madagascar they are similar to the species found in Mozambique, with most meadows being dominated by *Thalassodendron ciliatum* and *Thalassia hemprichii* (Bandeira and Gell, 2003). Seaweeds are also a common feature in intertidal and subtidal seagrass areas of Madagascar (Rabesandratana, 1996).

Mascarene Islands – Around Mauritius and Rodrigues islands, seagrass beds cover a surface area of 5.5 km^2 and 64.9 km^2 respectively (Turner and Klaus, 2005). The most abundant species in Mauritian lagoons is *Syringodium isoetifolium*, with other species present being *Thalassodendron ciliatum, Halophila ovalis, H. stipulacea, Halodule uninervis* and *Cymodocea serrulata* (Montaggioni and Faure, 1980; Database of Marine Organisms of Mauritius, 2007). Seagrass beds are found both as extensive beds of mixed species and monospecific stands - constituting natural habitats for a diverse group of organisms in these lagoons.

2.2.5 Rocky shores and sandy beaches

Various types of rocky shores occur within the WIO region, the most common being limestone, sandstone and granite. Pleistocene limestone outcrops are the main rock formation within the WIO, being dominant in Madagascar, northern Mozambique, Tanzania and Kenya, while in northern South Africa and southern Mozambique they comprise aeolianite (e.g. Kalk, 1995; Ramsay and Mason, 1990; Ramsay, 1996). Basalt and granite rocks also occur, though to a minor extent, being common in Comoros and Seychelles (see Hill and Currie, 2007) and Mauritius. Table 2-9 lists some WIO locations with their main shoreline substratum type.

Rocky shores and sandy beaches - Seychelles (photo courtesy of Rudy v.d. Elst, ORI)

Table 2-9 Substrata forming some rocky shores in the WIO

Location	Substrata
Dar es Salaam (Tanzania)	Limestone (Hartnoll, 1976)
Inhaca (Mozambique)	Sandstone (Kalk, 1995)
Maputaland (South Africa)	Sandstone (Ramsay, 1996; Ramsay and Mason,. 1990)
Durban (South Africa)	Sandstone (Martin and Flemming 1988)
Seychelles	Coral rock, granite (Ngusaru, 1997)
Mauritius	Basalt, limestone (Baird and Associates, 2003; Hartnoll, 1976)
Kenya	Limestone (Ngusaru, 1997)
Tulear (Madagascar)	Limestone (Hartnoll, 1976)
Comoros	Basalt (Ngusaru, 1997)
Northern Mombasa	Limestone (Ngusaru, 1997)

Sources: Hartnoll, 1976; Kalk, 1995; Hill and Currie, 2007.

The porosity and hardness of rock affects its water retention capacity, and thus the development of epifaunal marine life in the intertidal zone, with limestone and basalt being more porous than granite. Clear biotic zonation patterns can be seen in places where hard substrata extend from the upper reaches of wave action to the lower spring tide levels, with bands of algae, bivalves and gastropods (Hartnoll, 1976; Ngusaru, 1997). The degree of exposure, slope of the substratum and tidal range control the abundance and number of species.

Sandy beaches are also a common feature within the WIO, dominating long stretches of coast that are highly dynamic and have different degrees and patterns of wave action. These coastal sandy areas, often with fine accumulations of shell and coral debris, have their own unique biota and ecological processes. (see Ngusaru, 1997; Barbosa *et al.*, 2001). The coastlines of the region's countries are thus strongly influenced by the nature of the substrate, as the sections that follow describe.

Kenya - The southern coast of Kenya and the islands north of Lamu comprise fossil Pleistocene rock formations, resulting in large areas of intertidal reef platforms and cliffs. These platforms are inundated by sea water twice a day, resulting in strong zonation of intertidal communities into a littoral fringe, eulittoral and sublittoral zones (Ruwa, 1996). Fringing coral reefs run roughly parallel to the coast between 0.5-2 kilometres offshore, growing on fossil limestone, while sandy subtidal habitats dominate the shoreline from Malindi to Lamu, strongly influenced by the Tana and Sabaki Rivers (Obura, 2001).

Tanzania - Many localities along Tanzania's shoreline are of raised coral limestone, generally with wide erosional platforms that rise to the level of mean neap tide (Hartnoll, 1976). Around Dar es Salaam the shore is divided into three zones: the lower eulittoral up to mean tide level, with a dense cover of small algae and characteristic fauna which does not extend to higher levels; an upper eulittoral which extends to about mean high water spring tide levels, with algae only under shading overhangs and an abundant fauna dominated by polychaetes (*Pomatoleios*), barnacles *(Chthamalus, Tetraclita, Lithotrya, Acmaea)* and bivalves (*Sarcostrea cucculata*); and a littoral fringe characterized by littorinids and *Nerita* snails, extending in some areas more than five meters above mean high water springs. This pattern of zonation is found with little modification throughout the WIO. In terms of botanical diversity, macroalgae are intermingled with seagrasses and the dominant species include *Cystoseira myrica, Enteromorpha* sp., *Gracilaria salicornia, Laurencia papillosa, Sargassum* spp. and *Ulva* spp. Extensive descriptions of macroalgae of Tanzania are provided by Jaasund (1976) and Oliveira *et al.* (2005) and are probably also applicable to Kenya and northern Mozambique.

Mozambique - The northern coast of Mozambique is characterised by limestone substrata and extensive coral reefs lying beneath the subtidal fringe, similar to Tanzania and Kenya. Some coral reefs occur in lagoons, usually within extensive, sandy intertidal areas. Considerable seaweed and seagrass communities, forming mosaics, dominate this coastline. The substratum in central Mozambique tends to comprise soft sediments, with sandstone rock occurring in restricted areas mainly in rocky fulcra or small capes common in many places in the southern part of Mozambique e.g. Ponta Mazóndwe at Inhaca, Ponta do Ouro, northern end of Bazaruto Island (e.g. Kalk, 1995; Bandeira, 1995, 1998). In southern Mozambique, Inhaca has exposed and sheltered rocky shores with different zonation patterns, the main difference being the presence of marine algae on the exposed rocks. The commonest macroalgae species are *Jania adherens, Padina biryana* in the upper zones, *Saragum* sp. and *Laurencia* sp. in the middle and *Gracilaria* sp. and *Sargassum* sp. in subtidal areas (Bandeira, 2000). The rocky outcrops in southern Mozambique are again interspersed by extensive beaches and sandy marine sediments (Robertson *et al.*, 1996).

South Africa - The rocky shores along the east coast of South Africa (Kwazulu-Natal) are mainly composed of aeolinite (beach rock) (de Clerck *et al.*, 2005). The south and central shore has rocky headlands, wave-cut platforms and shallow reefs, which are important features for the establishment of some organisms, while the northern part is more characterized by sandy beaches (de Clerck *et al.*, 2005). In general, there are three main intertidal zones. The upper zone is barely covered by seaweeds, with common genera including *Bostrychia, Gelidium, Rhizoclonium and Herposiphonia* and the fauna is also very sparse, relatively common species being littorinid snails and oysters (*Sarcostrea cucullata*) (de Clerck *et al.*, 2005). The mid-intertidal is colonised by limpets and barnacles, sometimes with *Pomatoleios* (tube worms); the commonest seaweeds are *Gelidium reptans, G. foliaceum* and *Gigartina minima* (de Clerck *et al.*, 2005). Coloured zoanthids and the mussel, *Perna perna*, dominate the lower intertidal zone and are associated with coralline turf algae (*Jania* spp.) and large populations of the red alga *Hypnea spicifera* (de Clerck *et al.*, 2005). A wide variety of seaweeds are present in the subtidal and shallow tidal zones, often dominated by coralline genera *Amphiroa, Arthocardia* and *Cheilosporum* (see de Clerck *et al.*, 2005). The ascidian, *Pyura stolonifera*, and oyster, *Striostrea margaritacea*, are also locally abundant in the near subtidal zone (Berry, 1978, 1982).

Seychelles - Although rocky shores are a common feature in the granitic islands, as well as in the raised coralline islands, they have generally been poorly studied, mostly because of difficulty in access (but see McClanahan and Young, 1996). The intertidal communities are relatively narrow due to the low tidal range, the commonest animals found there being limpets, barnacles and rock crabs.

Comoros – The Comoros Archipelago is of volcanic origin and has a dominant and geologically young rocky shore of basalt (Ngusaru, 1997).

Madagascar - The south and southeast coasts of Madagascar consist of narrow rocky platforms and incorporate scattered reef formations (Mollion, 1998). The southwestern region has a similar geomorphology to northern mainland East Africa with its coral limestone shores (Hartnoll, 1976).

Mascarene Islands - Calcareous limestone in Mauritius is found mostly on La Prairie, Balaclava, the south coast of the Ville Noire region, Ile aux Aigrettes and south of Wolmar (Baird and Associates, 2003). On such shores, the upper littoral zone is colonized by *Tetrachthamalus, Acmaea* and *Siphonaria* in the higher reaches and *Tetraclita*, together with various echinoids, in the lower reaches. Similar patterns occur on the basalt shores, but echinoids become abundant on the very exposed shores (Hartnoll, 1976). There is little documentation on the rocky shores of the other islands of Rodrigues and Réunion.

2.2.6 Coastal forests

Coastal forests in the WIO region include terrestrial vegetation with a continuous stand of trees (White, 1983), found adjacent to the coastal areas but excluding mangroves. The range inland can be up to 200 kilometres (*sensu* Burgess and Clarke, 2000) or to the maximum inland extension of the coastal forests.

There are four phytogeographical regions (= phytocoria) in the WIO mainland region supporting various vegetation types, namely the Cape Regional Centre of Endemism, Maputaland-Pondoland Regional Mosaic, Swahilian-Maputaland Regional Transition Zone, and the Swahilian Regional Centre of Endemism (see Burgess and Clarke, 2000). Table 2-10 summarizes the phytochoria, their area, geographical extent, geomorphology and vegetation types. The limits of the Swahilian Regional Centre of Endemism and Swahilian-Maputaland Regional Transition Zone correspond to the Zanzibar-Inhambane Regional Mosaic, as identified by White (1983).

Table 2-10 Phytogeographic regions on the WIO mainland

Phytogeographic region	Area (km²)	Geographical extent	Geology	Vegetation types
Maputaland-Pondoland Regional Mosaic (South Africa and Mozambique)	148,000	From the Limpopo River mouth to Port Elisabeth (25°S and 34°S)	Coastal plain composed of Cretaceous and Tertiary marine sediments.	Mosaic of forests, scrub forest and evergreen and semi-evergreen bushland, secondary grassland and woody grassland.
Swahilian-Maputaland Regional Transition Zone (Mozambique)	336,000	Coastal belt from southern Somalia (1º N) to the mouth of the Limpopo River (25º S)	Most land lies below 200 m; scattered hills in northern part of the coastal plain, underlain by marine sediments of various ages from Cretaceous onwards.	Forest, secondary wooded grassland, scrub forest, edaphic grassland; small areas of transition woodland, bushland and thicket
Swahilian Regional Centre of Endemism (Mozambique, Tanzania, Kenya and Somalia)				

Sources: White 1983; Burgess and Clarke, 2000.

Geographical distribution of coastal forests in the WIO region is controlled by climate, hydrology and geomorphology (Burgess and Clarke, 2000). In semi-arid coastal zones of Kenya and northern Tanzania, the coastal forests are located close to the ocean and are thought to be sustained by groundwater flow. Arabuko-Sokoke Forest in Kenya, covering a surface area of 410 km² (Burgess and Clarke, 2002) is one of the better-protected coastal forests in the region.

Most coastal forest sites are isolated from each other, over distances varying from one to several tens of kilometres. The vegetation between the forests is a mixture of farmland, savannah-woodland and thicket (Burgess and Clarke, 2000). The savannah-woodland is usually dominated by mixtures of miombo vegetation and coastal mosaics (see *Flora Zambesiaca* maps in Wild and Grandvoux Barbosa, 1967).

Somalia - Little coastal forest remains in Somalia, though lowland forests did extend for most of the length of the Jubba and Shabeelle River valleys. However, between 1960 and 1987, the forest along the Jubba valley was reduced from 93.5 km² to 9.0 km² (Burgess and Clarke, 2000).

Kenya - Coastal forests in Kenya are estimated to cover a surface area of about 660 km², however, the majority of them are now degraded (Burgess and Clarke, 2000). According to White (1983), Kenya's coastal forests fall within the northern range of the broad Zanzibar-Inhambane Regional Mosaic, an extensive biogeographical unit stretching from the southern tip of Somalia to the southern coast of Mozambique. Due to its plant endemism, the northern area has more recently been re-classified as the Swahilian Regional Centre of Endemism (Burgess and Clarke, 2000). The vegetation types are mostly semi-evergreen or evergreen undifferentiated dry forest (Burgess and Clarke, 2000; Clarke, 2000). Examples of coastal forests in Kenya include the Arabuko-Sokoke, Tiwi and Diani Forests.

Tanzania - Up to 50 individual coastal forests occur from near sea level to the highlands of Tanzania, rising up to 870 meters (Burgess and Clarke, 2000). These forest habitats include mainly dry forest, moist forest, hilltop, riverine forest and scrub forest. Notable coastal forests in Tanzania include the Jozane forest, one of the few remnants on Unguja Island (Zanzibar), Mlola forest on Mafia Island and Ngezi Forest Nature Reserve on Pemba Island. Apart from these, several sub-centres of endemism have been described along the coast of Tanzania, including the "Lindi Local Centre of Endemism" located some 200 kilometres north of the border (Ruvuma River) between Mozambique and Tanzania, in the Matumbi and Kichi Hills, with at least three species

Endemic coastal forest at Black River Gorges National Park in Mauritius (photo courtesy of Peter Scheren, UNEP)

of endemic plants, in the Pugu Hills, near Dar es Salaam, and the Usambara-Kwale Local Centre of Endemism, at the border between Tanzania and Kenya, with some 29 species of endemic species of plants (Burgess, 2000).

Mozambique - Coastal forests in Mozambique cover an estimated surface area of 1,790 km^2 (Burgess and Muir, 1994; Burgess and Clarke, 2000). Recent studies in the Quirimbas National Park, northern Mozambique, have identified five vegetation communities, namely: Acacia-Grassland, Miombo-Velloziace, Mixed Woodland, Miombo Woodland and Coastal thicket (Bandeira *et al.*, 2007). Two special vegetation associations found in coastal areas are the community dominated by *Icuria dunensis*, an endemic tree in Zambezia, Nampula and Cabo Delgado Provinces in northern Mozambique (Izidine and Bandeira, 2002) and that dominated by *Brenaniodedron carvalhoi* (ex *Cynometra carvalhoi)* and *Cynometra fischeri,* also endemic to northern Mozambique (Eduardo Mondlane University Herbarium records and Palgrave, 2002). In southern Mozambique, the dominant habitats include the coastal dune mosaics, coastal grassland, and miombo woodland. The southern tip of the country is home to the Maputaland Centre of Endemism, known to house some 230 endemic species in Mozambique and northern South Africa (Kwazulu-Natal) (van Wyk and Smith, 2001). The woody grassland and sand vegetation of the Licuati Forest also possesses large numbers of endemic species. The area extends from southwest Maputo Bay, southwards to South Africa and includes ancient coastal dunes, up to 30,000 years old, that contain many of the endemic species of the Maputaland Centre of Endemism (see van Wyk and Smith, 2001).

South Africa – Much of the country is covered by the Maputaland-Pondoland Mosaic which stretches along the east coast of southern Africa, extending from southern Mozambique (Limpopo River) and the Mpumalanga Province (South Africa) in the north, through eastern Swaziland to the

Eastern Cape Province in the south. Three clear foci of endemism and high biodiversity occur, namely Maputaland in the north, Pondoland in the middle and Albany further south near Port Elizabeth (van Wyk and Smith, 2001). The Maputaland and Pondoland centres cover a total area of approximately 19,500 km^2. The vegetation is comprised mainly of forests, thickets, woodland, grassland and aquatic communities rich in terms of species diversity (6,000 to 7,000 species), though with relatively low endemism - 15% of the species that occur in the Albany centre are endemic, and 60 % are succulent plants. The main coastal plant associations on South Africa's east coast are coastal scarp forest, Pondoland coastal forest, coastal lowland forest and dune forest (Pooley, 1994).

Seychelles – Even with the remoteness of its 115 islands, the original vegetation has somehow changed since the arrival of humans (Shah, 1993). The dominant vegetation associations now include the high altitude moist forest of the granitic islands, mid-altitude vegetation, coastal lowland vegetation and vegetation characteristic of raised coralline islands (Procter, 1984; Stoddart and Fosberg, 1984). The Seychelles possess some 250 species of indigenous plant species, of which 75 are reported to be endemic (see Gurib-Fakim, 2003). Examples of endemics species include *Vateriopsis seychellarm* ('Dipterocarp'), *Lodoicea maldivica* ('Coco de mer') and *Deckenia nobilis* ('Palmiste') (Hill and Currie, 2007).

Comoros - Up to 2,000 species of plants are found in the Comoros. Major natural plant assemblages include dense humid forests, shrubby thickets and open woodlands, although the number of endemic species is not known (see Gurib-Fakim, 2003).

Madagascar - Two phytocoria cover the island, the East Malagasy Regional Centre and the West Malagasy Regional Centre of Endemism (White, 1983). Although Madagascar's floristic composition is distinct from that of Africa, a floristic link was found between this island and eastern Africa, with 13 genera shared between the Swahilian and Madagascar/Mascarene phytocoria (Burgess and Clarke, 2000). About 8,500 species were known to occur in these two centres, some endemic families and genera, respectively, being Didiereaceae, Sarcolaenaceae, Humbertiaceae and *Dypsis*, *Tambourissa* and *Tina* (White, 1983). According to Gurib-Fakim (2003), up to 80 % of the Madagascar flora is composed of endemic species.

Mascarene Islands - Mauritius has some 300 plant species, 50% being introduced plants and only seven species are endemic (Gurib-Fakim, 2002). Areas of the coastline, such as Flic en Flac, are generally dominated by introduced species such as Filao (*Casuarina*), which has a poor ability to recover from cyclone damage (Baird and Associates, 2003). Rodrigues possesses 75 plant species of which only five are endemic.

2.2.7 Fisheries ecology

Only a very small portion of the sea in the WIO, less than 5%, is shallower than 200 meters, this being the zone of the seabed known as the continental shelf. The central coast of Tanzania (with the continental islands of Mafia and Unguja (Zanzibar)), the south-central coastal section of Mozambique including the Sofala Bank, parts of the west coast of Madagascar and the Seychelles Plateau that surround the main granitic islands of Mahe, Praslin and La Digue are the only areas where there are considerable expanses of continental shelf (Spalding *et al.*, 2001). The remaining 95 % of the region's ocean is deep, mostly between 500 and 4,000 meters. This deep water surrounds the oceanic islands of Mauritius, La Réunion, the east coast of Madagascar, all the Seychelles islands excluding those on the Seychelles Plateau, most of the KwaZulu-Natal coast of South Africa, the northern coast of Mozambique extending into central Tanzania, and almost the entire coast of Kenya and Somalia. All are fringed by a very narrow continental shelf, rarely wider than a few hundred meters.

Coral reefs of the WIO region are providing important habitat for diverse fish specieis (photo courtesy of UNEP)

Despite this relatively small continental shelf, the coastal zone of the WIO contains numerous marine ecosystems that are of vital important to the productivity of the region, particularly its fisheries. Mangroves are located at the estuaries of most rivers and seagrass beds flourish in shallow, soft bottom environments where the sun's rays are able to penetrate (Okemwa and Wakabi, 1993; Gove, 1995; Sheppard, 2000). Coral reefs have developed on rocky fringes and hard surfaces in clear, well-oxygenated waters, notably along sediment-free coastlines, forming hundreds of kilometres of fringing reefs along the edge of the mainland and around the oceanic islands (Okemwa and Wakwabi, 1993, Gove, 1995; Sheppard, 2000). All these ecosystems and the waters they are bathed in support plankton communities that in turn feed diverse and numerous fish populations (Sheppard, 2000).

Estimates vary, but the consensus based on relatively few studies, estimate that the overall fish diversity in the WIO region includes some 2,200 species, about 15 % of the global total of marine fishes, with few oceans sharing similar ichthyofaunal richness (Smith and Heemstra, 1986). This richness is due to the large variety of habitats and oceanographic conditions of the region (van der Elst *et al.,* 2005). In addition, there are zones of high endemism within the region as well as unique groups of fish (van der Elst *et al.,* 2005).

Of the 2,200 species of fish so far recorded in the region, plus the countless crustaceans, molluscs and echinoderms, several hundred are important to the five main fishery sectors, namely those associated with coral reefs, the shrimp fisheries, the fishery for small pelagic species, that for larger pelagic species and the deepwater demersal fishery. Whether a fishery resource is exploited or not, and to what extent, depends on many factors, including shifts in demand for the resource or species, increasing fuel prices and the technology available to exploit the resource. With this in mind, the basic ecological features of the five main fisheries in the WIO are described below.

Coral reef fisheries - The coral reefs of the WIO support thousand of species of animals and plants. Two main resources are of interest to humans along these shores, fish and the edible marine invertebrates such as octopus, squid, lobsters, crabs, sea cucumbers (Rajonson, 1993; Semesi and Ngoile, 1993). The collection, or gleaning, of marine invertebrates from reef crests, in shallow lagoons and seagrass areas is typically undertaken on foot, especially during low tide (Darwall and Guard, 2000; Horrill *et al.*, 2000). The majority of species taken are relatively immobile or sessile and harvesting may involve all members of a community, but tends to be the preserve of women and children (Darwall and Guard, 2000; Horrill *et al.*, 2000). A variety of methods are employed, including simple hand collection of shellfish (lobsters and crabs) and sea cucumbers in baskets or small nets, the use of natural or synthetic poisons in pools or, in deeper water, the capture of lobster and octopus using spear guns and, in some places, SCUBA diving gear (Horrill *et al.*, 2000; Semesi and Ngoile, 1993).

Most of the animals so collected are consumed locally, but some are marketed internationally (Rajonson, 1993). Sea cucumbers (bêche-de-mer) are, in particular, exported after preparation, mainly to markets in south-east Asia (Darwall and Guard, 2000; Gabrie *et al.*, 2000; Rajonson, 1993; Semesi and Ngoile, 1993). Many gastropods (marine snails) are eaten, but larger and more attractive species are specifically collected for their shells which are sold to tourists or exporters (Gabrie *et al.*, 2000; Rajonson, 1993; Semesi and Ngoile, 1993).

The capture of fish on coral reefs involves the use of a variety of traditional and modern gear, targeting hundreds of species of fish, but mostly fish of small to medium-size (10–30 cm), belonging to the families Acanthuridae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, Serranidae and Siganidae (Darwall and Guard, 2000; Laroche and Ramananarivo, 1995; Shah, 1993). Many are caught using baited fish traps, though nets are important in fisheries for the larger species (Darwall and Guard, 2000). Goat-fish (Mullidae) are caught in gill-nets set in lagoons and over seagrass beds, and often actively corralled into the net by the fishers. Parrotfish (Scaridae) and some surgeonfish (Acanthuridae) are also taken in nets as they cross the reef crest at high tide to feed (Darwall and Guard, 2000). Many species, particularly highly valued groupers (Serranidae) and snappers (Lutjanidae), are fished using baited hook and line set from dugout sailing canoes, small dhows or other vessels while at anchor on or around reefs (Darwall and Guard, 2000).

Penaeid shrimp fisheries - In WIO countries endowed with large river mouths and mangrove forests, nutrient-rich sediments support a productive soft sediment ecosystem dominated by benthic-feeding penaeid shrimps. These in turn support a coastal industrial fishery, notably in the estuarine fishing grounds of the Malindi-Ungwana Bay in Kenya, Rufiji and Wami Rivers in Tanzania, the Sofala Bank and Maputo Bay in Mozambique, the Thukela Banks in South Africa (Krantz *et al.*, 1989; Nhwani, 1988; Okemwa and Wakwabi, 1993; Turpie and Lamberth, 2005), and off the west coast of Madagascar (UNEP/GPA and WIOMSA, 2004b). In Mozambique especially, estuarine penaeid shrimp fisheries make an important contribution to the economy (UNEP, 2006).

Mangroves and estuaries are a vital element in the life cycle of the shrimps, acting as a nursery ground for the juveniles (Crona and Rönnbäck, 2005). The shrimp fisheries depend on the rivers that supply the estuaries with freshwater and nutrients brought to the coast from the hinterland. In some instances these extend hundred of kilometres inland and drain vast areas, e.g. the Rufiji and Zambesi.

Fishing for penaeid shrimps is undertaken by a wide range of fishers and their gear, from large industrial and smaller commercial trawlers (15–30 m in length) to artisanal fishermen using seine-nets, traps and scoop-nets, operating on foot or from small canoes (De Young, 2006; Fennessy and Groeneveld, 1997; FAO, 2003). Many of the industrial vessels in the region are foreignowned and operate under license. The catch is dominated by *Penaeus indicus, Penaeus monodon* and *Metapenaeus monoceros,* but there is also a significant finfish by-catch (Fennessy, 1993; Fennessy, 1994; Sookocheff and Muir, 2006; Fennessy *et al.,* 2008). Estimates from Tanzania and Kenya's Ungwana Bay suggest that the weight of by-catch is up to twice that of the shrimp, with the majority of the valuable finfish by-catch (commonly snappers, groupers, emperors and jacks) landed and not wasted (Anon, 2006; Fennessy *et al*., 2003). However, since the by-catch also includes juveniles which inhabit the highly productive estuarine areas, prawn fishing may threaten recruitment to finfish stocks (Fennessy, 1994). Other fauna such as turtles also form a threatened by-catch but their capture is being alleviated with by-catch exclusion devices (Muir, 2006).

Deepwater demersal fishery - Beyond the depth of coral reefs, on the wide expanses of the Seychelles Plateau, the Saya de Malha Bank (Mauritius) and at the edge of the continental shelves of mainland countries and western Madagascar, a community of demersal fish are targeted in a deepwater fishery at depths from 100-200 m (De Sousa, 1987; Samboo and Mauree, 1987; Silva and Mauree, 1987; Lablache *et al.*, 1987). Various sharks (e.g. Charcharhinidae), groupers (Serranidae), jacks (Carangidae) and especially deep-water snappers (Lutjanidae) live on the edges of the continental shelf and slopes, moving to and from shallower depths to feed and rest (Fischer and Bianchi, 1984). The crimson jobfish (*Pristipomoides filamentous)* is a deepwater snapper and comprises the main target of a trial demersal fishery at Saya de Malha where the potential sustainable yield is estimated at 567 kg/km^2 per annum (Grandcourt, 2003). Though not very well researched, the growth (and recruitment) rates are thought to be slow in members of this fish community and it is widely agreed that fishing pressure may rapidly over-exploit the resource. Nevertheless, in the Seychelles, this deepwater resource makes an important contribution to the artisanal fishery (Robinson and Shroff, 2004). In Tanzania, the setting of gill-nets for such deepwater species yields sharks and other species, but also a by-catch of coelacanth which threatens the local population of this rare species (Ribbink and Roberts, 2006).

Small pelagic fish and baitfish fishery - In the same way that the inshore waters along the continental margins of the WIO and the coast of Madagascar benefit from nutrients and sediments that nurture the mangrove-based shrimp fishery described above, large populations of small pelagic species feed on the rich plankton in the water column (Sheppard, 2000). The same waters off estuaries that support the industrial shrimp fisheries thus yield schools of herrings, sardines and shads (Clupeidae), anchovies (Engraulidae), pony-fish (Leiognathidae), scads (Carangidae) and larger mackerel (Scombridae) (Fischer and Bianchi, 1984). Cast-nets, beach-seines, gill-nets, scoop-nets and traditional and commercial purse-seines are used to land large quantities of these small pelagic species (De Sousa, 1987; Ralison, 1987; Silva and Mauree, 1987; Lablache *et al.*, 1987; Jiddawe and Öhman 2002). In Tanzania, purse-seine fishing is undertaken at night with lights to attract and aggregate schools of fish, much of which is consumed locally, fresh or dried (Jiddawe and Öhman 2002).

Large pelagic fishery - The oceanic waters of the WIO region are the territory of migratory and shoaling schools of various species of tuna (notably yellowfin, skipjack and bigeye), all of the family Scombridae, as well as other oceanic species including dorado (Corphyaenidae), sailfish and marlin (Istiophoridae), and sharks (Fischer and Bianchi, 1984). Collectively, these fish are referred to as 'large pelagic species', restricted to warm water; many are known to migrate thousands of kilometres and occur from the surface to several hundred meters in depth (Fischer and Bianchi, 1984). At certain times of the year, juvenile tuna venture inshore to feed on small pelagic species (see above) while billfish roam the oceans feeding on pelagic squid, flying fish and juvenile tunas (Fischer and Bianchi, 1984).

Stocks of tuna form the basis of two distinct fisheries: a local small-scale inshore fishery and an international, large-scale and highly mechanized industrial fishery (Kambona and Marashi, 1996). Of the latter, there are two forms, long-liners that deploy kilometres of baited hooks, and purse-seiners capable of rapidly setting 200 meter-deep nets around moving schools (Miyake *et al.*, 2004). The countries with the largest EEZs, such as Seychelles and Mauritius, benefit the greatest from the pelagic fishery, while smaller mainland Africa countries like Kenya see little profit from this resource (De Young, 2006).

2.2.8 Species of special concern

In addition to the diverse ecosystems described earlier, the region has unique habitats, with high areas of endemism and species of special concern. The term includes rare and endemic groups as well as those that are threatened by over-exploitation or by the destruction of their natural habitat. Examples are discussed below:

Coelacanths: The coelacanth is a 'living fossil' previously believed to have become extinct at the time of the dinosaurs until its re-discovery in 1938 by Marjorie Courtenay Latimer, the curator of a tiny museum in the port town of East London, South Africa (Ribbink *et al.*, 2006). It is now classified as critically endangered in the IUCN Red List 2004 and listed in Appendix I of CITES (www.cites.org). Two species of coelacanth have so far been identified in the Indian Ocean region: *Latimeria chalumnae* from the Comoros Islands and other parts of East Africa and *L. menadoensis* from Indonesia (Ribbink *et al.*, 2006). Coelacanths are usually found at depths of 120-250 meters, where they congregate in caves, with as many as 14 fish crowded together in a single cave. More than 180 coelacanths have been caught thus far, from Comoros, Mozambique, Madagascar, South Africa, Kenya and Tanzania (Benno *et al.*, 2006). In the last two years, the steep shores off Tanga in northern Tanzania have yielded over 30 coelacanths, mainly caught by artisanal fishers using gill-nets for deep water sharks, driven by the demand from China for shark fins (Richmond, *pers. comm.*). Efforts are underway to estimate the local population of coelacanths and protect this area from this form of fishing.

Cetaceans (Marine mammals): Marine mammals in the WIO region are members of the orders Cetacea (whales and dolphins) and Sirenia (dugong). It is estimate that there are 80 species of marine mammals worldwide (Carwardine, 1995), of which approximately 34 species occur in the WIO (Bandeira, 1997 & 2002). Several cetacean species only occur in the region during the migration season. However, little information is available regarding the feeding ecology, distribution and abundance of these species.

Dolphins: Species that are encountered within the WIO include the Indo-Pacific bottlenose (*Tursiops aduncus*) and common bottlenose (*T. truncatus), the Indo*-Pacific humpback (*Sousa chinensis*), the spinner dolphin (*Stenella longirostris*) and pan-tropical spotted dolphins (*S. attenuata*), Risso's dolphin (*Grampus griseus*), and rough toothed dolphin (*Steno bredanensis*) (see Berggren, 2000 & 2009; Amir *et al.*, 2005). The main contemporary threat to cetaceans is entanglement in gill-nets (Amir *et al.*, 2002). Dolphin beachings have occurred on Bazaruto (Mozambique) and Unguja Island (Zanzibar) in 2006 (Jiddawi *et al.*, 2006) and off northern Madagascar in 2008 (Best, 2007).

Whales: The fishery for whales started in the WIO in 1791 with the arrival of the whaler *Delagoa Bay*, while exploitation in Seychelles waters commenced in 1823 (see Best, 1983 & 2007). Various species of whales were captured, including, sperm whale (*Physester macrocephalus*), humpback whale (*Megaptera novaengliae*) and the right whale (*Eubalanea glacialis*). Humpback whales and sperm whales are two of the species that have been known to strand on some beaches

The WIO region provides important refuge for many vulnerable species: marine turtle at Itsamia, Mohélie, Comores (photo courtesy of Farid Anasse, DNE)

off Zanzibar and mainland Tanzania, for unknown reasons. Threatened whales within WIO are shown in Table 2-12.

Table 2-12 Threatened whale species within the WIO region.

Species of whales	Status
Megaptera novaeangliae (Humpback whale)	Vulnerable
Balaenoptera borealis (Sei whale)	Vulnerable
B. edeni (Tropical whale)	Data deficient
B. musculus (blue whale)	Endangered
B. physalus (common rorqual)	Endangered
Mesoplodon densirostris (Blainville's beaked whale)	Data deficient
Physeter macrocephalus (Sperm whale)	Vulnerable
Eubalaena glacialis (Right whale)	Endangered

Source: www.iucnredlist.org (2007)

Dugong: Dugongs (*Dugong dugon*) are usually found where there are extensive seagrass meadows which occur from the high inter-tidal to shallow sub-tidal areas off the coast. Within the WIO region, the largest known population of dugongs is found around the Bazaruto Archipelago in Mozambique where up to 200 dugongs were counted in 2007 (Provancha, *et al.*, 2008; Cockcroft *et al.*, 2008; Guissamulo *pers. comm.*) Others are known to occur around Lamu Island

(Kenya), Aldabra Atoll (Seychelles) and from accidental catches in Tanzania (off the Rufiji Delta) and Comoros (WWF-EAME, 2004).

Whale shark -The Whale shark (*Rhyncodon typus*) is the largest fish in the world's oceans. It is distributed worldwide and occurs in all tropical and warm temperate waters. The first scientific record of this fish in the Indian Ocean dates back to 1828 and, in the Seychelles, to 1768 (Rowat and Engelhardt, 2007). Currently, the whale shark is listed in Appendix II of the Convention on the International Trade in Endangered Species (CITES) and it is also included in the Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks of the United Nations Convention on the Law of the Sea (UNCLOS) (Rowat and Engelhardt, 2007). Though widespread, there are regular sitings and aggregations at three locations, off Silouette Island (Seychelles), Mafia Island (Tanzania) and Bazaruto Archipelago (Mozambique).

Turtles: Five species of turtles are found in the WIO: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) (see Frazier, 1980; Howell, 1993). All five species are featured on the IUCN Red List of Threatened Animals (1996 version), with the hawksbill and leatherback listed as 'critically endangered' and the green, loggerhead and olive ridley as 'endangered'.

Turtles have complex life cycles, migrating between different foraging grounds at different times of their life, often hundreds of kilometres apart. They also migrate from these foraging grounds to nesting beaches during the reproductive season. Well protected populations of loggerhead and leatherback turtles nest on northern beaches of South Africa's East Coast during the months of November and December (Hughes, 1974a & 1974b; Humphrey and Salm, 1996). The number of nesting female hawksbill turtles in the Seychelles has declined by more than 50 % over the past 20 years, and is expected to decline significantly more in the next five years (J. Bijoux, *pers. comm.*) This decline has been attributed to intense over-harvesting of nesting females during the 1970s, 1980s and early 1990s, which prevented successful reproduction at numerous nesting sites in the Seychelles. Since 1981, more than 2,000 nesting green turtles have been tagged at Aldabra (Seychelles). The present knowledge of turtle migrations was derived, in part from turtle tagging at Aldabra and from a comprehensive 45-year tagging programme along the coast of KwaZulu-Natal, South Africa.

Seahorses: Seahorses (mainly of the genus *Hippocampus)* are listed as vulnerable or endangered on the IUCN Red List, but are traded worldwide as souvenirs, aquarium fish and, primarily, for use in Asian traditional medicines. Given concern over the sustainability of this trade, the genus was added to Appendix II CITES. This is a genus that in which early warning signs of depletion in its wild populations can be determined. Their biology renders them particularly vulnerable to habitat loss (shallow coastal habitats with seagrass beds and coral reefs) and over-exploitation. Five species of seahorses have been recorded in East Africa, namely *Hippocampus histrix* and *H. kelloggi, H. borboniensis, H. camelopardalis* and *H. fuscus* (Foster and Vincent, in press). In Kenya, seahorses are exported as aquarium fish in negligible numbers and, in Tanzania and Mozambique, they are sold as souvenirs to tourists and in bulk to Chinese traders. In Tanzania, the seahorse trade has been reported to export large numbers of seahorse species (alive and dried), mainly to Asian countries. This also occurs in Kenya, though the figures are not as high yet, but merit attention (Mcpherson and Vincent, 2004).

Sawfish: Sawfishes are a group of extremely large, shark-like rays which occur in the muddy shallow waters of tropical bays, rivers and lagoons. All sawfishes are classified under the family Pristidae, a name derived from an ancient Greek term for sawfishes. Though fearsome in appearance, sawfishes are very docile. The toothed rostrum of the sawfishes makes them especially prone to accidental entanglement in fishing nets and fishing line. Sawfish are exploited for their rostra, fins and meat and are highly prized exhibits in public aquaria. Some past sawfish declines are known to have been largely driven by a lucrative market for meat and fins. After decades of incidental capture in nets set for other species, sawfish populations worldwide have become severely depleted and threatened (Simpfendorfer 2000). The two critically endangered species that occur in the WIO are *Pristis microdon* and *P. zijsron*. Both occur in Tanzania, Mozambique and South Africa, and the latter also in Mauritius.

Giant groupers: Because of their great size, slow growth, territorial behaviour and vulnerability to fishing, giant groupers and potato bass (*Epinephalus lanceolatus and E. tukula*) are rare throughout their range. Found throughout the WIO, giant groupers can attain a body length of 270 cm and weight of 400 kg (Fishbase, 2006), making them the largest bony fish to be found on coral reefs. They are found in shallow waters and known to live in caves, around wrecks and also jetties in harbours. Giant groupers feed on a variety of species, including fish, spiny lobsters, small sharks and batoids, and juvenile sea turtles. The giant grouper is listed as vulnerable in the IUCN Red List of threatened animals. Its populations are thought to have declined at an average rate of 20% over the past 10 years (Fennessy, 2007).

Coconut crabs: The coconut crab (or robber crab), *Birgus latro, is the l*argest terrestrial arthropod on earth (Grub, 1971). They have been found to attain weights in excess of 5 kg (Fletcher and Amos, 1994) and are very powerful creatures with extremely strong pincers (or 'chelae') that can allegedly cut through a broom handle (Johnson, 1965). The coconut crab comes from the same family as the hermit crab, the Coenobitidae, which includes two genera: the *Coenobita* the land-hermit-crabs, and *Birgus*, comprising only the coconut crab, *B. latro* (Johnson, 1965). Although the two genera appear very different in adulthood, they share similar juvenile lives. Like adult hermit crabs on land, the coconut crab occupies an empty snail shell when young, eventually growing too large for a suitable shell, thence undergoing metamorphosis into the adult form (Murdoch, 2004). Coconut crabs live almost exclusively on small tropical islands, yet despite their wide distribution, they are threatened with extinction. In remote regions, they have become a valuable cash food crop as they are considered a delicacy and are eaten privately or sold to restaurants. Intensive harvesting in combination with their ease of capture has resulted in their virtual extinction in some countries, hence recent entry to the IUCN Red List (Fletcher and Amos, 1994). They are common on Chumbe and Misali islands (Pemba, Zanzibar), on Mafia Island, in Kenya on Wasini Island and Aldabra of the Seychelles.

Species threatened by curio trade: In addition to seahorses (see above), some other species that are harvested for the curio trade and listed in Appendix II of CITES include the blue coral (*Heliopora coerulea)*, organ-pipe coral (*Tubipora musica*), staghorn corals (*Acropora* sp.*)*, giant clam (*Tridacna* sp.), some species of cowries (*Cyprea* sp.), cone shells (*Conus* sp.), auger (*Terebra* sp.*)*, Murex (*Murex* sp.), conch (*Lambis* sp.) and the giant triton shell (*Charonia tritonis*). Countries with highly threatened marine curios include Comoros, Mozambique, Madagascar, Kenya and Tanzania.

A summary of the status and main threats to species of special concern is presented in table 2.12.

Table 2-12 Species of special concern in the WIO: their status and main threats.

Species	Status IUCN red list	Main threats
Coelacanth (*Latimeria chalumnae*)	Critically endangered	Accidental mortality (by-catch)
Dolphins (various species)	Deficient data or low risk	Accidental mortality, water pollution, harvesting (food, trade), cultural, scientific and leisure activities
Whale shark (Rhincodon typus)	Vulnerable	Harvesting (food, trade), poor recruitment, low densities
Seahorses (*Hippocampus spp.*)	Deficient data	Habitat loss/degradation, harvesting (trade, cultural, scientific, leisure activities), water pollution, accidental mortality
Sawfish (two species)	Endangered and critically endangered	Habitat loss/degradation, harvesting (for food, trade and medicine), accidental mortality (by-catch), pollution, human disturbance
Giant grouper *Epinephelus lanceolatus*	Vulnerable; extinct in Mauritius	Habitat loss/degradation, harvesting (for trade, medicinal and cultural habits), accidental mortality, low density
Coconut crab (*Birgus latro*)	Deficient data	Delicacy vulnerable to exploitation,
Whales	Low risk, endangered, vulnerable and deficient data	Accidental mortality (by-catch)
Sea turtles (five species)	Endangered and critically endangered	Habitat loss and degradation, accidental mortality, harvesting (food)
Dugong (Dugong dugon)	Vulnerable	Habitat loss and degradation, harvesting (food, trade, medicine, cultural and scientific activities), accidental mortality, pollution, natural disasters, slow population growth rates, human disturbance

Source: www.iucnredlist.org (2007)

CHAPTER 3 - SOCIO-ECONOMIC SETTING

3 SOCIO-ECONOMIC SETTING

3.1 General socio-economic characteristics

3.1.1 Introduction

The socio-economic characteristics of coastal regions of the West Indian Ocean are strongly influenced by the availability and patterns of natural resource utilization. Fish and fisheries, coral reefs, mangroves, coastal forests, seagrass beds, coastal wetlands, minerals, oil and gas and coastal agricultural lands all provide opportunities for extractive use of commercial value and for subsistence. Numerous coastal communities depend on these resources for their livelihoods, particularly for acquisition of food, fuel, shelter and income, while the condition of these resources determines the social and economic status of these communities.

The WIO countries are at various stages of economic growth, with considerable differences in their Gross Domestic Product (GDP), the majority being classified as 'poor' by World Bank criteria. The overview shown in Table 3-1 indicates that Seychelles had the highest Gross National Income (GNI) per capita in 2007, followed by Mauritius, South Africa, Réunion (France), Kenya, Tanzania, Comoros, Madagascar and Mozambique (World Bank, 2009a). Thus, World Development Indicators (World Bank, 2009a) indicate that only Seychelles and (almost) Mauritius are classified as High Income with Mozambique and Tanzania as Low Income; the other four countries being classified as Lower-middle Income. Clearly, this has a direct bearing on living standards and ultimately on the implications and capacity to deal with land-based activities and sources of pollution. The same follows from a comparison of the human development indices (HDI) for each of these countries (see Table 3-1), with the highest values recorded for the most 'developed' nations of Seychelles, La Réunion (France) and South Africa. However, the trend in annual HDI values over the past 30 years is insightful with positive gains for Mozambique, Madagascar, Mauritius and Comoros, but deteriorating HDI values for South Africa and Kenya (UNDP, 2007).

Interestingly, there is a trend that suggests better HDI levels in countries that have a longer coastline relative to their land surface area. Thus, Seychelles (HDI = 50 out of 177), Mauritius (65/177) and Comoros (121/177) have better HDI levels than the rest of the participating countries. The inference of this trend is that the marine and coastal environment and its resources generally benefit the economy and its people.

3.1.2 Demographic characteristics

The ten WIO countries had a combined population in 2007 of 178 million in 2007. The distribution of this population is linked to a number of factors, especially economic development and the availability of resources. Proximity to the coast is clearly desirable for gaining access to coastal and marine resources. However, proximity to the coast also leads to greater environmental impact on coastal ecosystems. Overall about 1/3 of the region's people reside within 100km of the coast, and 1/5 of the population falls into the 25 km zone where regular access to resources will be most pronounced. Hence the main beneficiaries of coastal and marine resources are those

35.9 million who live within the 25km coastal strip, while impact on the coast is created by the wider 61 million people that reside within 100 km from the coast. (World Resources Institute, 2003; World Bank, 2009a) (see Table 3-1).

The proportion of coastal population in the 25km strip varies substantially between countries from a low 6.1% in Kenya and 13.6% in Tanzania to 100% in the small island states. The population density also varies with some countries such as Somalia and Mozambique being sparsely populated (see Figure 3.1), at population densities of 14 and 27 people per square kilometre respectively, while other countries such as Comoros and Mauritius are very densely populated, at 315 and 650 persons per square kilometre respectively (UNEP/GPA and WIOMSA, 2004b; The Encyclopaedia of Earth, 2007, Demography Unit, Central Statistics Office, Mauritius, 2007).

Many of the coastal zones of the mainland African countries have experienced an influx of new residents and rapid expansion of economic activities. Population growth in coastal areas places heavy demands on inshore marine ecosystems, notably seagrass beds, coral reefs and mangrove forests, leading to damage and depletion of some species. All WIO countries have some form of coastal infrastructure, much of which is related to particular economic activities such as tourism, ports and harbours, industry, mining, road and railway transport. These activities are usually an attraction to immigrant populations (UNEP/GPA and WIOMSA, 2004b), seeking to better their lives and improve their status.

According to World Bank, 2009a projections[1], the annual population growth rate in the region in 2007 ranges from 0.4% in South Africa to 2.6% in Madagascar (Table 3-1). Similarly, life expectancy in the WIO varies from country to country, with the small island states having relatively higher life expectancy compared to the mainland countries.

There have been significant year-on-year trends in the annual population growth rate of WIO countries. While the past two decades have witnessed very high growth rates in most, this trend has slowed considerably and projections indicate that the rate of population increase has declined by 63%. While several factors may be attributable to this trend, the prevalence of HIV/Aids in some of the countries is a primary factor in lowering the overall age at mortality. Most significant changes in this regard have taken place in South Africa, where the life expectancy is one of the lowest in the region (Table 3-1).

The paragraphs that follow describe the salient demographic features of the WIO countries:

Kenya – The 2007 population was estimated at 37.5 million people of whom approximately 2.3 million (or 6.1% of the total) reside within 25km of the coast (World Bank, 2009a). Population size and density on the Kenyan coast varies from place to place with the highest density in the urban centres, like Mombasa, Malindi, Kilifi, Kwale and Ukunda as a result of significant rural-urban migration. Mombasa is the largest urban centre with a population of 665,018 (Republic of Kenya, 2005). Rapid population growth, especially along the coast has been identified as one of the fundamental threats to coastal and marine resources because of the increased demand for goods and services, and means of livelihood (Government of Kenya, 2007).

1 It should be noted that various population growth rate estimates and projections are available from different sources. For this analysis, World Bank statistics have been used as a basis.

Table 3-1 Land area, population size, life expectancy and GDP of the Western Indian Ocean countries.

Country	Area (km^2)1	Pop. (millions)[2] 2007	% Coastal pop. In 2000[3] <25km	< 75km	<100km	GDP 2007 (US$ billions)[4]	GNI Per Capita 2007[2] (US$)	HDI5 2005	Pop. growth rate[2] 2007	Life expectancy[2] 2006
Comoros	2,170	0.63	100	100	100	0.45	1,150	0.561	2.0	63
Kenya	582,650	37.53	6.1	7.5	8	29.51	1,540	0.521	2.6	53
Madagascar	587,040	19.67	23.2	45	55	7.33	920	0.533	2.6	59
Mauritius	2,040	1.26	100	100	100	6.36	11,390	0.804	0.7	73
Mozambique	801,590	21.37	32.7	52.1	59	7.75	690	0.384	1.9	42
La Réunion (France)	2,517	0.76	100	100	100	4.6	6,000	-	1.4	74
Seychelles	455	0.09	100	100	100	0.73	15,450	0.843	0.5	72
Somalia	637,657	8.70	30.5	52.7	55	-	-	-	2.9	48
South Africa	1,219,912	47.6	23.4	35.9	39	277.6	9,560	0.674	0.4	51
Tanzania	945,087	40.43	13.6	17.3	21	16.18	1200	0.467	2.4	52
TOTALS		178.04	20.1	30.4	34.3					

Abbreviations: HDI – Human Development Index
Sources: 1&2: World Bank, 2009a; 3: World Resources Institute, 2003; Gossling, 2006; 4: World Bank, 2009; 5: UNDP Human Development Report, 2007; Kelleher and Everett 1998; Hatziolos *et al.*, 1994; World Bank, 2001; World Bank, 2007. World Bank, 2008; CIA World Factbook, 2009 (https://www.cia.gov/library/publications/the-world-factbook); Central Statistics Office, Mauritius, 2007.

Madagascar - About 23% of the total population of 19.7.1 million people live within 25 km of the coast (World Bank, 2009a). Much of the island of Madagascar is sparsely populated with an average density of about 34 inhabitants per square kilometre. Although the majority of the population in Madagascar still lives in rural areas, an increasing proportion resides in the large cities such as Toamasina, Antananarivo, Sambava, Manakara, Farafangana, Mahajanga and Tulear, most of which are located in the coastal zone.

Mozambique – In recent years the population exceeded 21 million (UNDP, 2007), and, according to the last census, the population growth rate in 2000 was about 2.3% per year (INE, 2000). However, more recent estimates place the growth rate at a lower 1.9%. Approximately 32.7% of the population lives within 25 km of the coast and, of all WIO mainland African nations, Mozambique has the highest percentage of population living in the coastal zone.

Somalia – Of the total population of 8.7 million, about 2.65 million (or 30.5%) live within 25km of the coast (World Bank, 2009a). This approximation of coastal population is much higher than the estimates by Kelleher and Everett (1998) and Hatziolos *et al.* (1994) that placed an estimated 1 million people in coastal Somalia. This latter estimate appears more realistic as Somalis are nomads of the plains and not traditionally associated with the coast.

South Africa – In 2007, about 47.6 million people lived in South Africa of which about 11 million resided within 25km of the coast, equivalent to about 23% of South Africa's total population (World Bank 2009a). The coastal population density of 81 people per square kilometre is high compared to the average sub-Saharan African density of 55 people per square kilometre. Population growth rates declined from about 2.9% per year in the early 1980s to 2.4% in 1995, dropping further, to 1.1% in 2005 and 0.4% in 2007 (World Bank, 2009a).

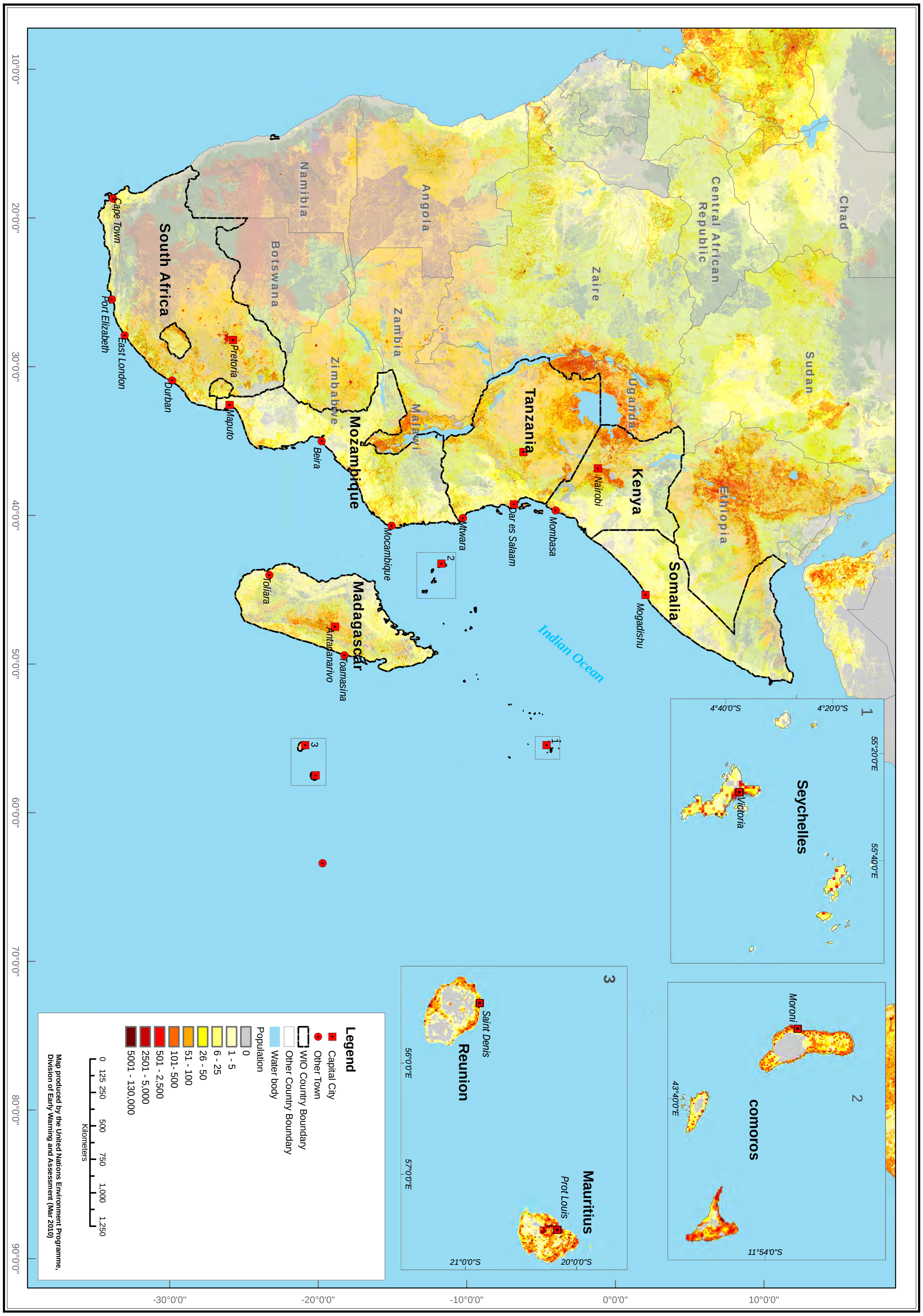


Figure 3-1: The distribution of population densities in countries of the WIO region

Seychelles and Mascarene Islands - The entire population (2.8 million people) of the Small Island States of the WIO, namely Seychelles, Comoros, Mauritius,and La Réunion live within 25 km of the coast (World Resources Institute, 2003) (see Table 3-1).

Tanzania – Of a total population of 40.43 million, about 5.5 million live in the 25 km coastal zone. As in the case of Kenya, the Great Lakes provide habitation for a significant section of the population. Coastal population densities varies widely with the Dar es Salaam region having the highest population of 2.5 million people followed by Tanga with a population of 1.6 million. There has been significant rural-to-urban migration, particularly to centres such as Zanzibar and Dar es Salaam, as people seek alternate livelihood opportunities and better living conditions (Mvungi, 2003). As a result, Dar es Salaam has had the highest rate of population increase at 4.3% followed by Unguja Island (Zanzibar) with 3% (Mvungi, 2003).

3.2 Socio-economic activities

Most coastal communities in the WIO region depend on nearby coastal and marine resources for their livelihood in terms of food security and income. The main activities associated with these resources are fisheries, tourism, agriculture, industry, forestry, shipping and ports, mining, conservation (e.g. national parks and reserves), urbanization and infrastructure. However, a recent study conducted by Hoagland and Jin (2008) revealed that, in absolute terms, the WIO region is among the lowest in terms of development of marine industries[2]. Clearly, this presents opportunities for improvement to the overall socio-economic development of the region, through diversification of marine and maritime activities and industries. More details on the various types and levels of economic activities in the WIO region are presented in the following sections, including two of the most important activities that impact on shared and transboundary resources, i.e. fisheries and tourism.

3.2.1 Fishery resources

The area of sea defined by the United Nations' Food and Agriculture Organisation (FAO) as the western Indian Ocean covers approximately 8% of the world's oceans and, in 2006, generated 4.8% (4.5 million tonnes) of the total global fish catch (FAO 2009). The countries included in this study were responsible for only 7.6% of the reported catches within the area but it has been suggested that some of these countries under-report their catches particularly those from the informal, traditional sectors (van der Elst *et al.*,2005). In general, the western Indian Ocean is not as productive (0.15 $t.km^{-2}$) as some of the other FAO fishing areas such as the northwest Pacific (1.03 $t.km^{-2}$) and the northeast Atlantic (0.65 $t.km^{-2}$). This can mostly be attributed to the absence of any large nutrient upwelling systems in the region but is possibly compounded by the under-reporting of catches (van der Elst *et al.*,2005).

The livelihood of the 35.9 million people that inhabit the 25 km coastal strip of the WIO countries, are intimately linked to coastal and marine resources, with fisheries especially important in terms of food security, employment and income generation. For most countries in the region, these resources are either primary contributors to their GDP or vital elements of socio-economic stability in the coastal region (Van der Elst *et al.*, 2005).

Fisheries statistics published by FAO indicate that there has been an approximate doubling of marine fish capture from 1997 to 2005 in the western Indian Ocean fishing area (FAO, 2007).

2 The study used an indexing system, comparing Large Marine Ecosystems (LMEs) around the world, on the basis of different types of marine activities.

Countries under consideration in this report showed a 41% increase in catches over the same period. Most of the increase in catches can be attributed to a greater fishing effort directed at tuna, particularly by Seychelles (SFA 2006). The reliability of the data can be questioned. While some of the statistics appear to be sound, such as fisheries data for South Africa, Seychelles and the tuna operations of the Mascarene Islands fisheries, others are less comprehensive. Catch records submitted to the FAO are often under-reported and there may be distortions of actual fish landings, both from artisanal and the industrial sub-sectors. This is the situation for much of central and northern Mozambique, most of Tanzania and Kenya and, most likely, large parts of Madagascar (van der Elst *et al.*,2005; Jacquet *et al* 2007, 2008). Consequently, use and interpretation of these data should be treated with caution. Nevertheless, year-on-year comparison has shown a levelling off in the WIO over the past five years, suggesting that fish production from wild stocks in the WIO may be approaching its maximum harvest potential of about 4.3 million tonnes per annum.

Most of the many and diverse fisheries of the region are subjected to harvesting by the coastal states but the higher value oceanic resources are harvested mainly through purse seining and long-lining by foreign fishing vessels from Europe and Eastern Asia, with trans-shipment and canning in the region, primarily for export (FAO, 1997). At the artisanal level, over 160 different fishing activities have been identified in five WIO countries, ranging from passive trap net fishing conducted at village level to extensive beach seine operations (Van der Elst *et al.*, 2005; WIOFish, 2008). These authors conclude that the majority of the region's artisanal fisheries are not adequately supported by scientific information and that management strategies need to be improved if the enormous development challenges of East African countries are to be met.

Table 3-2 provides an overview of artisanal fisheries activities in the WIO region. Restricted to inshore areas mostly, the artisanal fisheries are conducted in all coastal habitats, including sandy

Destructive fishing techniques, such as the use of seine nets, are an important cause of ecosystem degradation (photo courtesy of Rudy v.d. Elst, ORI)

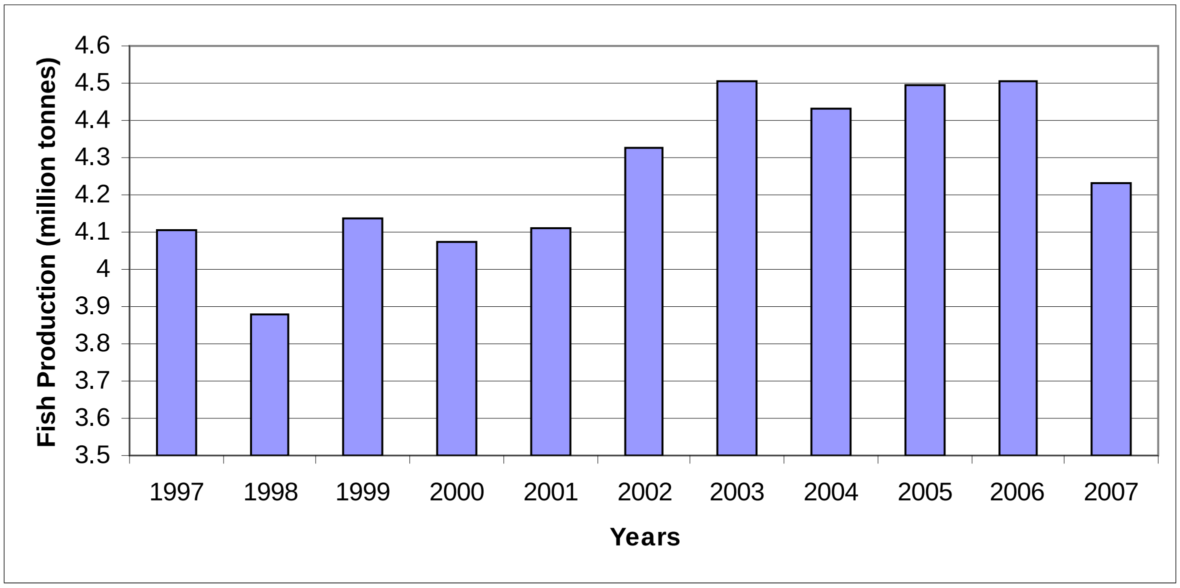


Figure 3-2 Total marine catch in the western Indian Ocean (Source: FAO Fisheries Statistics, 2009).

beaches, estuaries, coral reefs, lagoons, wetlands, bays, mangrove forests and seagrass beds. While artisanal fishers may not venture directly into oceanic waters, they do harvest considerable numbers of oceanic and pelagic fishes, when such species move closer inshore. Examples include several species of tuna, larger mackerel and sailfish. While much of the artisanal fishing is conducted on a small-scale using simple equipment with the catch primarily for own or neighbourhood market use, others have graduated to more advanced gear and the use of outboard motors. These small-scale fishers supply a wider range of domestic markets and some sell their catch to middle-men for export. Although typically individual daily catches per fisher are no more than a few kilograms, the collective total of the large number of fishers is considerable (van der Elst *et al*, 2005). In the case of Tanzania, Kenya, Comoros and Madagascar, this accounts for more than 80% of their countries' total marine catch in. Artisanal harvests are not confined to finfish and in many of the countries modest catches are made of invertebrates, including spiny lobsters (*Panulirus versicolor*, *P. penicillatus*, *P. longipes* and *P. ornatus*), mangrove crabs (*Scylla serrata*), octopus, squid and sea-cucumbers, either for local consumption (especially to tourism sector) or for export in small quantities. In some regions, especially in Kenya and Mauritius, the live capture of ornamental species for export is a significant activity, as is the taking off ornamental shells for trade in most tourist areas.

The following sections describe the salient features of the fishery sector of each of these countries.

Comoros – The fisheries on all three of the islands are mainly artisanal, using pirogues and vedettes, some powered by engines, hand-lines, gill-nets and traps. Being largely volcanic, with little continental shelf, many operators also fish in deep water with lines for tuna, tuna-loke species and oilfish (*Ruvettus ruvettus*), coincidentally also taking coelacanths (locally *Gombessa*) at times. Closer to shore, large shoals of scad (*Decapterus*) are an important target for fishers and a valuable source of food security at local markets. Unfortunately, very few investigations have to date been undertaken and documentation of catch, effort and species diversity is scarce and outdated (Williams, 1988; Walmsley *et al.*, 2006). Comoros often fails to submit annual reports on fisheries to regional management bodies such as IOTC (IOTC, 2007). The annual productivity per unit area of the Comoros fishing grounds was believed to be about 7 tonnes/km^2 which is higher than 5 tonnes/km^2 often assumed for highly productive coral reef grounds (Williams, 1988). In 1985 the total catch was calculated to be 5500 tonnes, increasing to 9134 tonnes in 1990 and 14 115 tonnes in 2003. The catch, comprises 70% pelagic species, 10% shark and 5% reef species such as Lethrinidae. It has been suggested that the limited reef fish resources are at or near their level of full exploitation (Aboubacar, 1991; Talla *et al.*, 2004; FAO, 2007), although the pelagic stocks, including tuna, are less likely to be impacted by local fishers as they are wide ranging and shared with other countries of the region.

Most of the fish production in Comoros is for local consumption and represents an important source of food security, but some fisheries production has generated export earnings since the latter part of the 1980s. It has been estimated that up to 30,000 tonnes of fish could be landed per year from the Comorian EEZ, using vessels equipped for deep-water fishing for both demersal species (e.g. snappers) and oceanic species like tuna and billfish (Metz, 1994). The fisheries agreement between the European Union and Comoros (2005 to 2010) is based on a catch of 6,000 tonnes per year, taken by European vessels (Spain, Portugal, Italy and France) in the Comoros EEZ waters, at a fee of 35 per tonne (www.ec.europa.eu/cfp/bilateral agreements/Comoros).

Table 3-2 An overview of selected artisanal fishing statistics per country.

Country	No. artisanal fishers	Artisanal catch (t/yr)	Principal fish families
Comoros [1]	8,000	5,500 - 7,507 – 13,500 ('97)	Scombridae, Gempylidae, Decapterus
Kenya [3]	10,000	8,000 – 16,000	Lethrinidae, Siganidae, Scaridae, Lutjanidae, Serranidae, Scombridae, Caranx, Penaeidae.
Madagascar [4]	10,651	12,382 – 70,000	Mugilidae, Serranidae, Carangidae, Gerridae, Hemiramphidae, Elopidae
Mauritius [5]	2,365	950	Lethrinidae, Mugilidae, Siganidae, Acanthuridae, Scaridae.
Mozambique [6]	70,000	100,000 – 120,000	Siganidae, Monacanthidae, Labridae
Réunion (France) [2]	521	866	Scombridae, Sparidae
Seychelles [7]	1,700 – 1,800	4,000 – 5,000	Carangidae, Sphyraenidae, Scombridae, Siganidae, Serranidae, Scaridae
Somalia [8]	4,200	6,000	Lobsters, Sharks
South Africa (KwaZulu Natal only) [9]	5,183	2,153	Mugilidae, Carangidae, Ambasidae, Scombridae, Leiognathidae, Gerridae,
Tanzania (including Zanzibar) [10]	58,000	70,000	Lethrinidae, Serranidae, Siganidae, Mullidae, Lutjanidae, Carangidae, Scombridae, Cluepidae

Sources: 1: Williams, 1989, WWF, 2005; 2: Direction Régionale de l'Environnement, 2003; 3: Malleret *et al.*, 2004, Ochiewo, 2004; WWF, 2005; Kenya Fisheries Dept., 2007; 4: Ralison, 1987; Stabrawa, 1999; WWF, 2005; 5: Ministry of Agro Industry, Food Production & Security, 2006; 6: Hoguane *et al.*, 2002. Santana-Afonso *et al.*, 2004; WWF, 2005; 7: Robinson and Shroff, 2004; Robinson *et al.*, (2004); 8: Kelleher and Everett, 1997; Fielding and Mann, 1999; Hatziolos *et al.*, 1994; Lovatelli, 1995; World Bank, 2001; 9: ORI-unpub. data, 2006; FAO Fisheries Country Profiles, 2005; IUCN, Jakarta mandate, 2002; 10: Jiddawi, 2003; TCMP, 2001; WWF, 2005.

Kenya – Kenya has rich inland fisheries contributing 94% - 98% to overall national fisheries production, and the marine fishery production contributes only 2% - 6% of the total (FAO, 2007). Marine landings varied from 4,763 to 7,774 tonnes per year over the past decade, although more realistic estimates for all 'inshore' landings are put at 12,000 tonnes (Sanders *et al.*, 1990). Lake Victoria catches dominate the national total with 120,000 tonnes, which is down from a high of 210,000 tonnes in 2000 (FAO, 2007). Kenya's EEZ is known to include considerable tuna and tuna-like resources which are harvested by international fleets (IOTC, 2008). Several authors have calculated or speculated as to the potential total yield of Kenyan marine waters, but their results range enormously, from 20,000 tonnes (FAO, 1990) to 350,000 tonnes estimated by the Kenyan Fisheries Department (King *et al.*, 2003). Clearly, the actual value and sustainability levels of the Kenyan fisheries resources are not known and remain a challenge, likely to be addressed by the SWIOFP project.

In 2008 the Kenyan marine fishery had 2,368 fishing boats, of which only 194 were motorized. A total of two longliners operated under the Kenyan flag, with 59 and 49 foreign longline licenses issued in 2006 and 2007 respectively. A total of 33 purse seiners were licensed. Sharks are an important resource and popular commodity in Mombasa. Attention is being focussed on developing a Kenyan Plan of Action for sharks (IOTC, 2008). The artisanal fisheries of Kenya are multi-species in nature (WIOFish, 2008), landing over 95% of the marine catch and estimated to generate over US$ 3.2 million per year, (UNEP, 2006a). Dhows, outriggers, canoes and planked boats are used to fish with gill-nets, hand-lines and tangle-nets. The most productive fishing areas are the Lamu area that covers Kiunga, Kizingitini and Faza, the Malindi Bay and Tana River Delta, and the south coast around Majoreni and Vanga (Ruwa *et al.*, 2003). Although much of the artisanal fishing takes place in the inshore shelf areas, among coral reefs, pelagic species such as tuna are also exploited by artisanal fishers. Using gillnets, handline and longlines, these fishers operate up to 10 nm miles during calm-sea periods. The artisanal tuna catch peaked in 2004, but has declined since then (IOTC, 2008).

After decades of growth, the artisanal fishery is now considered fully exploited with over-fishing and intense fishing over coral reefs with ensuing changes in community structures and reef degradation which in turn adversely affects the productivity and species diversity. Similarly, trawling for shallow water prawns in the Malindi–Ungwana Bay has resulted in destruction of seagrass habitat, impacted on productivity and fish diversity, with resultant conflicts between artisanal fishers and trawler operators (KMFRI, 2002; King *et al.*, 2003). These factors, including the high levels of by-

Artisanal fishing 'fleets' are an important means of subsistence to the coastal population (photo courtesy of Rudy v.d. Elst, ORI) catch, impact on turtles and general environmental threats posed by the trawl fisheries prompted the government in 2006 to enforce a ban on trawling within 3 nm of the coast, effectively closing the trawl fishery in the Bay (*pers comm*: C. Munga KMFRI; Fulanda and Munga, 2006). This conflict of resource-use in the Bay was especially aggravated by the lack of a management strategy, which is now being developed.

Kenyan fisheries also have a strong recreational element, mostly targeting yellowfin tuna, sailfish, marlins and swordfishes. Records have been maintained for several decades, confirming the value of this sector to the tourism industry.

Madagascar – This large island state has an enormous coastline with a great diversity of fisheries, many of which provide critical socio-economic support and food security to the nation. Deepwater, offshore resources are accessed by about 100 industrial vessels that land about 25,000 tonnes a year, mainly tuna for export. The industrial shrimp fisheries, shallow and deep water, are similarly an important foreign exchange earner in Madagascar with over 7,600 tonnes landed in 1995 (FAO, 1997), increasing to 11,500 tonnes (FAO, 2003a). Artisanal shrimp fishing also takes place, mostly of a high quality and supplied directly to large processing plants. Shrimp fishing is seasonal from March to October (FAO, 2003b). Small pelagics are also important and in the late 1980s it was estimated that the fishery for this resource had a potential yield of 135,000 tonnes for the west coast and 11,800 tonnes for the east coast (Ralison, 1987).

Small-scale fishing is composed of 'traditional' fishers harvesting on foot or from dugout canoes and artisanal fishers using motorised boats that have an engine capacity of less than 50 horsepower (Soumy, 2005). Madagascar has about 80,000 traditional fishers, some of whom are engaged full-time and others part-time (Soumy, 2005) These fishers contribute significantly to the enrichment of the population's diet and in 2002 were responsible for about 53% of the total marine fish catch (Soumy, 2005). Artisanal gear types typically include various gill-nets, traps and beach seines.

Mauritius – A considerable diversity of fisheries is found in Mauritius, Rodrigues and the wider Mascarene region, ranging from small-scale artisanal operators to extensive offshore fisheries. About 10,000 persons are involved in fishing activities which can be divided into four types, namely the coastal (artisanal) fishery, the banks fishery, the semi-industrial chilled fish fishery and the sea cucumber fishery.

The artisanal fishers in the coastal fishery traditionally operate in the lagoon areas with wooden pirogues of 6-7 metre length, equipped with hand-lines, basket traps, large nets, gill-nets and harpoons or hand spears. These fisheries provide direct and indirect employment to around 2,300 fishers (MAIFDS, 2007). These fishers have experienced a significant drop in catches from 1,302 tonnes in 2002, to 640 tonnes in 2007. The decline in total catch has in part been attributed to a decline in effort by artisanal fishers.

The banks handline fishery involves seven vessels that operate on the shallow water banks of the Saya de Malha, Nazareth, Albatross and in the Chagos Archipelago, while a further four vessels operate around St Brandon. The main target species are lethrinids which contributed 83% of the total catch while the remainder of the catch is made up of snappers, groupers and tunas. The catch from the banks fishery around St Brandon, which includes octopus, is landed frozen, chilled or salted. In 2007 the total catch from St Brandon was 140 tonnes (3.5 tonnes were octopus) while for all other areas the catch was 2,127 tonnes. Octopus resources appear to have been substantially depleted, attributable to dredging and siltation of the lagoon systems. Initiatives are underway to create artificial reefs that will re-establish octopus habitat (Panray 2007).

The 17 semi-industrial vessels operate primarily on the Soudan Banks, Albatross, Nazareth and Saya de Malha. The catch from these vessels is either frozen or chilled at sea and has a similar composition as the banks fishery comprising lethrinids, snappers, groupers and tunas. Total catch for 2007 was approximately 171 tonnes.

Mauritius has an important stake in the tuna fishery, partly as the basis of a local tuna processing industry and also as an important tuna trans-shipment port since the early sixties (IOTC, 2008). The artisanal fishery for tuna has also developed, especially around fish aggregating devices. In addition, Mauritius is a popular destination for big game sport fishers, who target billfish and other large pelagics (van der Elst, 1990). In recent years swordfish harvesting has become a significant factor (IOTC, 2008).

Commercial harvesting of sea cucumbers from the lagoons began in 2005 with licences issued to six operators. The total catch in 2006 was 414.5 tonnes and 620 tonnes in 2007 (MAIFDS, 2007). Species harvested were *Actinopyga echinites (*brownfish*), Actinopyga mauritiana (*surf redfish*), Bohadschia marmorata (*brown sandfish*), Stichopus chloronatus (green fish), Stichopus variegatus (curry fish), Holothuria scabra (sandfish) and Holothuria nobilis (*black teatfish*).*

Mozambique - The fishing industry is traditionally one of the largest generators of foreign exchange in Mozambique, with export of shrimp from Sofala Bank contributing to about 40% to the foreign revenue generated in the late 1990's (FAO, 1997). The contribution made by fish, including shrimp, has however dropped substantially in recent years, in part attributable to greater export earnings in other sectors, amounting to only 5.4% of total export value in 2005 (Macia, 2004; FAO, 2007b). Total marine fishery production is estimated at between 100,000 to 120,000 tonnes per year with domestic consumption estimated at 7.5 kg per capita (Hoguane *et al.*, 2002).

While industrial fishing, at various levels, contributes significantly to overall landings, artisanal fisheries provide livelihoods for more than 70,000 fishers and their families, whilst also providing food to a large section of the population at the coast and in the hinterland. The number of artisanal vessels has been estimated at 15,000 (IDPPE, 2004; Hoguane *et al.*, 2002). Wooden, non-motorised canoes are commonly used to reach fishing grounds, while hand-lines, cast-nets, beach seines, gill-nets, trap, cages and trolling lines are popular gear types. Although extensive data collecting systems are in place (Baloi *et al.*, 1998) the historic data of artisanal landings appears to have been considerably under-reported (Jacquet *et al.*, 2008).

Deepwater fishing by about 150 industrial and semi-industrial vessels earns the country close to US$ 100 million each year (US$ 96 million in 2005; FAO, 2007b). These landings include a variety of resources, including valuable deep water lobsters, langoustine and pink prawn. Sport line-fishing, mainly by South Africans, has increased significantly since 1992, and with little or no control in the southern waters of Mozambique. Many cases of "sports" fishers exporting quantities of valuable linefish to South Africa have been reported (Massinga and Hatton, 1996), although a draft new linefish management plan is likely to provide better control. Apart from fish and shrimp, other important exploited resources near urban centres include invertebrates such as crabs, clams, and sea urchins (WIOFish 2008).

Réunion – Three main fisheries operate in Réunion: the small-scale coastal fishery, the longline fishery and the Southern Ocean fishery (European Union, 2006). The small-scale coastal fishery targets reef fish and small pelagic fish that inhabit the narrow coastal areas and the total catch is approximately 800 tonnes per year (FAO 2008). Gears utilised include handlines, driftlines, troll-lines, seine nets, tangle-nets and gillnets (Biais, 1987).

The longline fishery harvests 3,400 tonnes of swordfish, tunas and billfishes annually (FAO, 2008) using 30 longliners (European Union, 2006), while the Southern Ocean fishery targets toothfish and crayfish using seven large vessels of 75 m or longer (European Union, 2006). Catches in the Southern Ocean are estimated at 6,000 tonnes per year.

The fishing industry in Réunion directly employs approximately 900 people and a further 120 people are employed by the land-based processing companies and equipment suppliers (European Union, 2006).

Fish is the second-most important export product of the island after sugar-cane and the main recipient nations being Japan, the USA and France. The majority of fish products are provided by the medium and large-scale (industrial) fisheries, accounting for approximately 6,000 tonnes per year or over US$ 40 million (Direction Régionale de l'Environnement, 2005). Only a small portion, approximately 866 tonnes per year, at a value of approximately US$ 13 million is derived from small-scale artisanal fisheries activities, of which a large part is sold locally.

Seychelles – The fishery sector is one of two major foreign exchange earners, along with tourism, and comprises industrial, semi-industrial and artisanal fisheries. In 2005, Seychelles earned US$ 192 million from tuna exports, equal to 41% of total export value for that year, (FAO, 2007b), derived mainly from the industrial fishery. The artisanal fisheries are also of great importance in terms of food security, employment, and cultural identity in the Seychelles. The total catch from the artisanal sector has remained fairly stable since 1985 with landings typically ranging between 4,000 and 5,000 tonnes per year (Robinson *et al.*, 2004).

The artisanal fishery sector employs approximately 1,800 fishers (Murray and Henri, 2005) and utilises 400 vessels (Azemia and Assan, 2006). Spiny lobster, crab, octopus and sea cucumber are very important resources in this sector, constituting valuable export products. Smaller boats (pirogues) of 5-16 meter length are used for more inshore areas, with hand-line, trapping, various nets and SCUBA diving gears used widely.

The main fishing grounds in Seychelles for the semi-industrial fleet are the offshore banks and drop-offs of the Mahé Plateau. Fishers use fully decked inboard vessels ('schooners') and fish with handlines, especially for the popular "Bourgoise" being the emperor snapper *Lutjanus sebae* (WIOFish, 2008). Most of the catch is sold and consumed locally, meeting the demands of the tourism industry, but a small percentage (< 5%) is exported (Azemia and Robinson, 2004).

Somalia – At 3,200 km, this country has one of Africa's longest coastlines and includes potentially one the region's richest fishing grounds, driven by seasonal upwelling off the Horn of Africa. Traditionally, Somalis are not a fishing nation, but after the 1960s significant foreign support and development of fishery resources took place, including the establishment of large fishery canning and processing plants at several sites (Lovatelli, 1995). Mostly, these factories were intended for the processing of small pelagics (*Sardinella, Decapturus* etc) as well as several tuna species, mostly caught by artisanal fishers (Sanders and Morgan, 1999). Initially about 21,000 tonnes of fish were landed but for a variety of reasons, these fisheries and their infrastructure failed and only relics of these industrial activities are visible today. Considerable tuna harvests continued to be made in the Somali EEZ by foreign operators and mostly offloaded in Seychelles. However, recent piracy has curtailed that significantly (IOTC, 2008).

Acoustic research surveys in the mid 1970s gave estimates of fisheries potential, with a maximum of 300,000 tonnes per annum, about half of which are small pelagics. An estimated 4,200 artisanal fishers (Hatziolos *et al.*, 1994; Lovatelli, 1995) target diverse resources. Artisanal fishing at several sites such as Bosasa, Berbera, Eyl and Zeila land no more than 4 to 8,000 tonnes of finfish per year to supply limited local markets. However, the demand for shark fin and shark oil has resulted in intense gill netting along the coast from Harbo to the Horn, (van der Elst and Salm, 1999). These nets also take a large bycatch, including dolphins and green turtles, the latter commonly eaten. Lobsters along the north-eastern coast from Benda Beyla to Eyl represent an important resource with up to 500 tonnes taken by artisanal fishers annually for export. However, uncontrolled harvesting has lowered catch rates to levels that pose concern (Fielding and Mann, 1999).

At present, Somalia does not have any vessels that are large enough to exploit offshore stocks. Various attempts have been made to establish fisheries agreements with foreign operators, but these have been legally flawed as they were not developed by a legal administration and thus not recognised by different communities along the coast. Unfortunately, Somali fisheries data are sparse and unreliable, especially in the context of the ongoing national tensions in that country.

South Africa - Indian Ocean fisheries in South Africa are relatively minor compared to the large-scale, industrial fisheries found on the Atlantic coast. Nevertheless, numerous subsistence fisheries exist off the KwaZulu-Natal coast on the Indian Ocean. The fisheries sector is a relatively small sector within the national economy of South Africa, with an overall contribution to GDP less than 1% (Japp and James, 2005).

South African fisheries have generally been well-managed with frequent revision of management procedures reflecting progressive change within the management structures as well as changes in international trends (Japp and James, 2005). Overall, the industrial fishing operation generates approximately US$ 270 million annually, while recreational fishing generates about US$ 200 million annually. The small penaeid shrimp fishery of KwaZulu-Natal is highly variable in direct relationship with river run-off. Thus in 1990 it contributed about 670 tonnes, but no catch at all in 1994, 1995 and 1996. The catch from this fishery in 2006 was 133 tonnes (FAO, 2009).

The purse-seine fishery for small pelagic species (anchovy, pilchard, round herring, and juvenile horse mackerel) is South Africa's largest fishery in terms of volume with the 2005 total allowable catch (TAC), combined for anchovy and pilchard, approximating 697,766 tonnes (Fishing Industry Handbook, 2007). The bulk of this catch is traditionally taken in the Atlantic Ocean, a shift in species' distribution and directed fishing for adult pilchard on the South Coast Agulhas Bank is a recent development (since 2000).

Commercial fishing employs 27,000 people (with an additional 60,000 people employed in related industries), of which approximately 2.3% work in the KwaZulu-Natal and 13.6% in Eastern Cape Provinces (DEAT, 2005). Recreational fishing employs 131,000 people in related activities. In addition, at least 3.6 million South Africans depend largely on coastal food sources through subsistence activities, estimated to be worth US$ 175 million annually. A range of small, engine-powered boats are used to access sea conditions that can be challenging. Fishing gears used include on foot beach collection, hook and line, beach-seine, traps, hoop-nets, shove nets, cast-nets, drag-nets, and gill-nets (WIOFish, 2008).

Tanzania – As for Kenya, freshwater catches outweigh marine landings. Data for 1984 - 1995, show marine fish landings ranged from 45,000 - 59,000 tonnes for mainland Tanzania (including from Mafia Island) and 15,000 - 20,000 tonnes for Zanzibar (TCMP, 2001). The combined annual total of about 70,000 tonnes is a realistic figure for a fishery that employs an increasing number of fishers, estimated at 58,000 in 2000, who land about 90% of all catches (TCMP, 2001).

The coral reefs of Tanzania support 70% of the marine artisanal catches (Ngoile and Horrill, 1993), landed from dhows, outrigger canoes and canoes, using gill-nets, beach seines, hand-lines, fixed traps, basket traps, poison, dynamite and spear guns. Most fish caught from inshore waters by artisanal fishers are demersal, but large pelagic species (e.g. tunas) and small pelagic species such as sardines are also important. Others are sharks, rays, crustacean, octopus and squid (Jiddawi and Stanley, 1999). In addition, shrimp exports are an important source of foreign exchange. The trawling companies operate as joint ventures between Tanzanian and foreign companies (TCMP, 2001), and combined with the artisanal contribution, the shrimp fishery (for export) is worth over US$ 6 million annually.

Along much of the coast, the collection and fishing of marine products is without restriction or size limitation, and there is little monitoring, control or surveillance of the artisanal fishery. Some species of sea shells and sea cucumbers are now considered to be over-exploited, driven by the export market (Marshall *et al., 2001)*. There have been few population studies of commercially exploited species, however traders claim that the sizes have reduced tremendously. Shark fin trade has also declined and some fish species are rarely seen now in Tanzania waters (Barnett, 1997; Jiddawi and Shehe, 1999).

Artisanal fishing, though an important activity for the coastal population, has contributed to the severe degradation of the marine environment and reduced overall catches. Destructive fishing techniques continue to be widely used with considerable damage, especially to coral reefs (e.g. from dynamite fishing, drag nets and spear-guns. In Tanga for example, the coral reefs were severely damaged during the 1980s by dynamite fishing as evidenced by the present fractured massive framework of coral colonies, craters and rubble patterns, exacerbated by anchoring techniques employed by artisanal fishers, and reducing the recruitment rate of many species (Francis *et al*., 2002).

Problems related to fisheries in the WIO region

The artisanal fisheries in all of the participating countries share similar problems and challenges. Lack of targeted management plans, failure to implement management, inadequate scientific information and absence of monitoring, all pose long-term threats to these fisheries and their dependents (van der Elst *et al*., 2005; WIOFish, 2008) Improved management is needed across the entire coastal fisheries sector in much of the region if development challenges are to be met.

Pressure on the coastal zone has been increasing over the past 20 years, as a result of population growth, the development of international tourism as well as the introduction of coastal aquaculture (Cunningham and Bodiguel, 2005). One common feature of artisanal fisheries in the region is that many (54%) are fully- or over-exploited (SWIOFC, 2006), hence allowing for little additional growth. Some of the problems facing the fishery industry in WIO region include:

- Poverty and lack of alternative livelihood systems: over-harvesting of marine fisheries in the region is blamed on poverty, rapid population growth and urbanization. Over-fishing has serious consequences on fishery yields, livelihood and conservation. For instance, evidence exists to show that some sites in WIO have experienced a 40% decline in reef fishery over the last 20 years (WWF, 2004).
- Destructive fishing practices: destructive fishing techniques commonly used in the region include dynamite fishing, inappropriate use of small mesh-size nets and gill-nets, use of beach seine nets, un-supervised prawn trawling, and fish poisoning. Due to their high dependence on fishery resources, degradation of traditional fishing grounds, as well as increased demand for the product, in some countries fishermen have resorted to using destructive fishing techniques such as poison and dynamite (Muhammed *et al*., 2005), degrading the very marine ecosystems on which the fish depend for nursery and breeding grounds (Jiddawi, 1998).
- Transformation of habitats: across the region, there is very poor public understanding of the linkages between fisheries and the supporting ecosystem such as mangroves, seagrass

beds and coral reefs. Trampling, during collection of octopus, shellfish, sea cucumbers and seaweeds in the shallow intertidal areas is also causing physical damage throughout the region. Mangroves and other critical habitats are being cleared and transformed to other land uses (Semesi, 1998).

- Lack of effective governance: inadequate, and in certain instances, outdated fishery management plans, policies and regulations have contributed to poor governance of the marine fishery.
- Inadequate scientific capacity: while many marine scientists work in the WIO countries, very few are adequately skilled in stock assessment and population dynamics needed to underpin effective management.
- Inadequate enforcement: most fishing activities are carried out in remote areas along the coast. Inadequate allocation of financial resources, lack of technical support and poor staff management hampers effective management of marine fisheries.
- Lack of capacity to explore offshore fishery resources: the inadequate allocation of state funds and dearth of private sector support, have hindered exploration and exploitation of offshore fish resources in most parts of East Africa.

3.2.2 Mariculture

Globally, aquaculture production has been dominated by freshwater fish species, mainly from activities in SE Asian countries and China. In 2005, total aquaculture production at 48 million tonnes was about half as much as capture fish production at 93 million tonnes (FAO, 2007c). Mariculture, involving marine and brackish water species (excluding plants), makes up 39% of the total aquaculture production. In 2005, mariculture generated 18.8 million tonnes, equivalent to 22% of total marine landings, up from 16% in 2000 (FAO, 2007c). While this appears to be a positive trend in meeting global demand for fish products, the rate of growth has been slow, especially in the WIO region. The WIO is historically not renowned for its aquaculture production although some changes have taken place over the past two decades and today many countries have at least experimented with some form of mariculture and in some instances providing valuable contributions to local economies.

Mariculture comprises different categories, ranging from intensive pond culture to extensive culture using cages, rafts or impounding larger natural areas. The extensive mariculture can also involve the "farming" of macro-algae for the eventual production and export of alginates. Tanzania, in particular Zanzibar, has been farming red seaweeds of the genera *Eucheuma* and *Kappaphycus* for over 15 years, and exports between 5,000 and 7,000 tonnes of the dried product each year providing valuable incomes to over 15,000 farmers (mostly women). Having started in Zanzibar, the practice has since spread to many areas along the coast of mainland Tanzania including Mafia Island, Tanga, Lindi, Mtwara, Bagamoyo and Dar es Salaam. Outside of Zanzibar, the industry employs at least another 15,000 people. Other countries, for example Mozambique, are conducting trials to evaluate seaweed production in that country and it is expected that the regional production of alginates will grow.

The intensive form of mariculture involves the production of shrimp, fish and other organisms from managed land-based ponds, providing products primarily destined for export. Shrimp farming in the region was first conducted at Amatikulu in KwaZulu-Natal in the mid 1970s, with Mozambique also developing experimental facilities in Maputo, as did Kenya. These and several other new initiatives did not live up to expectations and were not converted into major commercial ventures for a variety of reasons. Several new projects have recently taken off, including in Tanzania,

Production of shrimp, fish and other organisms in land-based ponds in Lumbo as a source of food and income for the local communities, Mozambique (photo courtesy of Peter Scheren)

with a single operation on Mafia Island and others planned in Pemba and Mozambique which produced 1,016 tonnes in 2005 (FAO, 2007c). Shrimp has become one of Madagascar's main seafood exports but there is concern that the development of shrimp farming may be reaching unsustainable levels (UNEP/GPA and WIOMSA, 2004a & 2004b). In South Africa, mariculture generates only 1,815 tonnes annually but is limited by the paucity of sheltered bays, although land-based culture for abalone has proven to be successful with 830 tonnes produced in 2005. Seychelles produced just over 1,000 tonnes of shrimp in 2003, although this amount appears to be declining (FAO 2007c; Hoagland and Jin, 2008). Milkfish (*Chanos chanos*) and rabbitfish (*Siganus sutor*) have been farmed experimentally on Zanzibar for ten years (Mmochi *et al.*, 2001; *Kyewalyanga*, 2004; Sullivan *et al.*, 2007), while moon-pearl oysters and edible oysters have been the focus of trials of small women groups in Mafia Island and Mombasa, respectively.

Though quantities and contributions to overall fishery production from farmed species remains modest, the expectation is for considerable further expansion, since environmental conditions, suitable land, brood stock, export infrastructure and labour are available in most countries, especially in the case of shrimp farming in Tanzania, Mozambique and Madagascar. However, as Rönnbäck *et al.* (2002) concluded, without clear recognition of its dependence on natural ecosystems, the aquaculture industry is unlikely to develop to its full potential in the region. Furthermore, Ridler and Hishamunda 2001, draw attention to the complex requirements of policy, regulatory and legal framework, economic support and especially justification for mariculture. While mariculture for high-value export products, such as shrimp, may generate foreign earnings and local upliftment, these initiatives need to be juxtaposed to the production of lower-value products that contribute more directly to food security, such as milkfish, mullet and rabbitfish. Notwithstanding the high expectation that aquaculture will make up the shortfall in demand of wild caught fish, the fact is that aquaculture is itself extremely dependent on marine fisheries for its inputs and may not actually be reducing the overall dependency on wild marine fisheries (European Community, 2008).

3.2.3 Tourism

Much of the WIO region is endowed with a good climate, beautiful sandy beaches, clear tropical seas and a rich biological and cultural diversity, resulting in a huge tourism potential. Tourism and associated service industries are major sources of foreign exchange and are increasingly becoming dominant components of development in many of the WIO countries, particularly in the Seychelles and Mauritius (UNEP, 2006)[3]. In general, tourism arrivals in sub-Saharan Africa have increased by 8% over the past 15 years (World Bank, 2009a). Kenya has flagged tourism as a key feature of its Vision 2030 – a plan for development. Tourism is especially important for its potential to create employment and support local enterprise (Government of Kenya, 2007).

Tourist arrivals in the WIO region, their average length of stay and total spending vary enormously between countries (see Table 3-3). However, it is difficult to delineate the value of tourism derived from coastal ecosystems as tourist destinations may or may not be interrelated. For example, it cannot be assumed that all tourists who visit terrestrial parks, will also visit marine and coastal attractions. Nevertheless, coastal tourism is undoubtedly a major factor in the economies of the WIO countries see Fig. 3-3).

Production of seaweed for expert in Zanzibar provides a source of income to over 15,000 people (photo courtesy of Rudy v.d. Elst, ORI)

3 While tourism is a major income generator in the small island states of Seychelles and Mauritius, it should be noted that a considerable proportion (often over 70%) of the income generated is used to purchase goods from outside, due to lack of local production. The challenge is therefore to ensure that tourism actually supports the local economy more widely, i.e. agriculture, fisheries and handicrafts.

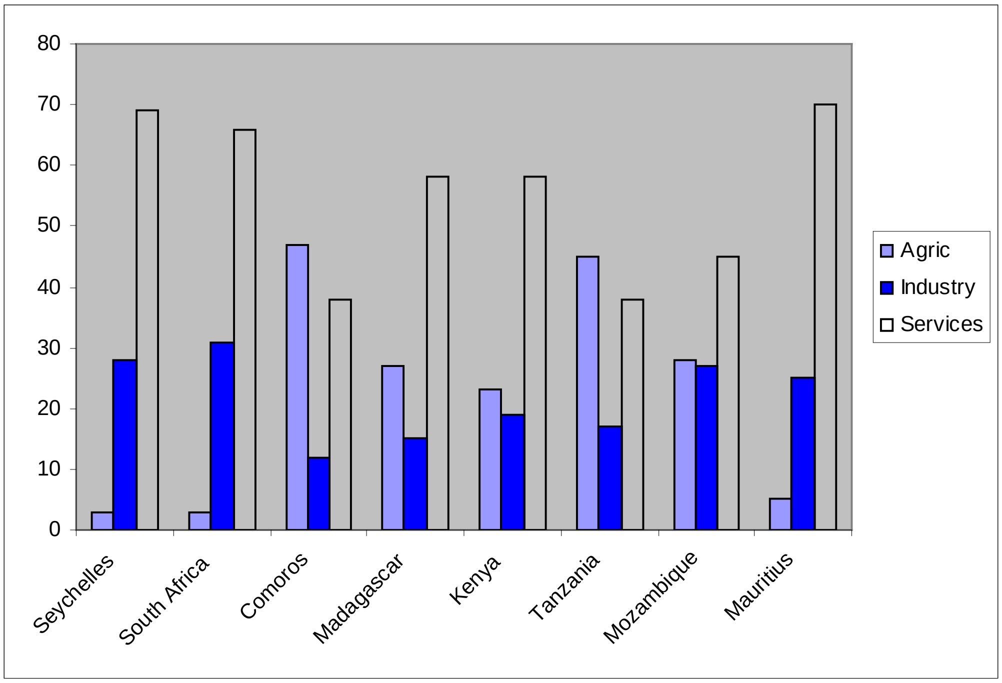


Fig 3-3 Relative percent contribution made by different sectors to the GDP of WIO countries in 2007 (World Bank, 2009a).

Table 3-3 Tourist arrivals, average length of stay and total spending in the Western Indian Ocean, 2000-2004 .

Country	Tourist arrivals ('000)	Average length of stay	Total spending (US$ millions)	Spend in US$ per tourist visit
Comoros	24	-	15	625
Kenya	927	8.7	329	354
Madagascar	170	21	115	677
Mauritius	907	10.3	1,356	1,495
Mozambique	550	3	138	250
La Réunion (France)	432	6.7	311	406
Seychelles	122	10.5	171	1,402
Somalia	-	-	-	-
South Africa	6,640	8	4,270	643
Tanzania	552	8	450	815

Sources: Gössling, 2006; Gössling and Hörstmeier, 2003; UNEP/GPA and WIOMSA, 2004b; Statistics Unit, Ministry of Tourism, Leisure & External Communication, Mauritius, 2007; South African Tourism Strategic Research Unit, 2007; Jones and Ibrahimo, 2008.

Political instability and security are major concerns for tourists visiting the region and therefore the industry is vulnerable to sudden perturbations as demonstrated in early 2008 by political uncertainties in Kenya that resulted in an 80% drop in tourist bookings. Similarly, the tourism sector in Somalia has never developed because of security problems. These two factors have influenced the level of development of the tourism sector in each country in the WIO region, as described in the following sections.

Tourism is furthermore vulnerable to the global economic situation. Usually, in times of crisis, tourist numbers drop considerably. The recent economic down-turn (2008-2009) still has to demonstrate its effect in this regard. Other factors, such as natural disasters and events may also have an important effect, such as for example demonstrated by the outbreak of Chickungunia disease in 2006 which had important effects on tourism in particular in Mauritius and Réunion[4].

Comoros – Despite its great tourism potential, the industry is not well-developed mainly due to political instability and also to its relative isolation and poor infrastructure. Nevertheless 20,000 tourists are estimated to have arrived annually over recent years (UNEP/GPA and WIOMSA, 2004a and b), contributing about 9.1% to the GNP and employing about 500 people in direct and indirect activities[5]. The main tourist attractions are dominated by coastal and marine activities such as beach holidays, sport fishing, diving and other water-related tourism and eco-tourism. The areas most frequented by tourists are the beaches of northern Grande Comoros, plus the beaches of Chomoni and Bouni, the salt lake and Turtle Island, all on Grande Comoros. The turtle-nesting beaches of the protected Moheli Island and beaches of Mutsamudu and Moya on Anjouan Island are also tourist attractions.

Kenya - Coastal tourism accounts for over 60% of Kenya's tourism earnings and contributes a total of 45% to the coastal economy (McClanahan *et al.*, 2005; UNEP/FAO/PAP/CDA, 2000). The main coastal tourist activities include diving, sport-fishing and, boating, the latter often involving traditional dhow sailing trips. The coast also has unique cultural and historic features, such as Stone Town in Mombasa and Lamu. The main tourist sites are the coastal areas immediately south (Diani beach) and north of Mombasa, as well as further to the north, at Watamu, Malindi and Lamu (Republic of Kenya, 2005), many associated with the well-established marine park network managed by the Kenya Wildlife Service.

In the early 1990's, approximately 800,000 tourists visited Kenya per year, with steady growth reported. Before the slump in 1998, tourism was a leading foreign exchange earner in the country. In 2007 there was considerable growth over the previous years with tourist arrivals exceeding 2 000 000 and generating US$ 910 million in revenue. More than half being generated from coastal tourism where over half a million people work in the sector directly or indirectly. Since the disputed election tourism numbers have declined by > 40% and projections suggest a slow recovery (World Bank, 2009b).

Madagascar – Madagascar has the most unique assemblage of biodiversity in the region. With its lemurs, spectacular vegetation, natural history and fascinating cultural features, it is a potential tourist paradise. In addition, the coast has corals, fine beaches and ample opportunities for water sports. Numerous coastal tourist destinations exist including Cape d'Ambre, Nossy Be, Tulear, Anakao, Diego Suarez and more. Tourism here has been growing steadily and each year the island receives over 80,000 tourists. Revenues from this sector amounted to US$ 91 million in 1998 and US$ 119 million in 2000, amounting to about 2% of the GNP (UNEP/GPA and WIOMSA, 2004b). However, this country can also not escape the vagaries of episodic climatic events and social unrest. Political instability severely curtailed tourism in 2009.

4 It may be argued to what extend other factors, such as the public opinion regarding carbon emissions, may have its effect: As many ecologists say "one of the best contribution you can make to reducing carbon emissions is to stop planes from flying", certain groups of tourists (in particular the many eco-tourists) may be discouraged from travelling to the region.

5 The main tourists in Comoros are actually business men, experts and the many Comorian immigrants in France that visit their families back home.

Mauritius - The success and growth of tourism is largely attributable to the exceptional natural coastal assets linked to the development of high-end hotels and resorts along the coast. Some 907,000 tourists arrived in Mauritius in 2007 when there were around 10,900 hotel rooms. The contribution of tourism increased from 3% of GDP in 1995 to 17% in 2007 and the total direct employment in the tourism industry more than doubled from 1990 to 2001, increasing from about 9,000 to 20,000. Mauritius is planning to further develop new and upgraded resort complexes near the coast, with a total area of 2,000 hectares, ultimately aiming to draw 2 million tourists per annum (Source: Central Statistics Office, Mauritius, 2007).

Mozambique - The coast of Mozambique has many excellent natural and cultural resources that have the potential to serve as world-class tourist attractions, characterized by beautiful beaches, rich mangrove-edged lagoons, estuaries and bays as well as extensive coral reefs. The tourist sector is one of the fastest growing economic sectors in the country. In 1994, 136,000 tourists visited Mozambique and the number increased to 470,000 in 2005 (UNWTO, 2006)

Coastal tourism is well developed at several sites such as at Ponta do Ouro on the Machangulo Peninsula (Abrantes and Pereira2003), Inhaca Island, the Macaneta Peninsula, the Biline-Xai-Xai-Chonguene coastline, the Inhambane coastline, the Bazaruto Archipelago, and more recently the Cabo Delgado Province in the northeast, centred on the port city of Pemba with its proximal chain of offshore islands in the Quirimbas group. Many of the tourism activities are beach-based, with gamefishing and diving being prominent.

Réunion – Tourism on the island is dominated by visitors from France. Approximately 80% of tourists of an annual total of 342,000 originate from the 'home-land' and a large proportion of these (about 34%) have family connections in Réunion. Beaches as well as marine-related activities such as diving, sailing and fishing are popular tourist activities (Direction Régionale de l'Environnement, 2005). However, the main attractions in Réunion are actually the inland landscapes, offering great opportunities for activities such as rafting and hiking, including visits to its dormant and active volcanoes. The tourism sector provides employment to 6,000-7,000 persons and an annual income of around US$ 500 million, representing 3-4% of the island's GDP.

Seychelles - Tourism is concentrated on Mahé Island and the nearby granitic islands of La Digue and Praslin. A great many tourist attractions exist, besides the standard water activities Seychelles offers excellent natural history, avifauna and geological features. More than 50% of all terrestrial areas are gazetted protected areas, many linked to marine areas. Coastal and marine tourism is one of the most important economic sectors for the country. Seychelles has successfully focused on high-value tourism, and there are plans to turn the country into a "3-5 star destination" (Gössling, 2006; Gössling and Horstmeier, 2003). In 2000, a total of 130,000 tourist arrivals generated US$ 112 million, corresponding to 20% of GDP and 60% of foreign exchange earnings (Shah, 2002). The tourism industry also provides approximately 5,000 direct jobs (UNEP/GPA and WIOMSA, 2004b).

South Africa - Diverse and abundant natural and cultural resources exist in South Africa, including wildlife, beaches, shopping infrastructure and cultural activities. Tourist arrivals have risen steadily since the late 1980s, exceeding 3.8 million in 1994, 6.5 million in 2003 (Department of Environmental Affairs and Tourism, 2004) and rising to 6.8 million in 2005 Between 30-40% of tourists book holidays near the coast, where the main activities include beach-based water activities, diving, snorkelling and sport fishing. However, additional pursuits have been developed, such as whale watching, cage diving for sharks and visits to several top class marine parks and aquariums. While only the East Coast of South Africa technically falls within the WIO region, it is no less important as KwaZulu-Natal draws large numbers of domestic and international tourist to its sub-tropical beaches. South Africa is involved in the Blue Flag programme for beach quality, a widely-recognized programme that assures recreational users of the quality of visits to the beaches. However, after initial positive implementation, a number of beaches have lost their Blue Flag status through poor waste water management, especially in the Durban region.

Tanzania - Coastal tourism is based on beaches, seafood, and aquatic features such as coral reefs and the nine MPAs. For example, 20-30% of the tourists who visit Zanzibar annually are attracted by its suitability for SCUBA diving and snorkelling (Westmacott *et al.*, 2000). Considerable tourism development is now found on the main Zanzibar island of Unguja, with growing development on the sister island of Pemba as well as on Mafia Island. Furthermore, since the 1990s there has been tourism expansion in Dar es Salaam, Tanga, Bagamoyo and a few other sites along the coast. Tourism brings in substantial foreign currency and provides important livelihood for the coastal population. It accounts for 16% of the national GDP, and nearly 25% of the total export earnings (Masekesa, 2003).

Problems and opportunities related to tourism in the WIO region

Tourism is often seen as the panacea for under development (for example Kenya's Vision 2030). It is true that tourism can, and has made significant contributions to the socio-economics of many regions and countries. However, tourism is also a fickle service industry that can collapse summarily, even if it has been built up over years. A single negative political or criminal event will impede tourist flow in a matter of days. Recent events in Kenya and Madagascar vividly illustrate this, with enormous socio-economic impacts on levels of employment and national economy. Tourism also requires an integrated approach. Often, tourism barriers are created by one government department without adequate consideration of the impact. For example, the acquisition of visas and payment of fees may be time consuming and costly. A good example is the passenger cruise ship operations out of Durban, which take an excess of 50,000 visitors to various island destinations in the WIO region. However, over-zealous officials who demand various payments, the high cost of a 6-hour visa and the time taken to process passports detracts from such low-impact tourism operations. As a result, the cruise company concerned will no longer be visiting Bazaruto in Mozambique and Anakoa (Nosy Ve) in Madagascar, depriving the people at these destinations of their livelihood (Starlight Cruise Director. S Cloete – *pers comm*).

One aspect of tourism that is often overlooked, especially in developing countries, is that of domestic tourism. The pre-occupation with drawing foreign tourists can mask development of a domestic tourism interests. Creating a strong domestic tourism market, especially attracting visitors from inland, can represent a huge socio-economic asset to the coast. However, this requires specific strategies of development and creating facilities and opportunities suited to domestic tourism. This includes pricing strategies and appropriate attractions. Already many popular beaches in Kenya, Mozambique, South Africa and elsewhere draw large numbers of short-term visitors, thereby creating tourism potential.

Tourism is highly competitive, not only between countries but also between regions and cities. It stands to reason that by creating unique and novel attractions tourism can be boosted. In the case of coastal tourism such initiatives are being pursued. For example, dolphin tourism (Berggren *et al.*, 2007), whale watching, tours to observe turtles nesting, shark diving, dhow sailing and public aquaria all enhance coastal tourism experiences.

Besides the above management-related issues revolving around tourism, it is well documented in this TDA that tourism can have significant impacts on the environment. Waste management, water abstraction, carrying capacity, PADH and other issues all pose challenges for sustainable tourism. A poorly managed coastline, depleted resources and high bacterial content of water are all issues that will shun tourism to the detriment of all. Climate change is also a factor that requires carful consideration in tourism planning: changes in rainfall patterns, coastal erosion and coral bleaching all impact on tourism development. Thus, while tourism does provide significant potential for development, this will not succeed without careful and integrated planning involving governance and stakeholders from the industry.

3.2.4 Industry

Despite considerable mineral resources, availability of raw materials, favourable climate and established shipping routes, the WIO region is not well industrialised. The emergence of industrial economies in the region has lagged behind that of many other parts of the world, partly attributable to poor domestic demand, isolation from complex industrial markets and a general lack of technological infrastructure, including affordable sources of energy. In many cases, sub-Saharan countries have only recently begun to emerge from a "subsistence economy" geared to serving internal priorities (World Bank, 2009a). In other cases, political instability has hindered industrial development, especially since stable governance encourages investment - a prerequisite for all industrial development. As globalization strengthens, and access to foreign markets are improved, so opportunities for the WIO to selectively develop industries that strategically target domestic and foreign markets should be explored. Such markets should not be confined to those of developed nations, but also serve markets within the WIO countries themselves and domestic needs.

The contribution made to the annual GDP of each of the participating countries varies substantially, evident from the Fig. 3-3 above (World Bank, 2009a). In all cases (except in Comoros and Somalia where data is lacking) the services make up the larger contribution to GDP. This revolves largely around tourism. Overall, services account for an average of 58% of GDP for the WIO countries, followed evenly by industry (22%) and agriculture (23%). It has been shown that economic production is closely linked to a number of environmental factors, such as soil types, rainfall, temperature, access to the coast etc..

Where industrial development has taken place in the coastal zone of WIO countries, this is largely achieved through output of primary products, mainly agriculture, fisheries and mining. Significantly many of these products have not been value-added, so that the full benefits are often not realised. For example, timber, fish, titanium, coal, diamonds and gold are some products that are essentially exported in their raw or semi-processed state – only to be processed into high-value products in other countries. Small island states of Seychelles, Mauritius, Comoros and La Reunion have their own unique challenges in terms of industrial development, especially considering the limited size of their domestic markets, restricted land mass and modest natural resources. Nevertheless, some have overcome such limitations. For example, Mauritius has an active export-based textile industrial sector. However, international competition, the relatively high cost of labour and the expiration of preferential trade agreements with the European Union, the emergence of these industrial sectors has been slower than normal (World Bank 2009a.

Despite increased globalization, industrial development in WIO countries has not improved much recently. Between 2000 and 2006 there was only a 2% overall increase in the contribution made by industry to the GDP of the countries of the WIO region, with Mozambique and Kenya recording most gains. Others remained much the same, except Mauritius which recorded almost a 20% decrease over the period. Industrial development in individual countries is discussed below.

Comoros – Comoros is a country with a low gross national income per capita, amounting to US$ 680 in 2007. Its small size (1,868 km^2), lack of major raw material and energy sources and relative isolation have not supported industrial development, which accounted for only 12% of the GDP in 2007. In the past, essential oils from Ylang-Ylang were produced from industrial-scale distilleries but these appear to have fallen into neglect. Lack of investment and political instability has hampered the development of any meaningful industrial activity to date. While it appears unrealistic for Comoros to develop large industries by global standard, the potential exists for the establishment or improvement of smaller niche industries based on processing of high-value specialist food and fish products for export.

Kenya – Historically, the port of Mombasa has dominated shipping trade and been the focus of coastal industries, many associated with export and trade, while the inland capital Nairobi has attracted industrial development associated with agriculture, mining, pharmaceutical and miscellaneous other sectors. Over the last six years, the coast has experienced a rapid increase in industrial development, in part due to the incentive to exploit the United Sates of America (USA) market under African Growth and Opportunity Act (AGOA) initiatives. Textile industries have been established in the Export Processing Zones (EPZs) in the coast region, especially in Mombasa and Kilifi districts, while other industries are engaged in primary production and agro-processing for export as well as local consumption. These include cashew husking works, pineapple canneries, rice mills, coconut processing and facilities for crops such as coffee, groundnuts and sisal. Cement manufacture, steel rolling mills, iron smelting and oil refining are also present. Larger urban centres provide the main market for industrial goods. Industrial activities outside Mombasa are primarily based on the processing of agricultural, livestock and forest produce for the domestic market (World Bank, 2009a)

Madagascar

Despite periods of strong economic growth since the 1960s, Madagascar is today still one of the poorer countries, largely due to several decades of economic mismanagement (World Bank, 2009a). Variable GDP rates and a high population growth, continue to pose barriers to economic development. Climatic impacts with frequent cyclones, alternating heavy rain and drought further pose development barriers. Madagascar's main sources of growth come from agriculture, tourism, mining and small-scale labour-intensive industries such as handicrafts, textiles and clothing. Large-scale industrial development has been sporadic but some are of major significance. For example: recent foreign investment in large mining operations, including coastal mining for minerals, more than offsets vulnerability to natural disasters. An oil refinery is located at the north-eastern port of Toamasina while diverse smaller industrial activities are located around the coast at the ports of Antsiranana, Ambilbe, Mahajanga, Tolagnaro and Toamasina. Notwithstanding some industrial progress, in 2006 the economy was disrupted as a result of water and power cuts and more recently political turmoil has presented further barriers. Madagascar is believed to have strong development potential but improved transport networks, access to international markets and skills development are seen as primary challenges (World Bank, 2009a).

Mauritius – The production of sugar from sugar cane is historically an important industrial activity, with 10 sugar mills producing 505,000 tonnes of sugar in 2006. However, declining sugar prices, competition with mainland sugar producers and the end of an era of preferential trade agreements with the European Union is limiting the future of sugar as a significant economic factor. The manufacturing sector, dominated by textile and clothing production, has been a growth industry since 1970. These industries are located near the harbour of Port Louis and also throughout the island. Here too, competition, such as from Asian textile manufacturing industries, is placing increasing pressure on this traditional sector. Nevertheless, these industrial activities contribute to Mauritius having the second highest GDP in Africa (World Bank, 2009a; Digest of Agricultural Statistics, 2006).

Mozambique – Mozambique is geologically endowed with considerable resources and minerals. Large rivers for hydroelectric power generation and the mineral rich Tete Province are significant assets. Over the last twenty years, since the end of the 16-year civil war, the industrial sector has grown fast, with the total number of industrial units listed for Maputo increased from 11 in 1982 to 137 in 1996. The industrial contribution to the GDP has risen a significant 27.4% in the period 2000 to 2006, relatively the highest of all WIO countries. The port city of Maputo has been the main growth point in this development benefitting from its links with South Africa and the Maputo Corridor project designed to foster transboundary economic growth. The large aluminium smelter at Mozel, power generation from Cahora Bassa and the gas pipe line to South Africa all strengthened the underlying industrial development. Increasingly, port cities of Beira and Pemba are also witness to growth in this sector.

Réunion – The largest industrial sector on the island is associated with the goods consumption industry, i.e. production of goods and services for direct use by inhabitants and visitors. Other large sectors are equipment manufacturing and agro-industry. Sugar cane processing produces approximately 200,000 tonnes of sugar per year. It is anticipated that in future, a big part of sugar cane production will be used for energy production, including electricity. Together with volcanic geothermal energy and wind farms, the island plans on becoming 'energy-independent' by 2025. (Region Réunion, 2008)

Seychelles - Most of the industries are concentrated on the east coast of Mahé. An industry of significant importance to the Seychelles is the tuna canning factory, which is one of the largest tuna canning factories in the world. The Mahé East Coast also hosts a paint making factory (Penlac) at Les Rochers, as well as a slaughter house and brewery, both serving most of the country's needs. This area also has a large number of garages, metal workshops, boat building yards and a granite cutting and polishing factory (Bijoux et al., 2008).

South Africa – The industrial development South Africa has been unusual in that most industries have historically been located inland in association with the gold mining activities around the Gauteng Reef complex. Furthermore, the past history of Apartheid also saw industrial development specifically located in so called "border areas" to underpin the separate development strategy of that time. To a large extent this meant that industrialization of the coastal zone was thus delayed, and indeed waste discharges were also lower than in comparable situations elsewhere. However, industries have since progressively developed along the coast, related mostly to port development such as at Richards Bay. Besides mining, South Africa has diverse industrial activities that account for about 1/3 of the national GDP, including energy production, automobile assemblies, machineries, textile, paper, iron and steel, tyre manufacture, chemicals, fertilizer and foodstuffs (World Bank 2009a). These activities are mainly based at all the large cities including the coastal ports of Durban, Richards Bay, East London, Port Elizabeth and Cape Town. Richards Bay has an aluminium smelter, large fertilizer plant and kraft mill. Durban has several industrial activities, including oil refineries, paper factories, chemicals, textiles, rubber goods, ship-building, a regional container hub and sugar milling.

Tanzania – Although there are many small industrial developments in coastal Tanzania, in 2007 the Tanzanian GDP was only credited with 17% industrial activity (World Bank, 2009a), one of the lowest in the region. Historically Dar es Salaam and the northern port city of Tanga have been host to small to medium industries, especially based on paper, sugar, textiles, shoes, wood products, fertilizers, plastics, sisal and cement industries. Traditionally coral mining has also been a significant industry, largely based on fossil coral beds, but under improved control in recent times. There have been barriers presented by periods of severe drought and power shortages, especially as ¾ of electricity is generated from hydroelectric systems (NEPAD, 2003). Nevertheless, the last decade has seen these industrial units increased, driven by a stable economy and improved power supply options, partly derived from the Songo Songo gas reserves. Gold and diamond mining have also contributed to the industrial development of Tanzania (NEPAD, 2003).

Somalia

The economy of Somalia is intimately linked to rangelands and livestock. Even during the pre-war days, industries were few and far between, except for the significant number of fish processing and canning plants that were established by international donors such as DANIDA and Soviet support (Lovateli, 1995). Today these are all defunct. Although Somalia has known hydrocarbon reserves, the lack of reliable energy sources, access to markets and political turmoil effectively impedes any significant industrial development in the foreseeable future.

3.2.5 Agriculture

Agriculture is a major economic activity, with more than half the labour force in sub-Saharan Africa involved in this sector, with a higher proportion of women involved in many cases. In the WIO region levels of employment in agriculture may be even higher, in 1982 stated to be close to 90% of the labour force. Nevertheless, the overall contribution of agriculture to the GDP of WIO countries is comparatively low as seen in Fig 3-3. While in some cases agricultural products are destined for export markets and do contribute directly to the GDP, in much of the region agriculture ranges from subsistence to small-scale. While not necessarily taken up in the formal economy and thus economically under-valued, it represents a critical element of food security.

Agriculture is closely linked to rainfall and other climatic parameters, so that climate change is likely to have significant impacts on future agricultural production and especially food security. While some of the high latitude developed countries may increase agriculture as a result of a longer growing season, the projection is that poorer countries in the WIO region will see negative impacts on their agricultural production in the years ahead (IPCC, 2007; WRI, 2007).

There are significant differences between the nature and extent of agriculture in the various countries. Agricultural land, irrigation, use of fertilizers, pesticides and other farm inputs differ significantly between countries. Mainland countries have the advantage of large land areas where industrial-scale agriculture and cattle ranching can be conducted. Small island states are more likely to produce high-value products such as vanilla, Ylang-Ylang and diverse spices. Since the 1970's the level and pace of development of agriculture in each country in the WIO region has differed, as described in the following sections.

Comoros – The small size of Comoros, with its volcanic landscape, is not conducive to large scale agriculture. Substantial quantities of agricultural products have to be imported, such as rice, meat and oil. Nevertheless, agriculture is a primary activity and accounts for 70—80% of employment and takes up almost 80% of the land area. The main crops produced for export are the high-value products of vanilla, ylang-ylang and cloves, which together account for approximately 95% of export earnings. Cereals, rice, potatoes, fruits and legumes are grown mainly for local consumption (World Bank, 2009a)

Kenya - Agriculture is the mainstay of the Kenyan economy, providing employment to about 70% of the country's labour force, equal to over 10 million people, compared to only 3 million employed in the formal sector. It also generates 80% of the export earnings and supplies over 70% of the raw materials to the agro-industry. While overall the sector contributes to more than 45% of annual government revenue, its contribution to the GDP has shrunk in relative terms from 33% in 2000 to 23% in 2007.

Agriculture is the main-stay of many WIO economies (photo courtesy of Peter Scheren, UNEP)

Kenya has an enviable record in the production of tea and coffee, as well as livestock. In the Coast Province a activities are mostly directed to produce food and non-food products at subsistence and small-scale commercial levels. Here, the main food crops include cassava, sweet potatoes, maize, coconut, cow peas and rice which are grown in irrigated areas, marshes, and floodplains. Similarly, vegetables and tropical fruits such as citrus, mangoes, bananas, pineapples and watermelons are grown for both subsistence and export. The other crops which are mainly grown for export include cashew nut, bixa and sisal. The average farm size in the Kenyan coast is 6-8 hectares. Tree crops (cashew nuts, coconuts, citrus and mangoes) occupy about 50% of the arable land. Traditional shifting cultivation, and slash-and-burn farming practices are widespread. Livestock production also contributes significantly to the Kenyan coastal economy. There are 85 ranches within the Coast Province of which 25 are operational. Livestock rearing is mainly concentrated on marginal land of the coastal region that accounts for 69% of the total area. The pastoral communities in Tana River district graze large herds of cattle in the lower reaches of the Tana River basin (Republic of Kenya, 1997).

Madagascar – Agriculture, jointly with fisheries and forestry, account for one-third of GDP, employs over 70% of active population (FAO, 1997) and contributes more than 70% of export earnings (UNEP/GPA and WIOMSA, 2004b). About 3 million hectares of land is under cultivation, and large tracts are used for cattle grazing pastures. Both, traditional and industrial agriculture operations are present in Madagascar, with food crops including rice, sweet potato and maize. The main cash crops include coffee, vanilla, pepper, sugar-cane, peas, cotton, tobacco, groundnut and cocoa. Traditional agriculture contributes 30-60% of the total agricultural production in Madagascar. Madagascar is well known for its export of high quality hardwoods derived primarily from indigenous forests, although excessive felling has resulted in significant areas of deforestation and associated erosion (World Bank, 2009a)

Mauritius – While up to 49% of this small island is potentially arable, only 3% is under permanent cultivation (NEPAD, 2002), mostly set aside for sugar cane, producing around 500,000 tonnes of sugar annually. Other agricultural land is used for food crops as well as tea and tobacco. The main food crops cultivated are potato, onion, tomato, chilli, eggplants, crucifers and cucurbits. The past decade has witnessed a constant conversion of agricultural lands to land for industrial and urban development. In this context agricultural land has decreased by approximately 5,500 ha over the past ten years. On the smaller island of Rodrigues most agriculture is linked to highlands pastures (NEPAD, 2002).

Mozambique - Agriculture is a very important sector in Mozambique and is mostly carried out by small-scale farmers. The commercial (mechanised) farming occupies only 250,000 ha, which represents only about 8% of the total crop land. More than 80% of the country's population gains its livelihood from the agricultural sector, which furthermore contributes about 40% of the country's export value (Hoguane et al., 2002). As seen from Fig 3-3, agriculture contributed 28% to the GDP of Mozambique in 2007, up from 23% in 2000 (World Bank, 2009). Most of the agricultural activities take place along, or close to the lower reaches of main rivers such as the Monapo, Pungoe, Maputo and Incomati rivers. Large scale sugar cane production has developed since the end of civil war, while the valuable cashew nut industry has also been revived since its demise over years of neglect. Other agriculture products include rice, maize, peanuts, beans, cotton, copra, sisal, sunflower and sorghum.

Réunion – Sugar cane production is by far the largest agricultural sector in Réunion, accounting for 33% of total agricultural production at a value of approximately US$ 160 million in 2004 (Direction Régionale de l'Environnement, 2005). Of the 37,000 hectares of arable land, two thirds is designated to sugar cane production. Sugar is also the main export product of Réunion, with the residues being used for alcohol production and energy generation. The remaining 67% of agricultural production by value is equally attributable to fruits and vegetables and animal husbandry mostly for the local market.

Seychelles – Due to the small size of the three main islands and the lack of arable land, there are only small areas suitable to agriculture in the Seychelles. For this reason, Seychelles is heavily dependent on the import of agricultural products, especially cereals and dairy products. Periodic shortages in products like potatoes and onions are not uncommon. Locally, coconuts, cassava, fruits and vegetables are cultivated, some on commercial basis, and many small-holders provide an important contribution by cultivating crops for domestic consumption (World Bank, 2009a)

Somalia – Almost ¾ of this large country has agricultural potential, with rangeland production of livestock a hugely successful activity. Historically, the bananas produced within the Juba-Shebeelle catchment were sought-after export products in many countries. Other rain-fed and irrigated crops were produced in this same region, though frequently interrupted by erratic rainfall and flooding (IUCN, 1997). At one stage, about 50,000 hectares was under intensive commercial crops and with an additional 150,000 ha for grain production (Ruwa *et al.*, 2004). . Although the civil war interrupted many of these agricultural activities, much production can still be reported, especially in terms of livestock. The supply of sheep and goats for the annual Haj has continued despite the war, with millions of animals exported from Bosaso, Berbera and other ports annually (van der Elst, 2000). Accurate records from the port of Bosaso in 1996 provide some insight into this (Table 3-4). Other products harvested from rangelands are equally important. Charcoal production, mostly based on indigenous Acacia trees provides the primary source of energy (woodfuel) and is an economic asset to the poorer people. Timber from juniper forests has been of value, while a range of other tree-based products are also important. These include myrrh, gum Arabic and frankincense, the latter accounting for an annual production of up to 12,000 tonnes (IUCN, 1997)

Table 3-4 Export data from the port of Bosaso in 1996

Commodity	Amount
Camels (heads)	17,104
Cattle (heads)	15,666
Sheep & goats (heads)	601,139
Hides (pieces)	531,490
Incense (tonnes)	237
Shark fins (dried-tonnes)	2.9
Lobster (tonnes)	8.3

Source: (Bosaso Port Authority, 1997)

Besides the traditional agricultural products described above, one of the socio-economically most significant agricultural products is *qaat*, a semi-narcotic plant, the leaves of which are chewed daily by most of the adult male population. Although most of this product is grown in the highlands of Kenya and Ethiopia, and imported fresh daily, it underpins much of the Somali local economy, estimated to turn over US$ 150,000 per day (van der Elst, 2000)

South Africa – Agricultural production in South Africa is well developed, providing not only most of the nation's food requirements but also major exported products. Major products include cereals, deciduous and citrus fruits, livestock, dairy products and silviculture. The coastal zone provides other and more diverse opportunities for agriculture, with generally poor but variable soils on the west coast and rich soils on the east coast. Towards the south coast of South Africa, grapes and the associated viticulture are primary activities while in KwaZulu-Natal sugar cane is the prevalent coastal crop. Dairy, hydroponic and vegetable-tunnel farming are also common in the coastal belt, as is a large poultry industry. Productivity of the latter is enhanced by the availability of fish meal as a feed additive, based on large scale anchovy catches made off the West Coast [Green Policy Paper 1998. In some coastal regions tea production has flourished while a significant recent growth industry has been horticulture, with the export of locally produced flowers to Europe. Despite South Africa's large commercial farming development, small-scale and subsistence agriculture prevails in most regions. These activities provide essential food security and also supply a plethora of products to local and village markets. Though inadequately documented, medicinal and traditional herbal agriculture is of enormous consequence (Cunningham, 1988). The majority of the 47 million people in South Africa make use of traditional medicines at some stage, placing demands on wild stocks of these plants but also stimulating a new emerging agricultural industry. One other activity of note is the tapping of sap from Ilala palms in several parts of Mozambique and KwaZulu-Natal, used in the production of a locally popular wine. Studies indicated that in some regions this represented the most significant informal economic activity (Cunningham, 1988).

Tanzania – The agricultural sector employs more people than any other sector and is considered a mainstay of the economy. Coastal agriculture is mostly rain-fed and dominated by peasant small-holder farmers typically cultivating on farm sizes that average between 1 and 3 hectares. The main food crops produced include cassava and maize. Various strains of rice are cultivated in river valleys and flood plains. Cash crops include sisal, coconut, cashew nut, cardamom, cotton, fruits and horticulture. Poor agricultural practices such as slash and burn have resulted in soil erosion and subsequent sedimentation of coastal waters (World Bank, 2009a).

3.2.6 Mining

Sub-Saharan Africa is generally endowed with non-renewable mineral resources. In some cases these minerals are especially prevalent in the coastal zone, where geological processes have contributed to concentrating certain deposits. Best examples are the rich diamond fields of South Africa's west coast and the titanium-rich dunefields and sandy shores of various parts of East Africa. Small island developing states often have inherent problems in sourcing materials for the building industry and thus resort to sand mining and various other forms of coastal extraction, with potentially negative environmental impacts. Besides, the sand and limestone deposits used in construction and building industries, mineral deposits also occur in several of the WIO countries, such as pyrochlore, gypsum, barites, iron ore, clay, apetite, galena, manganese and semi-precious stones. The geological exploration of the WIO region is far from comprehensive so that unknown deposits are likely to exist. In cases where mining for minerals is indeed undertaken there are many cases of major environmental disruption. The highly invasive extraction of heavy minerals from dunes, for example, has resulted in major environmental concerns (Weaver *et al.,* 1996).

Non-renewable mineral resources can provide important socio-economic benefits. However, these will clearly be short-term considering the non-renewable nature of most – perhaps technically excluding sand and coral. The long-term environmental impact of such mining thus needs to be carefully considered versus the short-term benefits. The loss of ecosystem services may indeed be higher than the financial gains made for the economy.

In Tanzania, diverse mining activities in the coastal zone mainly take place near Tanga in the north and Mtwara in the south. Other coastal mining activities take place in Kisarawe, Miono, Mkonge and Mandera, Dar es Salaam, Bagamoyo and Lindi. Mining of gravel, sand, limestone and rutile

Coastal mining for heavy metals causing physical alteration of the coast (Photo courtesy of Bronwyn Palmer, ORI) goes on throughout the coast of Tanzania (UNEP/GPA and WIOMSA, 2004b).In Mozambique mining activities for limestone take place in Salamanga, Buzi, Muanza and Nampula, while the mining of heavy mineral sands takes place in Chibuto.

Mining activities in Madagascar occur in the region of Taolagnaro where rich deposits exist for sapphire, beryl, garnet, amethyst, crystal, zircon, mica, bauxite and ilmenite. Extraction of heavy mineral deposits in Madagascar is now well underway, making a significant contribution to the country's economy.

In Mauritius, sand winning along the coast was an important activity until 2001 when it employed nearly 1,000 people with an estimated turn-over of US$ 8 million per year (Dulyamamode *et al.*, 2002). Its devastating impact was felt on the destruction of lagoon ecosystems and habitats, hence it was declared illegal in October 2001. In Comoros, coral sand, pebbles, gravel and corals are being mined for construction related activities (UNEP/GPA and WIOMSA, 2004b).

3.2.7 Solar Salt Production

Salt works are an important coastal zone economic activity in many countries, ranging from domestic or artisanal solar-driven production to larger commercial operations (UNEP/GPA and WIOMSA, 2004b). In Kenya, salt production takes place in cleared mangrove areas north of Malindi at Gongoni, Fundissa, and between Ngomeni and Kurawa. A total of eight salt works, covering an estimated 7,900 hectares of tidal wetlands, produced over 170,000 tonnes of salt annually in the late 1990s (UNEP, 1998). In Tanzania, the high demand for solar salt has resulted in clearing of mangrove forests to pave the way for construction of evaporation ponds for solar salt production. Solar salt currently contributes about 76% of the total salt produced in Tanzania (TCMP, 2001). In the northern provinces of Mozambique, the clearing of mangroves for solar salt production has impacted on some mangrove forests. Mauritius has remnants of small-scale salt

Ongoing oil and gas exploration in the WIO region is expected to result in increased oil and gas production works while South Africa has a large industrial-scale salt works located in the Eastern Cape at Coega. Somalia has a long history of salt production. Facilities at Hafun once exported 200,000 tonnes per annum (Anon, 1968), but now defunct save for the derelict but specially constructed ocean vessel loading jetty. One of the most intense artisanal solar salt works is that north of Zeila, just south of the border with Djibouti. Production data here are unknown but substantial in meeting local needs and for export, especially to Ethiopia (van der Elst, 2000).

3.2.8 Oil and gas production

As the global energy crisis gains momentum, so the search for hydro-carbons intensifies. To date the WIO region has only been subjected to modest oil and gas exploration, conducted over the past thirty years, revealing sporadic and generally small reserves. However, the new rush for "black gold" and the improvement in exploration and drilling technologies is seeing major developments in this sector. The entire East Coast of Africa has been divided into blocks that are being progressively explored (WWF 2009). Much of this exploration is conducted with sophisticated offshore seismic technology, generally with lower environmental impact than test drilling. Nevertheless many EIA studies are being conducted in association with these exploration activities.

Historically, the level and pace of development of the oil and gas industry in each country in the WIO region has varied. Similarly, the prospect of finding resources varies between countries. In Somalia, despite evidence of potential gas resources political instability and security problems have completely deterred exploration. On the small volcanic island states of Mauritius, Comoros and Réunion (France), the absence of a surrounding continental shelf limits the likelihood of oil or gas-bearing geologic formations. For the mainland Africa nations, Madagascar and Seychelles, the situation is different as shelf areas do exist that may hold reserves. The present status of such exploration is given for each country.

Kenya - Oil and gas exploration in Kenya has yet to reveal hydro-carbon resources along the Kenyan coast (UNEP, 2006a). However, if there is to be any potential, the most promising areas identified are near Malindi and the Lamu Basin where good source rocks and reservoir rocks for hydrocarbon deposits have been recorded. Exploratory wells have been sunk about 70 kilometres off the Lamu coast (Tychsen, 2006), but failed to confirm a viable resource.

Tanzania - Oil and gas exploration has been conducted for the last 50 years, more recently promoted by the Tanzania Petroleum Development Corporation (TPDC). Significant gas discoveries have been made at Songo Songo, Mkuranga and Mnazi Bay with exploration continuing along much of the coast and 35 exploration and development wells drilled to date (http://www.tpdc-tz.com /exploration.htm). The aim of the Songo Songo electricity project is to extract natural gas from the Songo Songo gas field in Kilwa District, supply gas to a power station in Dar es Salaam and local industries, providing a reliable source of low cost electricity. The project was completed in 2006 and is continuing to expand. The Mnazi Bay block, allocated to the Artumas Group (Canada), includes a gas field with about 500 billion cubic feet of proven gas reserves and a single drilled well, but plans are underway to conduct additional exploratory drilling. The estimated Mnazi Bay gas field may have more gas reserves than that of Songo Songo and generating facilities are now in place, supplying electricity to the city of Mtwara and surroundings. In addition, the Mafia Deep Offshore Basin in southern Tanzania has a high potential for exploration. Other areas with high potential for exploration include sedimentary basins onshore and offshore with open acreage at Rufiji Basin, inland rift basins of Lakes Rukwa, Tanganyika and Nyasa, and the Ruhhu Karoo Basin (http://www.tpdc-tz.com/exploration.htm). The Government of Tanzania, through the TPDC, has put up invitations to international petroleum and investor specialists to participate in exploration of hydrocarbons in Tanzania and production sharing agreements (PSAs) have been signed with several agencies. Options for exploration for four blocks near Unguja and Pemba Islands of Zanzibar, have already been successfully negotiated.

Mozambique – Known gas reserves are being exploited, with significant collaboration with South Africa in the Temane gas field in southern Mozambique to South Africa's Gauteng region, transported by a 925-kilometre pipeline. In early 1998, Mozambique signed a PSA, giving one company exclusive rights to explore 40,000 square kilometres off the Zambezi Delta. Another international consortium of oil firms has also signed three exploration agreements with Mozambique's state oil firm. There are plans for natural gas from Mozambique's Pande and Temane fields to be utilized for new and existing industries in Maputo and Beira (http://www.eia.doe.gov/emeu/cabs/Archives/africa/chater4.html). Mozambique has issued offshore licensing for blocks in the northern Rovuma basin and for blocks off the southern coast near the Bazaruto Archipelago (SASOL, 2005; Hydro oil & gas, Mozambique, 2006). A large exploration block in the Cabo Delgado area is also being explored.

South Africa – Although there has been intense exploration over the past few decades, only modest reserves have been identified and exploited. The South African national oil company, PetroSA has concentrated its exploration efforts on the country's western and southern coasts. Several discoveries have been made in the Bredasdorp Basin on Block 9, including the Oribi, Oryx and Sable fields. Combined, the Oribi and Oryx fields produce 16,000 barrels per day; however, PetroSA has indicated that both fields are in decline. Production at the Sable Field, located approximately 115 kilometres off the southern coast, commenced in August 2003. The project is a partnership between PetroSA and Pioneer and includes six sub-sea wells connected to a floating, production, storage and offloading vessel (FPSO) with the capacity to process 60,000 barrels per day of oil. Current production at Sable is around 23,000 barrels per day of oil.

Madagascar – Although there is much exploration taking place, and despite confirmation of some oil and gas reserves at Bemolanga and Tsimiroro oil fields (UNEP, 2006), actual oil and gas exploitation is still relatively under-developed. There is only modest production of oil in Madagascar. In April 2006, Madagascar opened up 96 new offshore oil and natural gas blocks for tender and these are set to hold promise for future development.

Seychelles – As the potential for producing oil and gas is believed to exist exists on the Mascarene Plateau and Seychelles Bank, offshore geophysical and geological exploration is continuing.

3.2.9 Shipping and ports

Each of the WIO countries has at least one significant sea port. In some cases there is more than one port, often attributable to the needs of export and import services from inland regions of land-locked countries.

Somalia – Significant port development in Somalia began in 1960 with improvements to Mogadishu and a new port at Kismayo. In the 1990s the US government made substantial further improvements to Mogadishu port. Both these ports remain closed because of interclan conflict. Soviet support for the port of Berbera in 1968 turned this facility into a key asset able to accommodate large vessels (Anon, 1968). The port of Bosaso in Puntland remains a viable traditional port, especially for larger sail vessel trade with Yemeni vessels. Both these ports remain functional. In addition there are smaller port facilities at other sites, including Zeila and also a significant facility in neighbouring Djibouti. Despite the political unrest and piracy, the northern ports remain operational, especially for export of livestock.

The WIO region hosts several major ports and important shipping lanes

Kenya - Shipping and ports are important economic activities accounting for 15% of the economy of the Kenyan coast. The Mombasa Port is not only the largest sea port in Kenya but is also one of the largest and most important ports along the East African coast. It is a natural harbour and is strategically positioned to serve a number of east and central African countries; these include Rwanda, Uganda, Burundi, north-western parts of Tanzania, Zaire and Sudan. Besides the main port, a traditional smaller port is located in the Tudor Creek of Mombasa which has remained active and receives smaller vessels. Other small ports are spread along the entire coastline and are located at Shimoni, Kilifi, Mtwapa, Kipini, Vanga-Funzi area, Malindi and Lamu. The latter have catered for dhow trade for over 2,000 years. All these Kenyan ports are managed by the Kenya Ports Authority. Mombasa Port is connected to the world's major ports with over 200 sailings per week, to Europe, North and South America, Asia, the Middle East, Australia and the rest of Africa (Hoyle, 2000; UNEP/GPA and WIOMSA, 2004).

Tanzania – The major ports are at Dar es Salaam, Tanga, Mtwara, and Zanzibar. There are also smaller ports in Kilwa, Lindi and Mafia. Dar es Salaam and Zanzibar have witnessed expansions and improvements to their port facilities, in part resulting from the increased tourism-related trade between the two destinations and recent economic development (UNEP/GPA and WIOMSA, 2004).

Mozambique – There are three main ports, located at Maputo, Beira and Nacala. The country also has several smaller ports located at Inhambane, Quelimane, Pebane, Angoche and Pemba (Hoguane, Dove and Sete, 2003). Maputo is a busy port which also provides a service to land-locked regiona and countries inland. However, this natural habour in the Bay of Maputo requires intense maintenance as the Polana entrance channel tends to become silted and too shallow. Plans have been announced to develop a new port to the south on the Machangulo Peninsula, although the wisdom and viability of this still needs to be proven. The environmental impact of this would be substantial (Fennessy and van der Elst, 2004). However, the 2009 proclamation of the Ponto de Oura MarinePark, which includes the entire Machangulo area, is likely to thwart plans for port development there (Peace Parks Foundation, 2009).

South Africa - Large commercial ports are situated at Saldanha Bay, Cape Town, Port Elizabeth, Coega, East London, Durban and Richards Bay. South African ports handle an average of 13,000 vessels carrying 500 million tonnes of cargo annually, with major upgrades underway to increase handling capacity and absorb the rapid increase in commercial traffic (www.safrica.info; www.ngo.grida.no/soesa/nsoer/issues/coast/). While Richards Bay handles the most cargo of any port in Africa, Durban is the busiest African harbour in terms of the number of vessels that visit annually. Most of the ports have a dedicated purpose. Coeaga, the newest port, was planned originally for export of aluminium, although this has not materialised; East London was for many years a major export route for Zambian copper; Durban is a regional container hub, Richards Bay exports mainly coal and woodchips, while Saldanha Bay is dedicated to iron and steel. Durban, East London and Port Elizabeth also have major vehicle export activities. Though these ports triggered extensive industrial and urban development, they also have had a negative impact on coastal waters (http://www.transnetnationalportsauthority.net/).

Madagascar – As the island is very large and the road and rail infrastructure not well developed, coastal settlements place great reliance on ports for transport. The island has 19 ports of varying sizes: Mahajanga, Toliara, Antsiranana (Diego Suarez), Tolagnaro, Manakara, Mananjary, Morombe, Morondava, Nosi-Be, Port Saint Louis, Ambilobe, Vohimarina, Antalaha, Maroantsetra, Ambodifoltatra, Analalava, Antsohihy and Maintirano. An estimate 60% of all vessel transport is international (long-distance) with 40% related to domestic port-to-part transport. Total import-expert traffic amounted to around 2 million tonnes in 1998 (Centre National de Recherche Environnemental, 2007).

Comoros - Each of the three islands has a small port facility catering for local trade: being the ports of Moroni (Grande Comoro), Fomboni (Mohéli) and Mirontsi (Anjouan). These ports offer only a limited service. For example, the largest port of Moroni does not accommodate ocean going vessels along a wharf and lighters are used to ferry the goods ashore. Mirontsi does have a modest wharf facility that can take a single medium sized passenger vessel. Comoros is on the main route of oil tankers with more than 500 million tonnes of oil passing close by, representing more than 5,000 tanker-voyages per year (Ministère de l'Agriculture, de la Pêche et de l'Environnement, 2007).

Mauritius - Port Louis, the main port of Mauritius, handles approximately 6.5 million tonnes of cargo per year through more than 2,000 vessel calls. Traffic is rapidly increasing with an increase of 9.0% in total handling and a 15.3% increase in container traffic having been recorded for 2007/2008 over the previous year. Port Mathurin serves the sister island of Rodrigues, mainly transporting cargo and passengers to and from Port Louis (Mauritius Ports Authority, Port Financial Year 2007/2008).

Réunion – The main harbour, Le Port, is located on the east coast of the island, around 30 kilometres to the south of the capital, St. Denis. Though small, this port has excellent and efficient facilities coping with large volumes of vehicle imports, sugar exports and passenger liners. There is a main power plant located in the port, as well as various depots and several smaller industrial enterprises (Direction Régionale de l'Environnement, 2005).

3.3 Valuation of ecosystem goods and services

The coastal ecosystems of the WIO, as presented in Chapter 2, provide many goods and services to the benefit of populations and economies of the region. Often these goods and services are taken for granted until such time that they are compromised through climatic events or pollution, poor management or other human-induced impacts. For this reason it is important to identify ecosystem goods and services and to ascribe a value to them so that the justification for their protection is fully recognised. Generally, ecosystem goods refer to products which can be extracted from an ecosystem, for direct or indirect human utilization, such as seafood, timber, honey, biomass, fuel and medicines, among others. Ecosystem services on the other hand refers to the conditions and processes through which ecosystems, and species that make them up, sustain and contribute to human well-being.

Although ecosystem goods and services are often inter-dependent, they can usefully be divided into specific categories. One of the most widely used groupings is that adopted by the Millennium Ecosystem Assessment (MA), being the four functional groups: Provisioning, Regulating, Cultural and Supporting. *Provisioning* being the products obtained from ecosystems, *Regulating* being those benefits derived from the regulation of ecosystem services, *Cultural* being the non-material benefits people derive from ecosystems while *Supporting* are those services necessary for the production of all other ecosystem services (Millennium Ecosystem Assessment, 2005a).

Examples of coastal and marine goods and services can be schematically depicted as follows

Provisioning	Regulating	Cultural
• Food/ fish	• Atmosphere and climate regulating	• Recreational
• Timber/ fuel	• Hydrological balance	• Spiritual and religion
• Building materials	• Disease control	• Aesthetic
• Curios	• Waste assimilation	• Inspirational
• Fibre	• Erosion control	• Educational
• Medicines	• Storm/flood protection	• Heritage
• Genetic resources		• Research
Supporting		
• Nutrient cycling • Primary production • Provisioning of habitat • Supporting life cycles		

Although goods and services are derived from all coastal and marine ecosystems, including the oceans, sandy beaches, estuaries etc, only those four coastal ecosystems highlighted in this study are discussed in more detail below.

Coral reefs

Coral reefs are not only centres of high biodiversity but also provide a great range of environmental goods and services, especially in the West Indian Ocean. Coral reefs are important to artisanal users but also to tourism and in contributing to employment and foreign exchange earnings. Corals provide services in each of the categories.

- *Provisioning* – Numerous goods or products are derived from coral reefs, especially many species of fish and shellfish. Included is a diversity of shells of ornamental and cultural value. Coral sand and limestone are used for building, while the coral reef environment has the potential to generate genetic products, some of significant medicinal and pharmaceutical benefit.

Besides providing food products for subsistence, the marine and coastal environment provides many other valuable services (photo courtesy of Rudy v.d. Elst, ORI)

- *Regulating* – Coral reefs provide a barrier that can protect shorelines from erosion and storm damage; the diversity of habitats within the reef creates numerous opportunities for colonization. Coral reefs also function as major nursery areas for a great diversity of species.
- *Cultural* – Coral reefs are enormously popular tourist destinations; they are of high educational and scientific value ;
- *Supporting* - The high biodiversity of coral reefs provides the basis for many harvesting opportunities with significant economic value to artisanal and commercial fisheries. Corals play a role in nutrient cycling, they contribute to primary production and the biochemistry of calcium, aragonite and CO_2.

Mangroves

Mangrove forests are among the most productive ecosystems and offer a variety of goods and services (Bosire, 2006). The mangroves of the WIO region provide goods and services with significant social and economic value to the coastal communities (UNEP/GPA and WIOMSA, 2004a; McLeod and Salm, 2006). Mangroves provide services in each of the four main categories.

- *Provisioning* - A variety of goods or products are derived from mangroves including finfish, shellfish, timber, fuelwood, charcoal, building poles and boat building materials. (Rönnbäck et al., 2002; Ngoile and Shunula, 1992). Traditional products exploited from mangroves include medicines, tannins for preserving nets and fishing gears, dyes for cloth, honey, insect repellents and leaves for consumption by livestock.

- *Regulating* - Mangroves stabilize the shorelines by their intricate root networks and the trees themselves form a barrier against storm damage (McLeod and Salm, 2006) thus mitigating socio-economic losses that could otherwise be incurred. The mangroves also filter and trap land-based sediments, heavy metals, nitrogen from domestic wastes and other pollutants, moderate water quality, protect the integrity of adjacent ecosystems, and fix and store significant amounts of carbon thus playing an important role in carbon sequestration.
- *Cultural* - Many local communities use designated locations in mangrove forests as sacred shrines. There is also growing interest in, and use of mangrove ecosystems for, eco-tourism due to its unique structure and diversity, which will enhance public awareness and mangrove conservation. Research into mangroves is also a service derived from this unique habitat.
- *Supporting* - The organic productivity within mangroves supports the nearshore fisheries production (Lee, 1999). The high biomass of shrimps, fish, molluscs and crabs that mangroves support has significant economic value to artisanal and commercial fisheries.

Coastal forests and grasslands

Coastal vegetation, including climax forests and grasslands, are important generators of benefits in the WIO. Although scientific information relating to the extent and nature of this habitat is not comprehensive, it is known that coastal vegetation is under threat, as discussed elsewhere in this report. Ecosystem benefits can be attributed to each of the four categories.

- *Provisioning* – Forests provide numerous direct benefits, including timber, wildlife, medicinal products, fruit, honey, insects and products used for curios. Genetic products are also derived from this ecosystem. Forests provide a source of fuel, especially in charcoal production.
- *Regulating* – Forests play a significant role in the cycling of nutrients and are especially important in carbon sequestration.
- *Cultural* – Coastal vegetation, and especially forests, are often places of cultural and heritage significance. The unique assemblage of plant species provides high scientific and educational value. Increasingly, forests are recognised as major tourist destination, many examples evident from several countries in the WIO region.
- *Support* – Coastal forests are major sources of primary production, acting as carbon sinks and oxygen generators. Forests and grasslands provide habitat for a large biomass and a great diversity of species, many of which spend all or major parts of their life cycle in this ecosystem. Nutrient cycling is a particular benefit, especially in the process of creating fertile organic matter.

Seagrass Meadows

Seagrass meadows are a common but inadequately studied ecosystem, despite the great benefits that are generated, as demonstrated by de la Torre-Castro and Rönnbäck (2004). Seagrasses are also notably vulnerable to climate change and human impacts.

- *Provisioning* – Throughout coastal regions of the WIO, subsistence fishers and gatherers collect food from seagrass meadows, especially during the low tides. These products include fish and shellfish, worms, sea cucumbers for export, clams, oysters and numerous other living marine species. In many cases the beds generate fishes such as seahorses and ornamental shells, ranging from large conch shells to the abundant cowries used throught the region in ornamental and traditional items. Though potentially impacting, seaweed cultivation takes place in and around seagrass meadows.

Table 3-5 Indicator values (in US dollars per year) for ecosystem services (after Constanza *et al.*, 1997).

	Climate regulation	Disturbance regulation	Water supply	Erosion control	Nutrient cycling	Waste treatment	Biological control	Habitat refuge	Food production	Raw materials	Recreation	Cultural	Total
Seagrass	..	..	..	..	19,002	..	..	..	..	2	..	..	19,004
Coral reefs	..	2,750	..	..	..	58	5	7	220	27	3,008	1	6,076
Tropical forest	223	5	8	245	922	87	..	..	32	315	112	2	2,008
Tidal marsh/ mangroves	..	1,839	..	..	..	6,696	..	169	466	162	658	..	9,990

Table 3-6 Valuation of annual ecosystem goods and services in the WIO region based on Constanza *et al.*, (1997) (see Chapter 2 for area estimates)

	Coral reefs		Mangroves		Coastal forests		Seagrass beds		Total
Country	Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Area (km^2)	Value (million US$)	Value (million US$)
Comoros	430	261	1	1	2,170	436	..	..	698
Kenya	630	383	500	500	660	133	34	65	1,079
Madagascar	2,230	1,355	3,000	2,997	..	..	..	..	4,352
Mauritius	870	529	1	1			70	133	1,072
Mozambique	1,860	1,130	3,902	3,898	1,790	359	439	834	6,222
Réunion (France)	<50	..	0	0	2,517	505	..	..	505
Seychelles	1,690	1,027	25	25	455	91	..	..	1,143
Somalia	710	431	91	91	2	0	..	..	523
South Africa	<50	..	30	30	19,500	3,916	7	13	3,959
Tanzania	3,580	2,175	1,250	1,249	700	141	..	..	3,565
Total	12,000	7,291	8,800	8,791	27,794	5,581	550	1,045	22,709

- *Regulating* – Seagrasses contribute to atmospheric regulation through their primary production. Waste assimilation, storm protection and erosion control are also services provided.
- *Cultural* – Seagrass beds are important traditional harvesting grounds for many coastal communities, Their scientific and educational value is significant.
- *Supporting* – Nutrient cycling, primary production and also

Placing a value on ecosystem goods and services

Each of the ecosystems found in the WIO contributes to goods and services, albeit in different ways. Together these goods and services represent a significant economic asset, both to countries' national budgets as well as to subsistence and artisanal communities in poverty reduction. Clearly, this is dependent on the continued health of each of these ecosystems.

Valuation of goods and services is a complex exercise (Millennium Ecosystem Assessment, 2005a), but one that assumes relevance in a human environment where economics and finance are pivotal aspects in decision making – including when it concerns the environment. Countries need to know the real cost of using the earth's natural capital and the consequences they may have through their actions (European Community, 2008). While placing a value on the provisioning of goods, such as fish, timber etc, may be relatively easy, the values associated with the other three groups are less readily established. Paradoxically, under-developed communities place greater emphasis on the value of provisioned goods as a direct source of income, even though they may be more vulnerable to the impact of failed ecosystem regulating and support services. It is also important to note that there is an inherent risk in the more direct estimation of the value of goods rather than valuing the regulating services as it can bias development decisions by over-emphasising the market value of the goods. Furthermore, poor people are less able to attach high values to goods and services than wealthier communities, placing them at an additional disadvantage in reducing poverty (Brown *et al.,* 2008). There are also clear links and trade-offs between ecosystem services and the Millennium Development Goals – MDGs (European Community, 2008).

As most ecosystem benefits are public goods they have no price. This means that different methods need to be developed to value these benefits. These can include rewards for maintaining the public goods, or the payment for ecosystem services, thereby creating a demand and markets. This could include "polluter pays" principles, carbon credits and waste assimilation costs such as those created by offshore pipelines.

One approach, especially relevant to goods includes the 'use' value and 'non-use' or 'passive use' value of a service. The use values may further be sub-divided into direct use values, indirect use values and option values, as described below (Millennium Ecosystem Assessment, 2005b):

- **Direct use values** - These are associated with the actual use of the environment such as fishing, harvesting of mangrove and coastal forests to obtain building materials like timber, firewood or charcoal, hunting of game, collection of honey and tannins, recreational use such as beach walks, tourist snorkelling and diving over coral reefs and bird watching. These ecosystem goods and services are "traded" in the market and therefore have direct use values. They support livelihood and income generation for the coastal communities and contribute to the national economies in the WIO region.
- **Indirect use values** – Most indirect use values are derived without physical interaction with the ecosystem, for example, people may enjoy watching videos on marine life or visit a marine park in one of the countries of the WIO region, thus deriving indirect use value.

- **Option values –** These refer to the value that people place on having the option to enjoy an ecosystem good or service in the future although he/she might not be using it at present.
- **Non-use values -** The simple existence of the goods and services, their altruistic and bequest values are referred to as 'non-use' values. Existence value is that which people place on simply knowing that something exists even if they will never have a chance to see it or use it. Bequest value on the other hand is the value that people place on knowing that future generations will also have an opportunity to enjoy an ecosystem product or its service. It is measured by what people are willing to pay to preserve natural ecosystem intact for future generations.

There are different approaches for estimating values of direct and indirect uses of ecosystems. Some of the most commonly used are based on quantifying the 'willingness-to-pay' for goods and services, or the market value of the resources, or on costs of replacing resources if lost, as described below:

- **Willingness-to-pay -** This is the potential amount users of services would pay for the services that are provided by the ecosystems, offering a kind of 'simulated' market value. In many cases, such methods involve obtaining the opinions of stakeholders. Because of this, the outcomes of such studies are often subjective due to their dependence on opinions involved or the individual's own financial environment. However, 'willingness-to-pay' studies do allow for incorporation of otherwise difficult to quantify indirect, non-use and option values.
- **Market value –** Here the actual market values of ecosystems are quantified in terms of the financial value of the goods and services provided. The limitation of such methods is that it is difficult to attach an actual market value for indirect, non-use and option values. Often in such studies, therefore, only direct use values are considered, therewith underestimating the actual value.
- **Replacement costs –** These are those costs associated with attempting to replace part of or an entire ecosystem (e.g. the cost of rehabilitating two hectares of mangroves). While this method is quite objective and scientifically justifiable, the weakness is that the value obtained often does not relate to the actual value of the goods and services provided by the ecosystem.

Many economic studies on valuating ecosystem goods and services have been concluded, including an assessment of services provided by global ecosystems. Despite their convincing results, many of the estimates vary widely. For example, while the coastal zone covers only 8% of the world's surface, the goods and services provided by the 100 km wide coastal zone is responsible for approximately 61% of the estimated total value of global ecosystem services: $44 trillion (UNEP, 2006). Yet, based on Constanza *et al*. (1997), the global value of ecosystem services was calculated to be US$ 33 trillion. Notwithstanding the variance and somewhat controversial nature of these studies it is abundantly clear that coastal ecosystem services do provide significant contribution to human well-being at a global scale.

The two sections that follow provide estimates based upon the first two methods presented above beginning with a valuation of ecosystem goods and services following an analysis of the two main direct use values derived from the WIO coastal ecosystems, namely tourism and fisheries.

3.3.1 Estimated value of key ecosystem services in the WIO

Based on the estimates made by Constanza *et al*. (1997), an extrapolation can be attempted to gauge the value of coastal and marine goods and services in the WIO. Constanza *et al*. (1997) based their calculations, either directly or indirectly, on the 'willingness-to-pay' of individuals for ecosystem services (see Table 3-5). Despite the obvious risks associated with using 'globalized indicators' within the local context of the WIO region, applying this method may provide at least an estimate for assisting in establishing the relative values of actual ecosystem services as a possible decision support tool. Where appropriate, perspectives on the estimates are provided, based on local case studies.

Coral Reefs

The value of coral reefs in the WIO region is estimated at US$ 7,291 million per year (see Table 3-6), based on the sum of the individual indicator values for ecosystem services show in Table 3-5 but excluding the smaller coral reef patches of South Africa and Réunion. Some discrepancy exists to the absolute values for ecosystem services. For example, a recent study conducted by the South China Seas Project (www.scs.org) rates the annual value of coral reef systems at US$ 1,181 per hectare per year. The total economic value of coral reefs in India has also been estimated but in terms of the nature of use, and valued at US$ 2,750 per hectare in terms of direct extractive uses and US$ 5,645 per hectare per year for aesthetic/recreational/tourism value (Wafar and Wafar, 2001), hence totalling US$ 8,395 per hectare per year. The total estimated economic value of coral reef ecosystems, as presented in Table 3-6, therefore provides a value in the middle, albeit at the higher end of the scale.

Restoration costs of coral reefs are potentially extremely high, with estimates ranging vastly, from US$ 13,000 to US$ 100 million per hectare, depending on the specifics of the situation (Lindahl, 1998; Spurgeon and Lindahl, 2000).

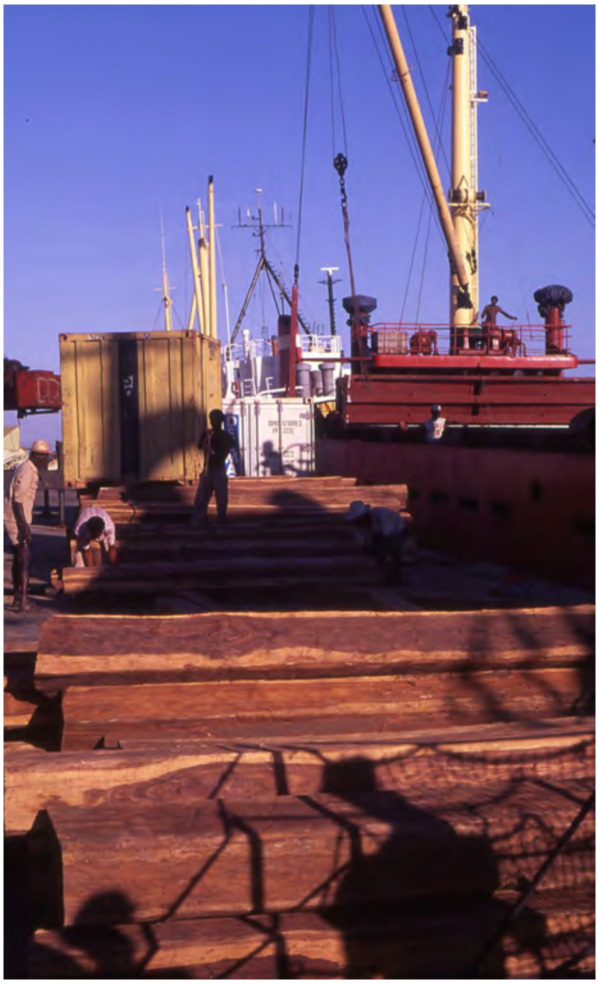
Mangroves

It is estimated that over 150,000 people in Tanzania earn their living directly from mangrove resources (TCMP, 2001). Mangrove exploitation for poles for construction and bark (for tannin extraction) both for export was common in Tanzania up to the mid 1990s. In Kenya, export of mangroves to the Middle East and Gulf countries went on until the 1980s when it was banned. In Madagascar, mangroves are an important source of income both for the local population and the national economy. The mangrove trees are harvested for building poles and firewood, and traditional and industrial shrimp fishing take place in mangrove areas. In Mauritius, there is no widespread traditional use of mangroves and only a few parts of the two species that occur in Mauritius (*Bruiguiera gymnorhiza* and *Rhyzophora mucronata*) are traditionally used for medicinal purposes. The non-market value of mangroves (ecosystem function) is however evident when the contribution of the coastal zone to foreign exchange earnings is considered (UNEP/GPA and WIOMSA, 2004a; McLeod and Salm, 2006).

The total economic value of mangrove forest goods and services in the WIO region may be estimated at US$ 8,791 million per year, concentrated mainly in Mozambique, Madagascar and Tanzania. However, this value may be an overestimate, with recent studies in Thailand (World Resources Institute, 2008) and in South China Seas (www.unepscs.org) providing values ranging from US$ 3,680 to US$ 2,872 per hectare per year, roughly one third of the values presented in Table 3-6.

Coastal forests

As for mangroves, coastal forests present a large range of direct and indirect use values. Two particular functions relevant to the coastal and marine environment are stabilisation of soil, which reduces erosion, and recharging of groundwater aquifers. Ultimately, these functions determine, in part, the dynamics of both sediment and water exchange in the coastal zone.



The export of timber is a major contributor to the economies in the region, in particular Mozambique and Tanzania (photo courtesy of Rudy v.d. Elst, ORI)

The total value of the coastal forests systems in the WIO region is estimated at US$ 5,581 per year. Unfortunately, there is little comparable data concerning the specific values of coastal forest goods and services with regard to their functions related to the coastal and marine environment, and the values presented in Table 3-6 should therefore be considered as the high end of the range.

Seagrass resources

Although seagrass beds are found in all countries of the WIO region, their actual extent is largely unknown. The largest recorded area is found in Mozambique (439 km^2), with the total estimated at over 550 km^2. Using the averages from Table 3-5, their total value reaches US$ 1,045 million per year (Table 3-6). However, a recent valuation study performed for the South China Seas attaches a much lower value to seagrass beds, at US$ 1,182 per hectare per year, an order of magnitude lower in value (www.unepscs.org).

In conclusion:

The above analysis is clearly highly speculative and should be applied with caution. The average values derived from Constanza (1997) are not only a decade old, but also highly variable. For example, about 50% of the coral reef services value is attributed to recreation while food production in the form of fisheries represents only 3.6%. In the calculation the coral reefs of South Africa were left out as being too small, yet the modest "Two-Mile Reef" at Sodwana Bay hosts up to 100,000 scuba divers per annum, generating considerable economic benefits. Similarly, the value attributed to nutrient cycling in seagrass beds accounts for nearly 100% of the total, when it is common knowledge that seagrass beds provide a major habitat for artisanal and subsistence fishers in the WIO region. Using lower estimates from the other studies quoted suggest that the value may be US$ 12.9 billion and not the US$ 22.7 billion as shown. Nevertheless, these preliminary data do indicate substantial values attributable to some extent to ecosystem goods and services derived from a number of key coastal and marine ecosystems in the WIO. It is also clear that some efforts at calculating WIO-derived values for ecosystem goods and services, preferably on an agreed template basis, would be justified in the future.

Drivers of change

Ecosystems are not static entities, nor are the benefits they deliver constant or always predictable. Change is inevitable, but the drivers of change need to be carefully identified and evaluated and their relationship to ecosystem services understood. Natural drivers of change are largely climate induced, although these may have their origin in human activities, such as global warming. Drivers of change can thus be direct or indirect in their effects on ecosystems and their services. It follows that human decisions can influence drivers and that this can take place at different levels, from national government policy to decisions of the individual. Drivers can be demographic, cultural, economic, political or technological while their effects may be physical, chemical or biological (Millennium Ecosystem Assessment, 2005c). Drivers of change may interact amongst each other in changing ecosystems. Some examples of drivers of change relevant to WIO region are tabulated:

DIRECT DRIVERS	INDIRECT DRIVERS
Local	**Local**
Changes in land use & cover Species introductions Habitat degradation Overfishing Pollution Agricultural practices Erosion	Poverty Community health
National	**National**
Natural disasters Migration Industrial development Water quality Catchment management	National policies Legislation Establishment of MPAs Tourism development Education Migration Industrial development
Global	**Global**
Climate change	Globalization Economics

3.4 Conclusions

Countries of the WIO have considerable latent potential to improve their stake in the global economy and to alleviate to some extent poverty, most notably in the coastal zone. Better use of natural resources with value-adding rather than export of raw materials is one clear opportunity. It is also evident that the ecosystem goods and services that could be generated are huge – even if the data is wanting. Some of the economically "richest" ecosystems occur throughout the region and improved management and use of those resources needs to be fully pursued.

A good example lies in tourism development. Clearly, each of the participating countries has great tourist potential, especially related to the coastal and marine environment. Generally the same attractions are on offer, ranging from beach vacations to more intrepid diving and fishing. In some cases, the attractions have special attributes, including unique biodiversity such as in Madagascar and Seychelles, and rich cultural heritage such as in Mozambique and Kenya. While this enhances the regional attraction to tourists, it also adds to competition between countries for tourist arrivals. Surprisingly, few of the countries appear to attach much importance to domestic tourism, which is a big economic driver in many parts of the world. Cruise ship arrivals also seem to be underrated, yet do have a significant role to play, especially along the coast. Theses and other opportunities in tourism development and hence economic benefits do exist and can usefully be pursued by each country and in the SAP process.

Fisheries of the WIO region are already quite intensely exploited and do provide substantial benefits, not only to national budgets but also to the millions who access these resources as subsistence or artisanal fishers and traders. Improved benefits may well be possible but these will depend on the effective interaction and joint development of Strategic Action Plans with the South West Indian Ocean Fisheries (SWIOFP) and the Agulhas-Somali Large Marine Ecosystem (ASCLME) projects. Better control over access by foreign fishers is clearly a key objective that will be best achieved in done with regional collaboration. A clear need also exists to improve fisheries and socio-economics data collection and sharing in the region. Many of the reports consulted contain conflicting data thus making it difficult to establish the reliability of much essential information.

Population growth rates over the past few decades have been high and at a rate that has imposed huge pressures on natural systems, especially the coast. Paradoxically, growth rates have slowed enormously in some regions, attributable to the impact of HIV-Aids. This presents more than population health challenges as it also impedes capacity and skills development in a young sector of society. While inland states appear to have relatively higher life expectancy, per capita GDP and human development indices, they are more vulnerable to environmental impacts and risks to their ecosystem goods and services.

Ultimately, securing substantial and reliable ecosystem goods and services requires a comprehensive understanding of the drivers of change and how these interact with the different *Provisioning, Regulating, Cultural and Supporting* services of WIO ecosystems. Ascribing values to these services can be used as a tool for decision making and evaluating trade offs where these are necessary. No matter how variable the natural environment may be, most of the impacts on ecosystem services, and consequently the well-being of people living around the WIO, depend largely on the level of informed and wise decision making.

CHAPTER 4 - ASSESSMENT OF MAJOR TRANSBOUNDARY PROBLEMS AND ISSUES

4 Assessment of Major Transboundary Problems and Issues

4.1 Introduction

This chapter of the TDA presents an analysis of the major documented and perceived problems related to land-based sources and activities.

4.1.1 Identification of major perceived problems and issues

The identification of the major perceived problems and issues is a first step in the TDA process. It constitutes the basis for subsequent in-depth scientific and technical analysis of such perceived problems and issues in order to validate and prioritize the same.

The classification of key transboundary problems related to LBSA is primarily based on the results of a regional specialist TDA/SAP workshop[1], which identified and grouped problems into three distinguishable clusters:

1. Water and sediment quality degeneration due to pollution from land-based sources;
2. Physical alteration and destruction of habitats; and
3. Alteration in freshwater flows and sediment loads from rivers.

During the TDA workshop, participants (including over 40 experts) established initial problem trees for these three problem areas, where necessary these were further divided into sub-clusters. The individual problem areas were further defined in more detail by the TDA Drafting Team in consultation with the various Task Forces and Working Groups as described in Chapter 1. A short description of each of these problem areas is presented below.

Water and sediment quality degeneration due to pollution from land-based sources

A significant amount of the pollution load introduced to the sea emanates from land-based activities, such as municipal and industrial discharges, contaminated surface and sub-surface run-off, agricultural return flows and atmospheric emissions. Pollutant loads from such land-based activities are typically and invariably disposed in the coastal zone where they affect some of the most productive areas of the marine environment, such as estuaries and near-shore waters. Moreover, contaminants which pose risks to human health and living resources can be transported long distances by watercourses, ocean currents and atmospheric processes.

The TDA identified five distinguishable pollution categories:

1. Microbial contamination
2. High suspended solids[2]
3. Chemical pollution

1 Held in April 2007 in Nairobi, Kenya
2 Specifically referring to particulate material

4. Marine litter (including debris)

5. Eutrophication (nutrient enrichment)[3]

Physical alteration and destruction of habitats (PADH)

One of the priority transboundary problems for the WIO region is the transformation and loss of habitats. The causes of these transformations are both physical, as in the dredging of waterways, deforestation, diversion of freshwater flows, construction of ports and jetties, tourist resorts, housing developments; and biological, as in over-exploitation of living resources such as coastal forests, mangroves, seagrass beds and coral reefs. In addition, global climate change, which is a cross-cutting concern attributed to human activities, is accentuating abnormal rainfall patterns, droughts, floods and sea level changes. Finally, land reclamation for agriculture and development as well as extensive upland deforestation cause acute problems for the major river catchments in the region, as witnessed in the Tana, Athi-Sabaki, Rufiji and Zambezi. The cumulative impacts of these transformations and losses have been manifested by significant physical and ecological changes in the region and an overall decline in many ecosystem services.

Although PADH impacts have been documented in all ecosystems, the five critical categories focused on in this TDA are:

1. Degradation of mangrove forests
2. Degradation of seagrass beds
3. Degradation of coastal forests
4. Degradation of coral reefs
5. Shoreline changes

Alteration in freshwater flows and sediment loads from rivers

One of the key areas of concern for the WIO region relates to the interaction between river basins and the coastal and marine environment. Throughout much of the region, but more so in the continental states, many of the coastal issues are linked to human activities and increased climatic variability far removed from the coast. The impacts of such distant impacts have altered the nature of the drainage of the river systems – large and small – impeding or increasing the flow of freshwater, thus changing the levels of terrigenous sediment and organic matter. They have also affected the quality of the water, mainly through the introduction of nutrients and pollutants from domestic sewage and industrial and agricultural chemicals.

The two key problem areas related to river-coast interaction that have been distinguished in the TDA are:

1. Alteration of river flow and degradation of water quality.
2. Alteration of river sediment load.

4.1.2 Approach and methodology

A number of targeted studies commissioned by the Nairobi Convention, largely as part of the WIO-LaB project, form the main basis and supporting data for the analysis presented in this chapter and resulted in a series of supporting documents (see Chapter 1, Section 1.6).

3 Refers to the effect of nutrient enrichment resulting in harmful/nuisance algal blooms

Apart from these supporting documents, the analysis comprises a comprehensive evaluation of other studies and reports[4]. The process of identification of such data and information as well as the validation of the conclusions of the study was undertaken in a series of technical workshops with experts in appropriate disciplines, the final validation being assigned to the Scientific and Technical Advisory Panel of the Project. For further details on the TDA development process, refer to Chapter 1 of this report.

The analysis of the above-listed perceived transboundary problem clusters, which are presented in the following sections, follows a systematic approach, as schematically displayed in Figure 4-1 and further elucidated below.

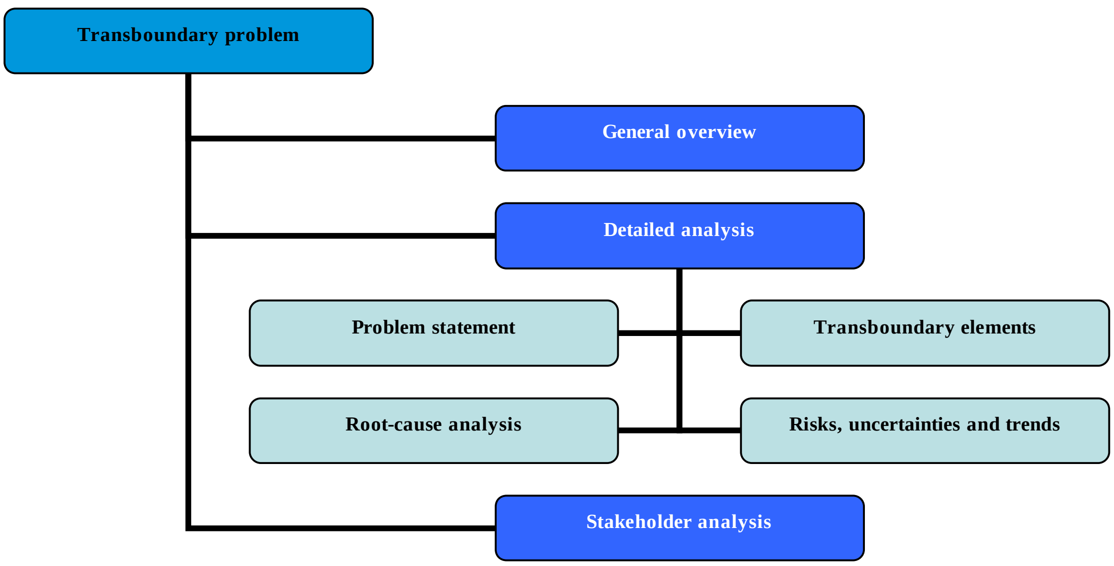


Figure 4-1 Schematic presentation of the problem analysis framework.

General overview

Each section first presents a general overview of the specific problem at hand, including:

- A general overview of the problem;
- A general overview of the (root and direct) causes as well as the environmental impacts and socio-economic consequences related to the problem; and
- An identification and description of the perceived hotspots of the problem.

Subsequent to this general overview, each problem is then further analysed in more detail at the level of the problem sub-categories as defined above (i.e. the five problem sub-categories of pollution and PADH and the three of river-coast interactions).

4 Such as the African Process, the Global International Waters Assessment (GIWA) programme, the Eastern African Marine Systems (EAMS) programme, GESAMP, TRANSMAP and various reports prepared by the UNEP Nairobi Convention Secretariat and the UNEP Global programme of Action for the Protection of the Marine Environment from land-based Activities (UNEP/GPA).

Detailed analysis
Each of the above problem areas are analysed in detail in individual sub-sections, organised in a similar way reflecting the various steps in the analysis, as follows:

a. Problem statement

Presents a brief definition of the problem, including its general perspective and context.

b. Transboundary elements

Provides a brief review of the transboundary elements of the problem, investigating to what extent the problem is relevant within the context of the TDA, and in particular responding to questions such as, 'Is the problem truly transboundary, in that it has transboundary causes and/or impacts? Is it a common problem in the region, or is it relevant to certain regions only (e.g. mainland versus islands)?

c. Root-cause analysis

This is the most substantial section, providing first a graphical presentation of the transboundary problem in the form of a problem tree, and describing and reflecting on the elements of the problem tree. The analysis is supported by a summary of relevant data and information based upon the detailed assessment reports presented above[5]. The root-cause analysis distinguishes five different levels, as schematically displayed in Figure 4-2.

d. Risks, uncertainties and trends

This sub-section presents an analysis of risks and uncertainties, such as important gaps in data/knowledge that may hamper adequate assessment of the problem and its effects, as well as uncertainties in future development. It also identifies any observed trends, such as

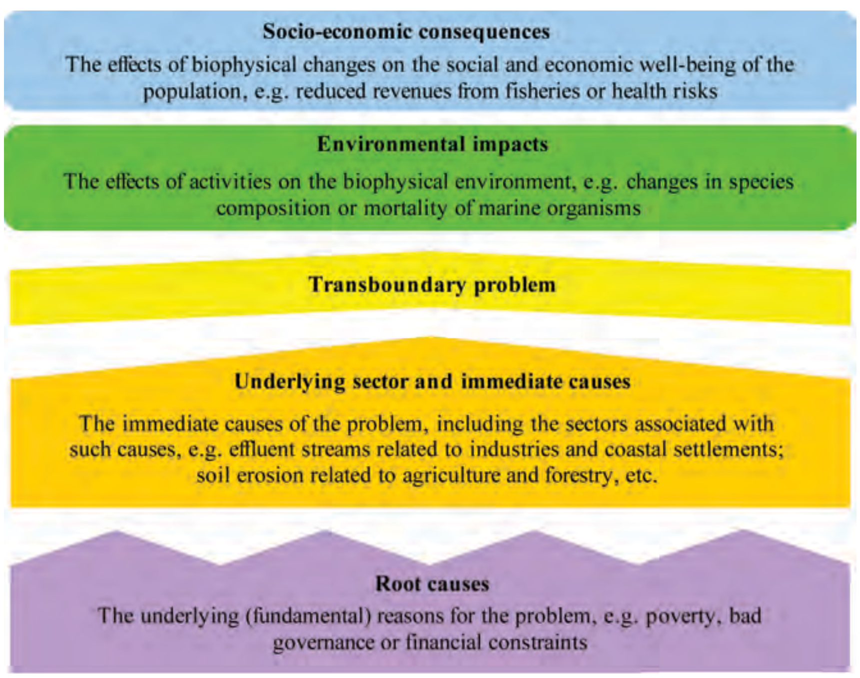


Figure 4-2 Schematic presentation of the various levels of analysis in the problem trees that follow.

5 It is stressed that the TDA report only presents a summary of relevant supporting data and information analysis and that detailed supporting data and information is provided in separate supporting documents.

developments that might cause a problem to be greater or more significant in the future and which should be noted now.

e. Stakeholder analysis

The final component is an analysis of the main stakeholders associated with the causes of the problem, as well as those affected by it. The analysis is based on a standard list of identified potential stakeholder groups and sub-groups

4.2 Problem Area 1: Water and sediment quality degeneration due to pollution from land-based sources

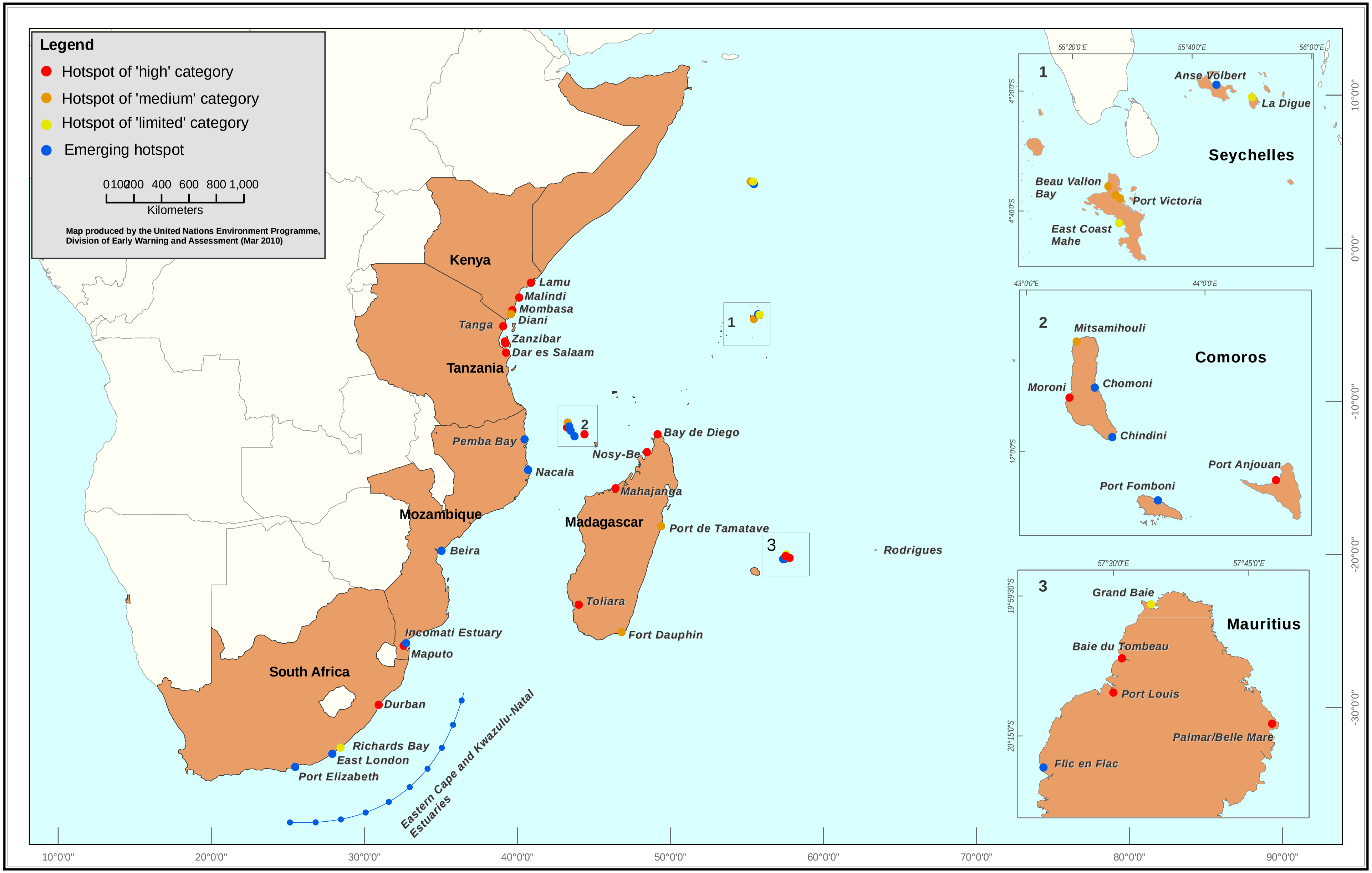
4.2.1 Overview

According to a world-wide study by the UN Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) in 1990, the majority of marine pollution (estimated to be 80%) originates from land-based sources through municipal and industrial discharges, contaminated surface and sub-surface run-off, agricultural return flows and atmospheric emissions. Pollutant loads from land-based activities are typically disposed of in the coastal zone where they affect some of the most productive areas of the marine environment, such as estuaries and near-shore waters. Moreover, contaminants which pose risks to human health and living resources can be transported long distances by watercourses, ocean currents and atmospheric processes.

The African Process, which preceded the WIO-LaB project, developed as initiatives under the Abidjan and Nairobi Conventions, aimed at identifying hotspots of pollution or sensitive areas and unique ecological areas along the sub-Saharan African coast (GEF/MSP, 2001). As part of this process, hotspots of land-based sources of marine pollution - described as those localities where there was readily observable evidence of pollution impacts that affected the health of the coastal environment or the coast's natural ability to deliver services - were identified in National African Process Reports (Francis *et al.*, 2002; Kazungu *et al.*, 2002; Jones *et al.*, 2002; Dulymamode *et al.*, 2002; Hoguane *et al.*, 2002; Clark *et al.*, 2002)[6]. Based on this initial analysis, an assessment of hot spots of pollution was undertaken as part of the WIO-LaB project, including a regional monitoring programme to asses the quality of water and sediments at the perceived hot spots (UNEP/Nairobi Convention Secretariat *et al.*, 2009b). The main hot spots of marine pollution in the WIO region resulting from this analysis are highlighted in Figure 4-3, while an overview of identified hotspots, including their specifics, is presented in Table 4-1.

The development and implementation of a water, sediment and biota quality monitoring plan for the WIO, under the WIO-LaB project, followed an attempt to make a first regionally comparable estimate of pollution in perceived hotspots of pollution in each of the eight participating countries. This included the preparation of National Pollution Status Reports (Anon. Mauritius, 2009, Mong *et al.* 2009, Anon Mozambique 2007, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Antoine *et al.* 2008, Weerts *et al.*, 2009), as well as the execution of a regional monitoring programme coordinated through a Regional Activity Centre (RAC), in this case the Council for Scientific and Industrial Research (CSIR) of South Africa. Results from these national

6. Madagascar and the Comoros did not participate in the African Process, but under the auspices of the WIO-LaB Project, these countries identified their hotspots which were confirmed during the 2nd meeting of the Water, Sediment and Biota Quality Regional Working Group established under the auspices if the WIO-LaB Project, held in Mauritius in February 2006.



'Hotspots' of land-based sources of marine pollution in the WIO region-reports are incorporated in a Regional Synthesis Report on Marine Pollution in the WIO region (UNEP/Nairobi Convention Secretariat *et al.*, 2009b). Other studies commissioned under the WIO-LaB project that are of relevance include the regional reports on the assessment of the status of municipal wastewater (MWW) management and marine litter problems in the WIO region (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a, UNEP and WIOMSA, 2008). These three reports form the main supporting documents for this section of the TDA.

Within this context, the focus of this analysis is on land-based sources of marine pollution as opposed to pollution linked to maritime transportation or dumping of waste at sea. Land-based sources of marine pollution in the WIO region are primarily associated with densely populated areas and industrial zones within urban centres and in the vicinity of river discharges, particularly those from larger river basins. Although, at present urban centres in the WIO region are still several hundred kilometres apart, creating distinct hotspots, rapid urbanization in the region could result in so-called 'strip development' of coastal areas where smaller coastal towns and suburban areas eventually join with the main cities, creating larger continuous urban zones along the coastline (Ruwa, 2006).Based on the draft National Pollution Status Reports prepared under the auspices of the WIO-LaB Project, five transboundary problems were identified (here defined as problems that are common to the countries of the WIO region), all linked to the deterioration of water quality in coastal areas (or marine pollution) as a result of land-based activities. These were:

- Microbial contamination
- High suspended solids
- Chemical pollution
- Marine litter
- Eutrophication (or nutrient over-enrichment).

The most important environmental impacts and socio-economic consequences associated with the priority transboundary marine pollution problems, as well as the most important direct causes of such problems are summarized in Table 4-2 and Table 4-3 respectively. It is apparent that the observed environmental impacts and socio-economic consequence may be the cumulative result of various pollution problems. Also, there are several direct causes linked to a single specific transboundary marine pollution problem – likewise the same direct cause can result in several different transboundary marine pollution problems.

Discharge of untreated municipal wastewater leading to pollution of coastal waters (photo UNEP)

Untreated wastewater is the main origin of microbial pollution causing unhealthy situations (photo courtesy of Peter Scheren, UNEP)

Table 4-1 Overview of selected pollution hotspots in the WIO region and associated or perceived pollution problems.

COUNTRY	HOT SPOT	CATEGORY[a]	TRANSBOUNDARY PROBLEM				
			Microbial contamination	Eutrophication (nutrient enrichment)	Marine litter (solid waste)	Suspended solids	Chemical Pollution
Comoros	Mitsamihouli beach	2	■	■	■		■
	Chindini Beach	4	■		■		
	Chomoni Beach	4			■		
	Moroni Port	1	■	■	■		■
	Anjouan Port	1	■	■	■		■
	Fomboni Port	4	■	■	■		■
Kenya	Mombassa	1	■	■	■	■	■
	Lamu inshore waters	1	■	■	■	■	■
	Malindi Bay and Sabaki Estuary	1	■	■	■	■	■
	Diani	2	■	■	■	■	■
Madagascar	Port de Mahajanga	1	■	■			■
	Port de Nosy-Be	1	■	■			■
	Toliara	1	■	■		■	
	Port de Tamatave	2					■
	Bay de Diego	1		■			■
	Baie de Fort-Dauphin	2	■				■
Mauritius	Pointe Aux Sables to Bay du Tombeau (through Port Louis)	1	■	■	■	■	
	Belle Mare/Palmar	1	■	■			
	Flic and Flac	4	■	■		■	■
	Grand Baie	3	■	■		■	
	Rodrigues[b]	?				■	
Mozambique	Maputo Bay	1	■	■	■	■	■
	Beira	4	■	■	■		
	Nacala Bay	4	■	■	■		
	Pemba Bay	4	■				
	Incomati Estuary	4		■			

COUNTRY	HOT SPOT	CATEGORY[a]	TRANSBOUNDARY PROBLEM				
			Microbial contamination	Eutrophication (nutrient enrichment)	Marine litter (solid waste)	Suspended solids	Chemical Pollution
Seychelles	Port Victoria	2	■	■			■
	La Digue	3	■				
	Anse Volbert	4	■				
	Beau Vallon Bay	2	■	■			
	East coast Mahe	3	■	■			■
South Africa	Richards Bay	3				■	■
	Durban	1	■				
	East London	4	■	■			
	Port Elizabeth	4	■				■
	Eastern Cape and Kwazulu-Natal estuaries and adjacent coastal areas	4	■	■			
Tanzania	Dar es Salaam	1	■	■			■
	Tanga	1	■	■			
	Zanzibar	1	■	■			

[a] Hot spots ranked in order of decreasing severity from 1 to 3; Category 4 refers to emerging hot spots.
[b] Rodrigues did not form part of the WIO-LaB regional monitoring programme and is consequently not ranked.

Table 4-2 Environmental impacts and socio-economic consequences potentially associated with priority transboundary marine pollution problems.

TRANSBOUNDARY PROBLEM					ENVIRONMENTAL IMPACTS
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical Pollution	
	X		X	X	Modification in marine biotic species composition
	X		X		Smothering of benthic communities
		X	X		Entanglement/suffocation of marine organisms
			X	X	Chronic effects on marine biota
	X		X	X	Mortality (acute effects) on marine biota
	X				Opportunistic/nuisance/harmful/toxic algal blooms
	X		X	X	Discoloration of coastal waters
	X				Anoxic conditions/bad odours
X					High levels of pathogenic organisms
					SOCIO-ECONOMIC CONSEQUENCES
	X	X	X		Loss of aesthetic value
X	X	X		X	Human health risk through contact recreation
X	X			X	Human health risk through ingestion of contaminated seafood
X	X		X	X	Loss in quality of seafood products
	X		X	X	Loss of fisheries resources and revenue

The root causes of the priority transboundary marine pollution problems identified in the WIO region are generally cross-cutting. Within the WIO region, the following root causes are considered relevant to marine pollution issues:

- *Population pressure* - Population growth is one of the key (or fundamental) root causes posing a threat to marine resources in coastal areas of the WIO region because of the increase in demand for goods, services and means of livelihood. The associated rapid urbanisation with changes in lifestyles characterised by high consumption rates, results in increased generation of waste. All of the countries in the WIO region have experienced rapid population growth and urbanisation in coastal areas, particularly within the larger coastal centres. More details on the demographic characteristics in the region are provided in Chapter 3.
- *Poverty and inequality* - The WIO region is characterised by some of the highest poverty levels in the world, as evidenced in the estimated per capita income in the different countries (see Table 3.1). Consequently, a lack of adequate resources is one of the main reasons for insufficient or unsuitable sanitation and solid waste disposal facilities in many of the countries in the region.
- *Inappropriate governance* - Governance sets the stage within which management occurs (UNEP, 2006). Based on the assessment of governance of marine pollution in the WIO region (Chapter 5), it is clear that some of the important building blocks for effective

Table 4-3 An overview of direct causes and underlying sectors linked to transboundary marine pollution problems related to land-based activities.

TRANSBOUNDARY PROBLEM					DIRECT CAUSE	UNDERLYING SECTOR
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical Pollution		
X	X		X		Disposal of un- or under-treated municipal wastewater	Urbanisation, Tourism
X	X		X	X	Industries[a] discharging un- or under-treated wastewater	Industry
			X	X	Dredging activities	Transportation
X	X		X	X	Waste from coastal mining and exploration activities	Mining
X	X	X	X	X	Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)	Urbanisation, Tourism, Industry, Mining, Transportation, Agriculture
			X		Destruction of coastal forests contributing to high suspended solid loads	Forestry, Mining
X	X	X	X	X	River discharges transporting high suspended solid loads (as a result of soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchments	Agriculture. Urbanisation, Industry
	X			X	Leaking and leaching of agrochemical (fertilizers and pesticides) from inadequate storage facilities, dumping or return-flows	Agriculture
X	X				Runoff from livestock rearing areas	Agriculture
	X			X	Atmospheric emissions (e.g. incineration of waste, vehicle and industrial emissions and wood/coal burning)	Industry, Urbanisation, Tourism, Energy production
X		X		X	Inadequate collection, treatment and disposal of solid waste	Urbanisation, Tourism, Industry, Transportation
		X			Public littering on beaches and in areas where litter can be transported into coastal areas	Urbanisation, Tourism
	X		X		Waste products from aquaculture farms that are high in nutrients and suspended solid loads	Aquaculture

a. Including: sugar factories, fish and food processing industries, textile industries, tanneries, paper and pulp mills, chemical, pharmaceutical, cement and fertilizer factories.

governance are not in place in many of the countries, the level of inefficiency varying from one country to another.

- *Inadequate knowledge and awareness* - Empowerment of people in society is considered a key factor in the alleviation of poverty (another root cause), allowing them to play an active role in effective governance and management of natural resources (including marine resources). Knowledge is a key pillar for empowerment of people. However, within the countries of the WIO region many do not have access to appropriate knowledge on matter such as:
- Environmental impacts and socio-economic consequences of human activities that, in many instances, are affecting people's quality of life.
- Technologies to prevent or minimize the impact on the environment and the goods and services that are provided, for example technologies for municipal wastewater treatment, solid waste treatment and disposal, and appropriate agriculture.
- Existing policies and institutional structures that provide (often legally) enforceable ways of preventing or mitigating impacts on the environment and socio-economic well-being of people.
- *Inadequate financial resources* - Lack of financial resources, both to implement and enforce appropriate technologies and practices to prevent or minimise environmental impacts and/or socio-economic consequences of human activities in the marine environment are a concern in many countries in the WIO region. Furthermore, the lack of commitment by politicians in many instances, to address issues of environmental concern (including marine pollution) is reflected in the low priority given to such issues in the policies and budget allocations of countries in the region. The socio-economic consequences of such impacts are also not properly communicated to politicians – knowledge that could change such behaviour.

As may be concluded from Table 4-3, the **direct causes** of the priority transboundary marine pollution problems can roughly be attributed to eight key underlying sectors, namely:

- Urbanisation
- Tourism
- Agriculture
- Industry
- Mining
- Transportation (including harbours)
- Energy production
- Aquaculture

The direct causes (or activities) contributing to transboundary marine pollution problems related to the above-mentioned sectors are further explored in the following sections.

Urbanisation and Tourism

Of concern in the countries of the WIO region has been the rapid and often uncontrolled urbanization, including tourism developments, occurring in coastal areas. Associated with this growth in urbanisation is an increase in municipal wastewater, municipal solid waste and atmospheric emissions such as those from the combustion of fossil fuel and vehicular traffic. Many of these are often not properly managed or controlled; thereby contributing to several of the priority transboundary marine pollution problems seen in the region (see Table 4-3).

Municipal wastewater Untreated sewage from sanitary facilities (septic tanks, pit latrines and malfunctioning wastewater treatment plants) is a major source of marine water quality degradation in many of the countries in the WIO region (Anon. Mauritius, 2009, Mong *et al.* 2009, Anon Mozambique 2007, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Antoine *et al.* 2008, Weerts *et al.*, 2009). Available information on municipal wastewater loads in coastal areas in the WIO region varies from one country to another, with some countries having detailed information on waste loads, others with very limited, often only qualitative information; the level of treatment of municipal (or domestic) wastewater, as well as the type of treatment (or lack thereof) also differs from one country to another (Maarouf, 2008; Mong, 2007; Montano, 2008; Mozambique Demographic and Health Survey, 2003; Mwaguni, 2008; Pybus, 2008; Radhay, 2007; Sangeu, 2008; UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a; WHO and UNICEF, 2000; WHO, 2003) (see Table 4-4).

Table 4-4 Indication of level of treatment of municipal (or domestic) wastewater in different countries of the WIO region

	Central sewer systems	Septic tanks & soak-aways	Pit latrines	Other (e.g. dry and chemical toilets)	None
Comoros	0.3%	5.3%	94.4%		-
Kenya	11%	17%	72%		-
Madagascar	-	11%	70%		19%
Mauritius	25%	73%	2%		
Mozambique	5.4%	24.6%	70%		-
Seychelles	7.5%	86.9%	3.9%		1.7%
South Africa[a]	47%	4%	18%	14.5%	16.5%
Tanzania	2.2%	9.8%	80.9%	0.1%	7.0%

Source: Maarouf, 2008; Mong, 2007; Montano, 2008; Mozambique Demographic and Health Survey, 2003; Mwaguni, 2008; Pybus, 2008; Radhay, 2007; Sangeu, 2008; UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a; WHO and UNICEF, 2000; WHO, 2003

a. Western Indian Ocean region, i.e. Provinces of Eastern Cape and KwaZulu-Natal (population of 25 coastal municipalities)

Available data on estimated volumes and loads of selected pollutants associated with municipal wastewater in coastal areas of the WIO region are provided in Table 4-5 and Table 4-6, respectively.

To varying levels, municipal wastewater is disposed of directly to the marine environment or enters the sea through seepage or via rivers in all of the countries of the WIO region. Microbial contaminants, nutrients and suspended solids are the main pollutants in untreated municipal wastewater. Highest concentrations of these pollutants are found close to the major cities. However, in many rural areas of the coast low-level sewage contamination from defecation on beaches or in coastal bush is common.

Table 4-5 Estimated volumes of municipal wastewater generated in coastal areas of the WIO region (i.e. potentially entering the coastal zone).

Country	Estimated wastewater generation (m^3/day)
Comoros	168
Kenya	145,500
Madagascar	176,000
Mauritius	100,000
Mozambique	29,149
Seychelles	4,922 (10,372[a])
South Africa[b]	255,000 (offshore, preliminary treatment) 46,300 (surf zone, secondary treatment) 31,500 (estuaries, secondary treatment)
Tanzania	37,912

Source: UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a.
a. Volume of wastewater to be collected and treated after planned extension of systems
b. Western Indian Ocean region, i.e. Provinces of Eastern Cape and KwaZulu-Natal (RSA DWAF 2004a,b&c)

Table 4-6 Estimated loads of organic material (BOD), suspended solids and nutrients generated from municipal wastewater in coastal areas of the WIO region

Country	Estimated load (tonnes/year)[a]			
	BOD	Suspended solids	Nitrogen	Phosphorous
Comoros	489	1,063	212	26
Kenya	2,744	3,889	802	97
Madagascar	2,962	6,869	1,417	172
Mauritius	598	1,388	286	35
Mozambique	1,137	1,203	108	26
Seychelles	541	1,254	259	31
South Africa[b]	39,502	30,478	4,518	2,259
Tanzania	21,741	50,413	10,398	1,260
Total	69,714	96,557	18,000	3,906

Source: UNEP/Nairobi Convention Secretariat *et al.*, 2009b

From the above analysis, it may be concluded that the highest pollutant loads entering the WIO originate from the mainland states as well as Madagascar, with South Africa and Tanzania far upfront. This finding is obviously not very surprising, considering the size of the coastal cities in these countries. However, in the case of South Africa, about 74% of the municipal wastewater is discharged to the offshore marine environment (Table 4-5) through properly designed marine outfalls where the quantity and composition of the effluent must be within limits that meet site-specific environmental quality objectives (RSA DWAF, 2004). In terms of wastewater volumes, countries having a more sophisticated system of sewerage management obviously generate and discharge relatively more wastewater than those whose pollution is mainly served by offline systems (pit latrines, septic tanks and soak-away pits). The example in this case is Mauritius, which generates equal or more wastewater than most (much larger) mainland states, although the pollution (BOD, N, P and SS) loads are much lower.

Solid waste disposal Information and data on the quantities of solid waste disposed in coastal areas of the WIO region varies considerably from country to country (UNEP and WIOMSA, 2008). At one extreme, South Africa has been publishing the results of research into marine litter for over two decades and there is information on the abundance, distribution and trends of different types of litter found around the coast. The sources of the litter are inferred rather than demonstrated, but it is obvious that most of it originates from littering and inappropriate waste disposal on land. Seychelles also has a good waste management system in place and has established that it contributes almost no marine litter. Mauritius falls into a similar category of wealth, governance and the ability to contain wastes. Mozambique, despite its poverty and inadequate governance, knows that it similarly contributes very little to the marine litter load. This is because it has a very poor transport infrastructure and the vast majority (about 70%) of the population live in rural poverty with limited access to products with plastic packaging. Additionally, informal 'recycling' of most salvageable products is commonplace. These factors have kept solid waste loads that may contribute to marine litter under control thus far but this situation may change (UNEP and WIOMSA, 2008).

At the other extreme, in Tanzania, Madagascar and Kenya, there is relatively little information on the quantities, types and characteristics of solid waste that contribute to marine litter, except that large quantities of litter from urban areas do reach the sea. The main reason for the littering is that none of these countries has an adequate solid waste management system (UNEP and WIOMSA, 2008).

However, a feature common to all countries is that most land-based sources of solid waste are associated with urban centres, particularly informal settlements and industrial/commercial areas, and that wastewater run-off is the main distributor - via rivers, streams and storm-water drains. According to UNEP and WIOMSA (2008), the major land-based sources of marine litter were found to be:

- Solid waste dump sites (legal and illegal) located on the coast or on rivers banks;
- Surface water runoff (from storm-water drains, untreated municipal wastewater);
- River discharge and flood water;
- Industrial wastewater discharges; and,
- Public litter on beaches and other coastal areas.

The major sources of solid waste contributing to marine litter in each of the countries of the WIO region are summarised by UNEP and WIOMSA (2008), and presented in Table 4-7.

Atmospheric emissions Activities linked to urbanization, tourism and subsistence agriculture that contribute to marine pollution through atmospheric emissions include:

- Fossil fuel fires - a large majority of coastal communities in the WIO region use fossil fuel for their domestic energy needs (therefore also linked to the energy production sector).
- Traffic emissions - motor vehicles emissions can contribute significantly to atmospheric pollution.
- Forest burning for land clearing – urban development adds pressure on land for growth.

Table 4-7 Summary of major sources of marine litter in the countries of the WIO region (Source: UNEP and WIOMSA, 2008, unless otherwise indicated).

Country	Major source
Comoros	Of particular concern is waste from hospitals, including compresses, syringes, braiding, packaging, plastic, glass and human waste discharged in open dumpsites, usually in the vicinity of the hospitals (Abdallah et al., 2006).
Kenya	The major sources of marine litter are reported to be beach recreation (66%), shipping (14%), dumping and surface run-off from urban areas.
Madagascar	The major sources are dumping on the beach and surface run-off from urban/industrial areas (including medical and household wastes) and other areas with crude land dumping practices. There are also reported to be numerous shipwrecks that contribute substantially to marine litter, occurring particularly during the annual cyclone period.
Mauritius	Marine litter arises chiefly from beach recreation, surface run-off from urban areas and from rivers. The volume of ship-generated garbage is far smaller than land-generated volumes.
Mozambique	Beach users, garbage from shipping, fishing gear, road users and urban storm-water runoff are the major sources of litter.
Seychelles	Most litter is from water run-off from rivers and storm drains, despite daily cleaning, from port wastes and particularly from public eating spots or picnic areas. Data are not available for litter generated by the fishing industry.
South Africa	The major source of marine litter is surface run-off from urban areas (via rivers and storm drains), confirmed by (a) litter deposition being greatest in the rainy season (winter in the Cape) and higher levels close to urban areas; and (b) the high proportion of South African-made articles (96%) in stranded litter. Commercial, industrial and low-income residential areas produce most litter. Ship-generated waste in South Africa is minor compared to land-based litter sources. Some litter comes across the South Atlantic in the West Wind Drift from Argentina, Uruguay and Brazil. Marine litter on uninhabited oceanic islands derives from local and foreign fisheries, and distant continents.
Tanzania	The major source of marine litter arises from uncontrolled disposal of solid wastes in unplanned settlements where, for example, about 70% of Dar es Salaam's population live. Most litter is from surface run-off, illegal dumping into river valleys and drainage from crude, open dump sites located near the beach and rivers. Marine litter also arises from fishing and shipping, as the important economic city of Dar es Salaam has a moderate-sized port and fishing is a major activity amongst the coastal communities. The latter are presumed to contribute a significant quantity of gear, boats, traps, and plastic bottles to marine litter.

Atmospheric pollutants can also originate from solid waste dump sites and burning of waste. Rotting processes can cause serious odour problems and methane gas emissions, while burning of wastes generates thick smoke which is not only aesthetically unpleasant, but also contains other pollutants, such as particulate matter and gases from burning plastics.

Data on atmospheric emissions (e.g. suspended solids, nitrogen, trace metals and hydrocarbons), particularly those which contribute to marine pollution, are lacking for the entire WIO region. In Mauritius, South Africa and Tanzania, atmospheric emissions are being monitored in some of the coastal centres (see Weerts et al., 2009; Mohammed *Et al.*, 2008; Anon Mauritius, 2009), but fail to provide insights into the actual loads being deposited in the marine environment.

Agriculture and Forestry

Agriculture is the backbone of the economy in most countries in the WIO region and is central to the alleviation of poverty and revenue generation. Agricultural activities contribute mainly to marine pollution insofar as practices produce elevated levels of four types of pollutant, namely suspended solids (the result of erosion due to inappropriate land use practices), inorganic nutrients (excessive use of fertilizers), pesticides (persistent organic pollutants) and microbial contaminants (typically associated with runoff from livestock rearing areas). Slash and burn clearing for subsistence agriculture adds to the atmospheric pollution in some countries. Pollutants from agricultural activities usually enter the marine environment through river discharges, although agricultural activities adjacent to coastal areas can directly contaminate coastal waters through surface or sub-surface runoff.

As reported by UNEP (1998b), the physical effects of soil erosion in river basins and the subsequent impacts related to suspended solid loading and siltation in coastal systems are currently of greater concern than agrochemical pollution in most countries throughout the region. Impacts from soil erosion are especially notable along the coasts of Kenya and Madagascar.

Agricultural activities in the countries of the WIO region are increasing and are becoming more industrialised. With this come the risk of increased soil erosion and the use of agro-chemicals. Even without substantial scientific evidence of existing impacts, it can be expected that marine pollution associated with agricultural activities (e.g. high suspend solid, nutrient and persistent organic pollutant loads) may well increase in coming years, unless appropriate and environmentally-sustainable agricultural practices are promoted within the large river basins discharging into the WIO region, employing the following precautionary approach.

The destruction of coastal forests also contributes to high suspend solid loading in coastal areas.

Industry

Major industries and mining activities situated within coastal areas of the WIO region include:

- Manufacturing industries
- Textile industries
- Tanneries
- Paper and pulp mills
- Breweries
- Chemical factories
- Cement factories
- Sugar refineries
- Food processing industries (e.g. fish factories and slaughter houses)
- Fertilizer factories
- Oil refineries
- Heavy mineral sands mining
- Oil and gas exploration (a highly significant emerging activity).

These industries and mining activities do, or potentially can, contribute to transboundary marine pollution problems through inappropriate disposal of liquid wastewater, solid waste or atmospheric emissions. An overview of the industries and mining activities and their potential contribution to transboundary marine pollution problems is presented in Table 4-8.

Table 4-8 Overview of key industries and their potential contribution to transboundary marine pollution problems in the WIO region.

Industry type	Transboundary problem				
	Microbial contaminants	Eutrophication (nutrients)	Marine Litter (solid waste)	Suspended solids	Chemical pollution
Manufacturing			X		X
Textile		X		X	X
Sisal		X	X	X	
Tanneries		X	X	X	X
Paper and pulp		X	X	X	
Breweries		X	X	X	
Chemicala		X		X	X
Cement			X	X	
Sugar production		X	X	X	X
Food processing (including fish)	X	X	X	X	
Fertilizer		X		X	X
Oil refinery				X	X
Oil and gas exploration				X	X

a. including production of agrochemicals and pharmaceuticals

In the Comoros, processing industries associated with agricultural and livestock production (including food processing) account for 85% (14.41 tonnes per annum) and 92% of the BOD and suspended solid load, respectively (Abdullah *et al.*, 2006). However, the loads of BOD, suspended solids and solid waste produced by such industries are considered to be small in comparison to domestic waste loads.

In the coastal areas of Kenya, most industrial activity is situated in and around the Mombasa, Kilifi and Lamu districts. Very few industries treat their wastewater which is discharged either to municipal sewers or storm-water drains. Due to the proximity of the industrial areas to the natural drainage systems, most of the pollution effluent generated on Mombasa Island and the surrounding mainland shores ends up in the estuarine creeks around Mombasa. The solid wastes from industries are of unknown composition and quantity, but likely to include hazardous components (Mwaguni and Munga, 1997). The petroleum refinery at Changamwe produces considerable hazardous sludge (containing toxic substances such as hydrocarbons and heavy metals) which is dispersed on agricultural land within the refinery grounds. Large quantities of solid waste are produced by cashew nut and sisal processing factories, producing about 15,330 and 8,400 tonnes/year respectively. The sisal processing industry also discharges considerable quantities of liquid waste directly into the sea, thereby introducing a significant BOD load.

Most industrial activities in Madagascar are situated in coastal urban centres, mainly near the ports of Antsiranana, Ambilbe, Mahajanga, Tolagnaro and Toamasina, with the exception of the textile industry, which is primarily located inland at Antananarivo. The industrial activities are focused on seafood processing, sugar extraction, oil and soap production, breweries, tanneries and sisal production (Mong *et al.* 2009). The majority of these industries do not treat their waste; however, where there is some treatment, it is limited to coagulation and decanting, or only decanting prior to discharge into a treatment system or directly into the sea (Mong *et al.* 2009;

UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a). By comparison with municipal waste, the pollution load from industry is considered to be relatively small.

In Mauritius, about 10 million cubic metres of industrial wastewater are produced annually, of which most is discharged to treatment plants (Anon Mauritius, 2009), from industries that include sugar production (the largest contributor to industrial wastewater), textiles (e.g. dye houses), breweries and food processing plants. Plaine Lauzun, Vacoas-Phoenix and Coromandel are the main industrial zones in Mauritius. The Coromandel industrial zone, comprising mostly dye houses and soap and food processing industries, directs wastewater to Mt Jaquot Wastewater Treatment Plant prior to discharge through a 600m long marine outfall into Pointe aux Sables lagoon. Industries in Plaine Lauzun and Vacoas-Phoenix discharge wastewater directly to the St Martin wastewater treatment plant. Other major Wastewater Treatment Plants are located at Grand Baie and Baie du Tombeau. The estimated pollution load from the 31 major industries located in Mauritius introduces 1,117 tonnes of BOD, 17 tonnes of nitrogen, 81 tonnes of total phosphorous and 2,306 tonnes of suspended solids to the marine environment annually (Source: Wastewater Management Authority, 2007).

Most industrial facilities in Mozambique are located in the coastal urban centres of Maputo, Matola and Beira and include textile, paper and tyre factories as well as a brewery. Most of these industries discharge untreated wastewater into the Infulene River that drains into Maputo Bay (Anon Mozambique, 2006). The total number of industrial units listed for Maputo has increased from 11 in 1982, to 29 in 1992 and 137 in 1996. These industries produced a total of 79,388 tonnes of BOD in 1996, including an unknown quantity of waste containing heavy metals such as mercury, lead, chromium, manganese, nickel and zinc (Anon Mozambique, 2006).

Major industries in the Seychelles known to be sources of marine pollution are the food processing and chemical industries. Estimates of BOD loads introduced to the coastal water environment by industrial activities indicate that the food processing industries (agriculture and livestock products) account for 71.6 % and 88.7 % of the BOD and suspended solid loads, respectively (Radegonde, 1997). Other major contributions are from the fish processing and canning industries (also food processing), which account for 17.7% and 6.7% of the BOD and suspended solid loads respectively. The brewing industry is reported to contribute 18% to the total BOD load. In Seychelles, industrial waste accounts for only 17.5% of the total BOD load discharged into the environment, with 72% derived from storm-water runoff and municipal wastewater. Fifty six percent of the suspended solid load was reported to be derived from industrial waste, with the remainder being derived from municipal sources.

In South Africa, industrial wastewater disposed to the WIO region occurs mainly in the larger urban centres along the east coast (e.g. Port Elizabeth, East London, Durban and Richards Bay) where an estimated 308,100 m^3/day of industrial wastewater is discharged to the sea. Most of this effluent, however, is discharged to the offshore environment through properly designed marine outfalls that are subject to regular environmental monitoring and assessment studies (RSA DWAF, 2004; Taljaard *et al.*, 2006).

Although the level of industrialisation in Tanzania is considered to be relatively low, disposal of untreated industrial waste is causing localised pollution. About 80% of the industries in Tanzania, including food processing industries (also referred to as agro-industries), chemical factories, breweries, soap and steel manufacturing plants, are located in the coastal city of Dar es Salaam where most of the industries discharge their wastewater into the Msimbazi and Mzinga creeks (Mgana and Mahongo, 1997 & 2002). Industrial wastewater discharge contributes an estimated 2,715 tonnes/year of BOD and 15,454 tonnes/year suspended solids to the marine environment. This is equivalent to 19% and 55% of the total BOD and suspended solid loads for the city, respectively. Breweries account for most of the BOD and suspended solids, while nutrient loads (nitrogen and phosphorus) originate mainly from slaughter houses.

About 43% of the major industries considered in Dar es Salaam emit atmospheric pollution. Among these, the cement industry (at Wazo Hill) is the principal atmospheric polluter, emitting approximately 2,831 tonnes of air-borne particulate material per year. If Wazo Hill is a representative model, the same levels of pollution may be expected from the cement factories located elsewhere in the region, e.g. Maputo, Bamburi (Mombasa) and Kaloleni (Kilifi).

In Zanzibar, industrial activities are mainly concentrated in the Saateni, Maruhubi and Mtoni areas and include mainly food processing (slaughter houses, dairy products and beverages) and chemical (soap production) industries, generating between 15 and 16 tonnes respectively of BOD and suspended solid loads per year.

Mining

Coastal mining in the WIO is an important but in places a highly destructive activity. Included are the extensive mining activities for heavy metals in the immediate coastal belt and at times subtidally. Such operations occur in KwaZulu-Natal, Madagascar and at other sites with prospecting currently underway in other regions. Besides destruction of coastal habitats (some of which will take decades to recover), changes to the water table and the high demand for fresh water needed to process the metals poses problems, notwithstanding the potential financial benefits. Other mining includes the extraction and subsequent baking of coral rock for construction purposes. These activities contribute to the deterioration in water and sediment quality through the disposal of solid waste, suspended solids and chemical pollution. No quantitative information on the contribution of these activities to marine pollution is available for the region.

Transportation

Almost all of the large urban centres within the WIO region support large commercial ports and harbours (Figure 1-1). Activities within harbours contribute significantly to transboundary marine pollution, including activities in dry docks, the disposal of garbage and dredging. Furthermore, industrial zones are often located in close proximity to the major ports and harbours. Issues that have been listed for ports and harbours in different countries are highlighted in Table 4-9.

Energy production

In general, energy production can influence marine water quality mainly through thermal discharges of cooling water and atmospheric emissions from combustion of oil, gas or coal by power generation installations. Other atmospheric emissions may be associated with burning of fossil fuels (e.g. wood, charcoal and paraffin) for domestic heating and cooking. Pollutant loads from these activities have not been properly quantified for the WIO region and further investigation is needed before conclusive statements can be made in terms of their contribution to marine pollution.

Aquaculture

Although the WIO may well have potential for aquaculture, these activities are currently limited to modest farming of shrimp and seaweeds in countries like Seychelles, Madagascar, Mozambique and Tanzania (WIOMSA, 2007). However, although aquaculture is still poorly developed in the region, it is an emerging sector that could have deleterious effects on coastal water quality, in terms of organic/nutrient pollution from uneaten feed or waste products (e.g. faeces), cleaning fluids and antibiotics in the feeds and suspended solids from cleaning of ponds. Large mariculture projects often also cause substantial physical damage if they are located in sensitive habitats such as estuarine wetlands.

Table 4-9 Major ports in the countries of the WIO region and associated marine pollution issues.

Country	Port/harbour	Major issues
Comoros	Mutsamudu	Located near a river and is becoming shallower as a result of continued sedimentation, reducing its capacity to accommodate larger ships and vessels (Abdullah *et al.*, 2006).
Kenya	Kilindini (Mombasa)	The port area is subjected to environmental perturbation due to shipping and other marine and land-based activities. Periodic dredging in the port and approach channels for maintenance and expansion of facilities re-suspends considerable quantities of particulate material and associated pollutants (e.g. nutrients, heavy metals, persistent organic pollutants, etc.) (Munga *et al.*, 2007).
Madagascar	Numerous ports, e.g. Antisranana, Mahajanga, Toamasina and Toliara	According to Mong *et al.* (2009), marine pollution linked to harbours is derived from: • Spillage of pollutants (e.g. chemical products and oil) during loading and offloading; • Lack of facilities to handle garbage, oil residues and wastewater from vessels; and, • Lack of facilities and infrastructure to remove wrecks.
Mauritius	Port Louis	Dredging is undertaken on an ad hoc basis for maintenance of existing channels as well as for port development (Anon Mauritius, 2009).
Mozambique	Maputo, Beira and Nacala and the smaller ports of Inhambane, Quelimane, Pebane, Angoche and Pemba	No specific issues have been listed, but major issues are most likely associated with dredging and spills. Waste management in all Mozambique harbour is a major issue with solid waste entering the port through streams and surface runoffs during rainy seasons. (Anon Mozambique, 2006).
Seychelles	Port Victoria	Dredging, land-reclamation, urban waste via rivers and waste from fishing vessels, food processing plants, including the tuna cannery. (Antoine *et al.*, 2008).
South Africa	Durban, Richards Bay, Port Elizabeth, East London and Ngqura	All ports contribute to marine pollution through poor operational practices and dredging activities and new developments (Weerts *et al.*, 2009).
Tanzania	Dar es Salaam, Tanga, Mtwara and Zanzibar	Heavy metals and organophosphates levels in sediments are of concern, while other issues are mostly associated with dredging operations and chemical spills. There are also waste management problems (Mohammed *et al.*, 2008).

From the above overview, it may be concluded that the main sectors contributing to the transboundary pollution problems in the WIO region are urbanisation, agriculture and industry, all having cross-cutting impacts. Added to this, aquaculture, tourism, mining, transportation and energy generation and consumption are associated with specific types of pollution.

4.2.2 Microbial contamination

Problem statement

Microbial contamination refers to the presence of pathogenic organisms of either human or animal origin in the aquatic environment (protozoa, bacteria and/or viruses) that can pose health risks to humans. In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater (including sewage), contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing and industrial effluents (mainly from food processing industries).

Transboundary elements

Although microbial contamination is often confined to a zone in the immediate vicinity of the wastewater source, this form of pollution is recognised as one of the main pollution problems for the WIO region (see Table 4-1). The fact that it is common to so many of the region's countries clearly makes it an issue of transboundary concern, even if the contamination is not directly transported across national boundaries. In particular, the impact on recreational bathing beaches and the consumption of locally harvested seafood present major water quality management challenges.

Root-cause analysis

The problem tree for microbial contamination in the WIO region, specifically linked to land-based activities, is presented in Figure 4-4. As indicated, the key sectors contributing to microbial contamination are urbanisation and tourism (e.g. municipalities and tourist developments responsible for municipal waste and wastewater disposal), agriculture (in particular livestock rearing), industry (specifically food processing) and transportation (referring to waste disposal facilities in harbours and ports).

Microbial contamination can have severe socio-economic consequences in coastal waters, such as:

- Human health risks associated with contact recreation or ingestion of contaminated seafood; and,
- Reduced quality of seafood products cultured or harvested in a particular area.

These consequences affect stakeholders across society, from local communities to international tourists, and industrial and aquaculture operations, all of which utilise the marine environment for recreation and the collection and culture of seafood.

Loss or potential loss of the recreational value of coastal waters, as reflected in unacceptable levels of faecal bacteria (typically used as indicators of microbial contamination), is evident throughout the coastal zone of the WIO region. Areas of concern are usually associated with larger urban centres where insufficiently treated or untreated waste and wastewater are some of the most important land-based sources of pollution. In many areas the situation may be exacerbated by unacceptable aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

Studies conducted around Taolagnaro (Madagascar) measured *E. coli* counts as high as 13,300 counts/100 ml in coastal waters, these high levels of faecal contamination being attributed to defecation on the beaches as well as inappropriate treatment of municipal wastewater (Mong *et al*. 2009); these included illness resulting from eating marine turtles (seven cases), sharks (eight cases), fish (one case) and molluscs (two cases), although the causal link to microbial contamination was not always clear. Recent (2007-2008) data collected for the purposes of the WIO-LaB water and sediment quality monitoring programme confirm that microbial pollution is an ongoing problem in some Madagascan coastal areas (Mong *et al*. 2009). High counts of enterococci and total coliforms were reported from Mahajanga and Nosy Be.

In Maputo Bay (Mozambique), microbial contamination has been recorded in shellfish, the bacteria *Vibrio parahaemolyticus* and *V. mimicus* being found in clams in the Incomati River mouth, in the bay adjacent to the Polana Hotel and near Matola in the Maputo Estuary. *Vibrio* spp. are the main cause of severe gastro-intestinal illnesses (Fernandes, 1996). High faecal coliform counts were also detected at several locations, including the area near the Infulene River mouth where values exceeded 2,400 counts/100 ml. Such high contamination results from inappropriate sewage treatment facilities - there is only one sewage treatment plant in Mozambique, located in Maputo City, which treats only about 50% of the city's sewage. Areas near the entrance of the Maputo Estuary (Miramar) are not considered safe for swimming. Faecal contamination has also been recorded in Beira Bay and Nacala Bay, although levels were lower than those recorded for Maputo Bay (Fernandes, 1995).

Along the coast of Mauritius, total and faecal coliforms are monitored on a monthly basis at eleven selected public beaches, namely Flic en Flac, Albion, Pointe aux Sables, Trou aux Biches, Mon Choisy, Le Goulet, Grand Baie and Blue Bay. The Ministry of Fisheries reported in 2004 that most of the stations were within the recommended water quality guidelines for contact recreation in Mauritius (counts of total coliform < 1,000 per 100 ml and faecal coliform < 200 per 100 ml), except some areas in Pointe aux Sables (near Port Louis) where levels exceeded the recommended guidelines (Dulymamode *et al.*, 2006), as confirmed also through the WIO-LaB monitoring programme (Anon. Mauritius, 2009).

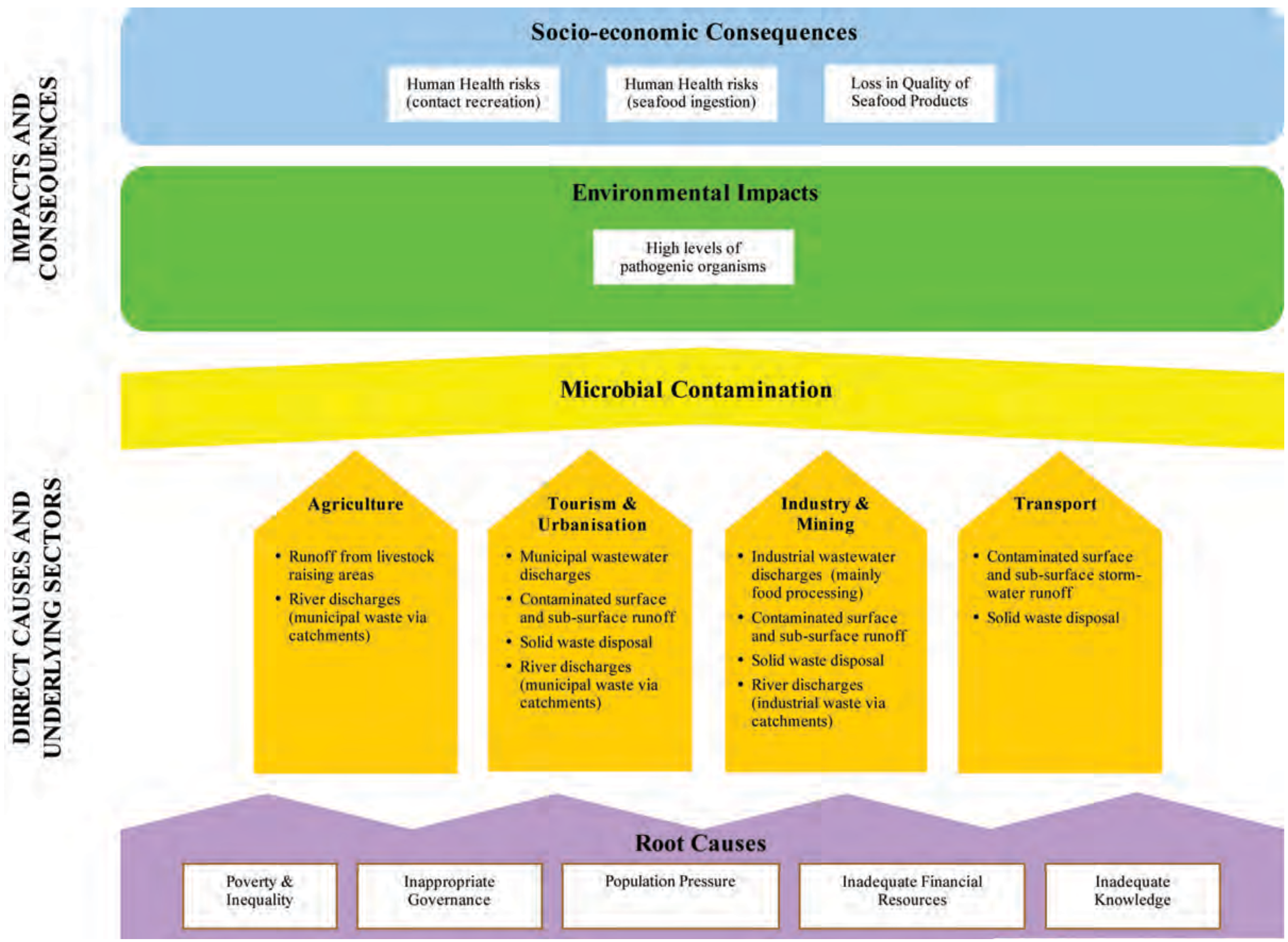
Studies conducted in Mombasa (Kenya) showed that microbial pollution levels in urban aquatic environments were several orders of magnitude higher than in rural aquatic environments (Mwanguni, 2002). Over 50% of all reported diseases in Kenya have been attributed to poor water quality associated with inadequate wastewater management, although no distinction can be made between effects from drinking water and coastal recreational (Mwanguni 2002). During the WIO-LaB monitoring programme, the highest levels of microbial contamination were recorded in the Kilindini/Port Reitz creek area and, to a lesser extent, the Sabaki estuary/Malindi Bay complex, compared with Funzi Bay.

In the Seychelles, effluent from wastewater treatment plants discharged directly into the ocean was found to contain total coliform counts between 2,000 and 5,000 per 100 ml, far above the stipulated standards of 500 per 100 ml (Antoine *et al.*, 2008). High microbial counts were recorded at Beau Vallon Bay during the rainy season, during the WIO-LaB monitoring programme; these were mostly associated with runoff from non-point sources such as rivers and small streams (Antoine et al. 2008). In Seychelles outbreaks of water and insect borne diseases usually occur during the rainy season and are mainly associated with defective on-site wastewater disposal systems.

Since about 1985, the design of offshore sewage outfalls in South Africa has followed the receiving water quality objectives approach where effluent quantities and composition must be within limits that meet site-specific Environmental Quality Objectives, as recommended in the South African Water Quality Guidelines for Coastal Marine Waters. Generally, long-term environmental monitoring programmes at these outfalls have indicated no detrimental impact on the marine environment or its beneficial uses (in terms of chemical and microbiological contamination). However, of greater concern is the rapid increase in discharges to less dynamic and sensitive areas such as surf zones and estuaries, where effluents from malfunctioning or overloaded treatment facilities are adversely affecting the marine environment and its beneficial use, albeit in a localised manner (RSA DWAF 2004a,b,c).

In Cape Town (South Africa) an extensive monitoring programme for microbiological contamination (using E. coli as an indicator organism) is conducted by the local municipality. In 2005 approximately 80% of stations sampled complied with the recommended South African water quality guidelines for contact recreation. Stations that did not comply (i.e. E. coli exceeded 200 counts/100ml in 80% of samples and 2000 counst/100 ml in 95% of samples) were in highly developed and urbanised sections of the coastline.

Figure 4-4 Problem tree: Microbial Contamination.



In Tanzania, the WIO-LaB monitoring programme conducted in 2007 showed contamination of waters around Dar es Salaam as well as Stone Town (Mohammed *et al.*, 2008). In Zanzibar (Tanzania), high total and faecal coliform levels have been reported, prompting health concerns and warning of health risks to swimmers in certain coastal areas, e.g. Stone Town. Similarly, some beaches in Dar es Salaam (e.g. Ocean Road and Banda beaches) have also been closed for swimming and other recreational activities due to microbial contamination (Mohammed *et al.*, 2008)

Risks/uncertainties and trends

Although the risks to human health associated with microbial contamination of coastal water are not always clearly documented, it was noted that, for example over 50% of all reported diseases in Kenya were related in one way or another to poor water quality associated with inadequate wastewater management [7], although no distinction was made between drinking water and coastal recreational–, (Mwanguni, 2002). Taking some of the root causes of microbial contamination into account, in particular *population pressure* and *poverty and inequality*, it is likely that this problem will intensify in future, posing even greater socio-economic risks to society, unless those responsible intervene in the different sectors that contribute to this problem.

4.2.3 High Suspended Solid /Sediment Loads

Problem statement

High concentrations of suspended solids enter WIO coastal waters from land-based sources, mainly in municipal and industrial wastewater discharges, river discharges and surface runoff, particularly during rainy seasons. Dredging activities, usually associated with ports and harbours, can also significantly contribute to this problem.

Transboundary elements

The transboundary element is based on the problem being common to most of the WIO countries, rather than interlinked (see Table 4-1). However, taking into account the ocean circulation patterns in the area (Figure 2-4); true transboundary impacts cannot be excluded, particularly where large discharges from rivers are concerned. Also, high levels of suspended solids tend to affect nearshore habitats, such as coral reefs and estuaries, which are important nursery and reproduction sites for a variety of species, resulting in a secondary transboundary impact.

Root-cause analysis

The key sectors contributing to high suspended solid loading in the marine environment are agriculture (linked to soil erosion in river basins/catchments), industry (particularly those discharging effluents containing high suspended solid loads/sediments) and transportation (primarily linked to dredging activities). The urban sector (e.g. local municipalities) also contributes through inappropriate disposal of municipal waste, while aquaculture farms may contribute to the problem through the disposal of waste containing high loads of suspended solids. These factors are depicted in the problem tree shown in Figure 4-5.

7 In the literature consulted here, many sources reported that human diseases in coastal areas were mainly water-borne diseases associated with poor water quality. These include diseases such as dysentery, cholera and diarrhoea. However, the literature seldom distinguishes between the exact sources, i.e. whether these are as a result of ingesting contaminated drinking (fresh) water or associated with contaminated coastal water (e.g. used for contact recreation). The former is probably the most dominant source of these water-borne diseases, although contaminated recreational water certainly contributes to the problem.

Key environmental impacts linked to high suspended solid loads are:

- Smothering of benthic communities
- Suffocation of marine organisms and loss of productivity through reduced light penetration
- Mortality (acute effects) of marine biota
- Chronic and acute effects on marine biota
- Modification of marine biota species composition
- Discolouration of coastal waters.

Consequences associated with the problem affect stakeholders across society, from local communities to large international tourism concerns. The social and economic consequences of increased suspension of solids in coastal waters include:

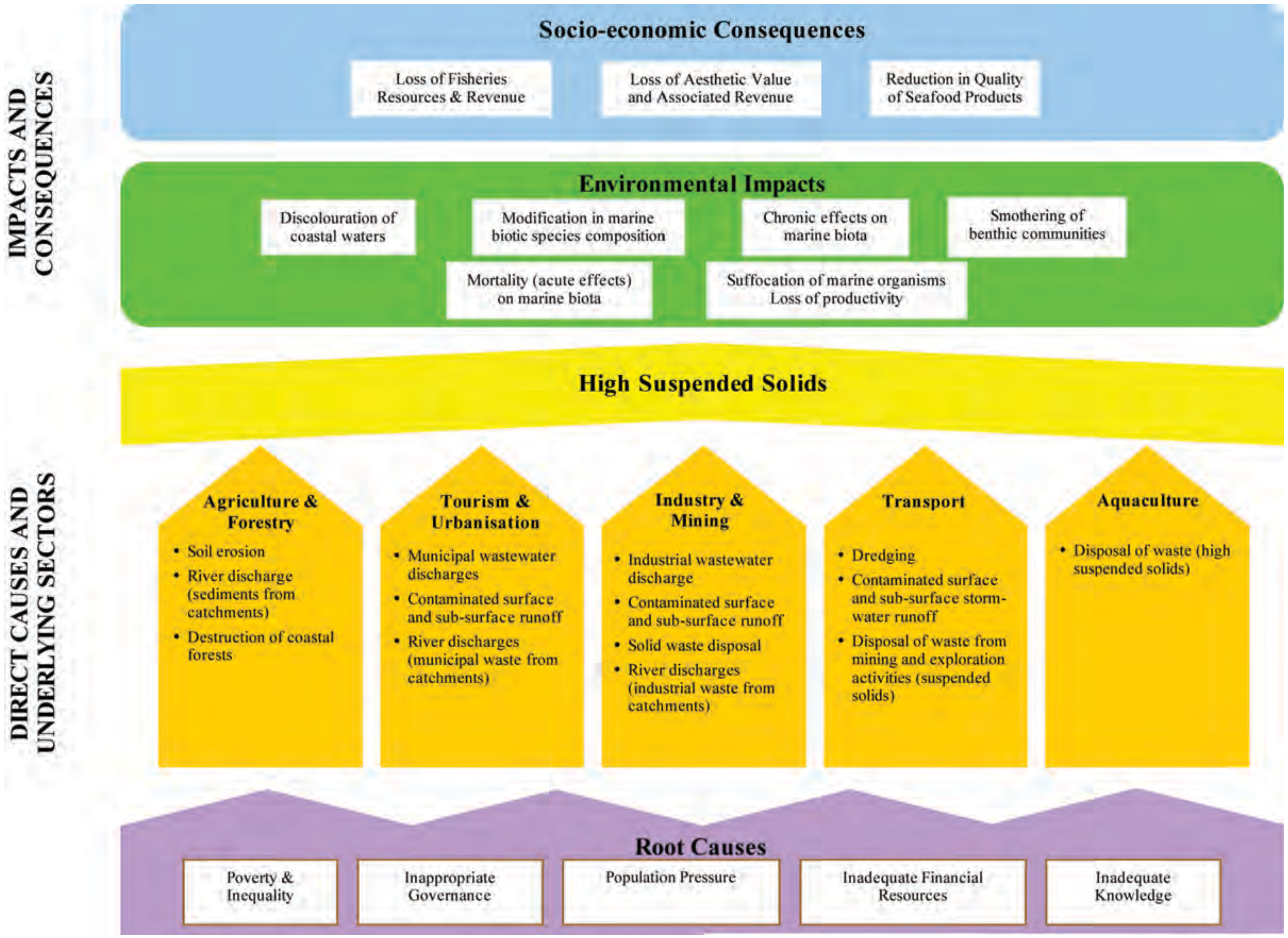
- Loss of aesthetic value
- Loss of commercial and/or artisanal fisheries resources and revenue
- Reduction in quality of seafood products.

Aquaculture and agro-processing industries are also affected.

Impacts associated with sediment loading have been recorded in the WIO region. For example, in Kenya, sediment loading has been found to affect the coral reefs in the Malindi National Marine Park and Reserve (McClanahan and Obura, 1997; Kazungu *et al.*, 2002; , Kitheka *et al.* 2003a). A decrease in the number of some local seagrass species has also been reported in Malindi Bay. In 1972, four endemic species were recorded at Mambrui in Malindi Bay, but in 1992 only two species remained (Wakibia, 1995). Coincidentally, the decrease occurred in an area experiencing heavy siltation. There is also concern that the loss of seagrass beds, due to sediment loading, may have negative impacts on fisheries, as these are important habitats for numerous fish species (Kazungu *et al.*, 2002). Finally, discoloration of coral reef waters impairs their productivity and results in a reduction in their aesthetic value, rendering them less attractive for tourism.

Sediment deposition and beach accretion, such as in Malindi Bay, has resulted in some hotel and resort developments ending up further from the seashore than originally planned with possible loss of tourism revenue, further manifested in loss of employment (Kazungu *et al.*, 2002). The port of Mombasa (Kenya) also requires regular dredging of the navigational channel to maintain the depth required for shipping activities. The associated costs of dredging are another socio-economic consequence of the impacts of high levels of suspended solids on the Kenyan coastal waters (Kazungu *et al.*, 2002).

Figure 4-5 Problem tree: High suspended solids.



In Mauritius, increased sedimentation and suspended solids (increased turbidity) have been reported in the lagoon at Rodrigues and in Grand Baie, respectively, resulting in the modification of ecosystems (Resource Analysis-EDC, 1999). In Grand Baie, the increased suspended sediment load was mainly associated with household wastewater discharges, while in Rodriques it results mostly from soil erosion originating from agricultural pastures in the highlands. Here, some of the bays are completely silted and channels have had to be constructed to facilitate the movement of boats. Sedimentation has also damaged coral ecosystem by smothering, thereby affecting artisanal fishing (Anon. Mauritius, 2009).

In Mozambique, poor land-use, including deforestation of the coast and hinterland areas, are the main contributors to sedimentation in the coastal environment. As a result, more frequent dredging of the Maputo and Beira harbours is needed. Past surveys have shown that between 1.2 x 10^6 m^3 and 2.5 x10^6 m^3 of sediments need to be dredged from the ports of Maputo and Beira annually (FAO, 1999).

In Seychelles, the main islands of Mahe, Praslin and La Digue have experienced higher sediment loads through discharge and reclamation projects, thereby contributing significantly about 10% to coral mortalities, together with other factors such as global warming (Jones *et al.*, 2002).

In Madagascar, with that countries enormous river systems and high seasonal sediment load, significant impacts have been recorded from mangrove areas, smothering the root systems of trees and causing die-back of some forests. Coral reef systems have also deteriorated as a result of localise higher suspended sediment loads (Mong *et al.*, 2009).

Risks/uncertainties and trends

With increasing agricultural activities in the countries of the WIO, so too does the risk of soil erosion due to inappropriate farming techniques and practices. Together with a projected increase in urbanisation (with its associated municipal waste) and industrial activities in the coastal zone, the problem of sedimentation is likely to intensify unless the sectors contributing to this problem implement mitigating measures, through better legislation and regulation, better land-use practices, education, advocacy and awareness.

4.2.4 Chemical Pollution

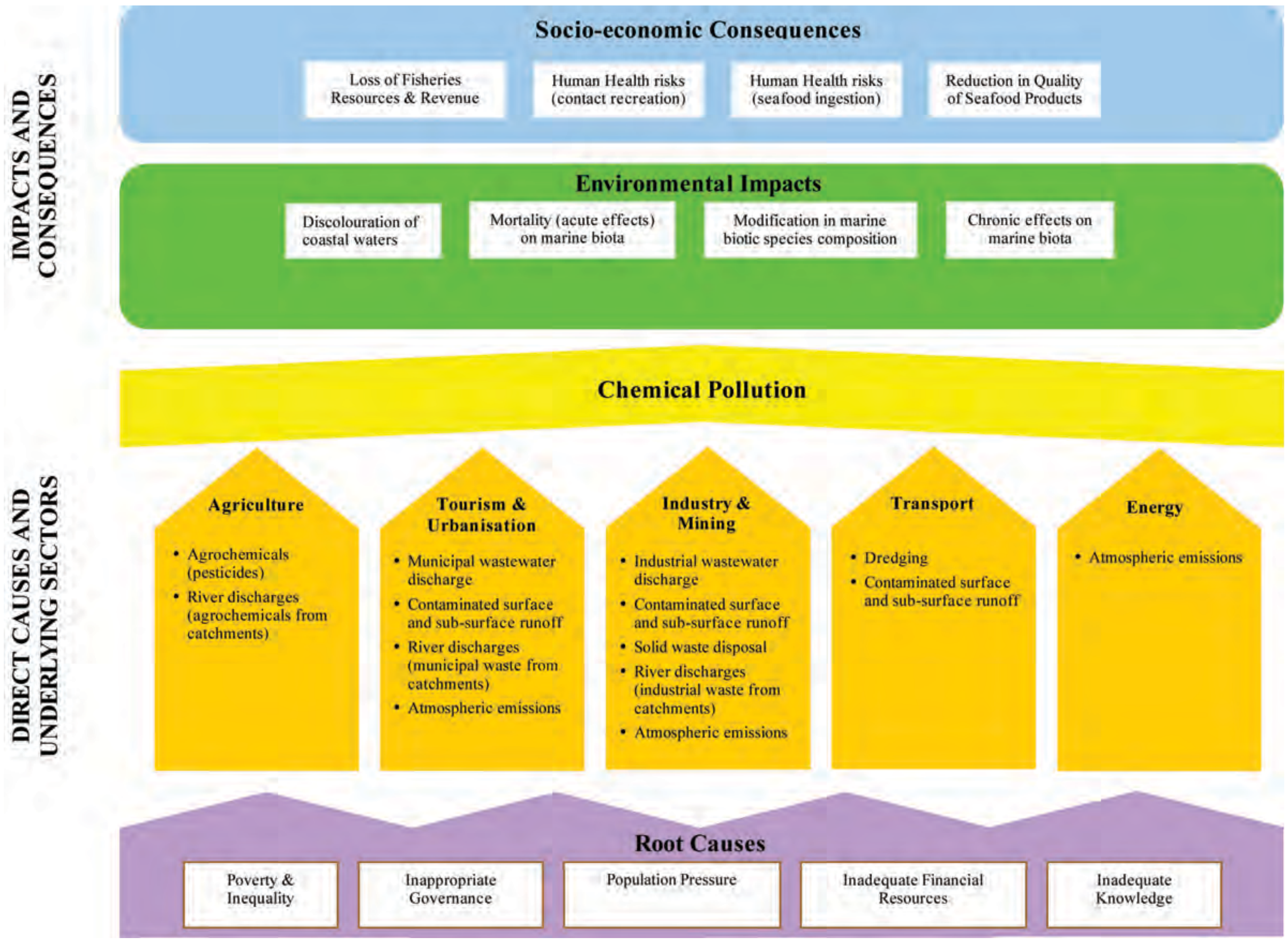
Problem statement

Chemical pollution refers to the adverse effects of chemical contaminants released in the coastal environment from land-based human activities. Chemical contaminants are here defined as compounds that are toxic, persistent and/or bio-accumulating. These can be grouped in three broad categories, namely heavy metals, hydrocarbons and persistent organic compounds such as pesticides. Sources in the WIO region are typically linked to the use of agrochemicals, dredging activities in ports and harbour which release sediment-bound heavy metals and hydrocarbons, atmospheric emissions and leachates from waste dump sites that can introduce a wide range of pollutants into the environment.

Transboundary elements

Chemical pollution is a problem common to most of the WIO countries, hence it has transboundary implications. (see Table 4-1). In cases where there is bio-accumulation, especially in larger migratory species such as marine mammals and sharks, the pollutants may impact resources and thus communities far removed from the originating source. Chemical pollution may also affect one or more life stage of a migrating marine organism, which could impact on the distribution and

Figure 4-6 Problem tree: Chemical pollution.



abundance of that marine organism in a neighbouring country or region. Furthermore, taking into account the ocean circulation patterns in the area, direct transboundary impacts where chemical pollutants are dispersed across national borders cannot be excluded. This is especially the case where discharges from large rivers are concerned (see Figure 2-2). Thus, chemical pollution has distinct transboundary implications in many cases.

Root-cause analysis

The three key sectors contributing towards chemical pollution of coastal marine waters in the WIO region include industry in disposal of toxic substances in wastewaters, agriculture with high loads of persistent organic pollutants and transportation that promotes dredging activities in ports and harbours. Probably to a lesser extent, the urban sector through traffic emissions and energy production generation from burning of fossil fuels, may also contribute to chemical pollution in places. Major industries contributing to chemical pollution in the WIO region include manufacturing, textiles, tanneries, paper and pulp mills, aluminium smelters, breweries, chemical, cement, sugar and fertilizer factories and oil refineries. Inappropriate utilisation, storage, transportation and disposal of agrochemicals, including pesticides, are also of increasing concern. Furthermore, accidental spills of oil and chemicals in harbours or along coastal transport routes is another source of chemical pollution in coastal areas. These are summarised in the problem tree for chemical pollution provided in Figure 4-6.

Specific environmental impacts linked to chemical pollution include:

- Discolouration of coastal waters;
- Chronic effects that can alter growth, reproduction and other physiological processes of marine biota;
- Acute effects that induce mortalities of marine biota; and,
- Modification of marine biotic species composition.

Ports and harbours are often hot spots of chemical pollution (photo courtesy of Peter Scheren, UNEP)

Consequences associated with chemical pollution which pose risks to human health affect stakeholders across society, from local communities to large tourist developments. The fisheries sector, both commercial and artisanal, as well as the aquaculture and seafood production industries, may also be affected. Particular socio-economic consequences include:

- Loss of artisanal and/or commercial fisheries' potential;
- Reduction in quality of seafood products cultured or harvested from a particular area; and,
- Human health risks associated with contact recreation or ingestion of contaminated seafood.

Signs of chemical pollution have been recorded in coastal areas in the WIO region. Studies conducted in the Killindini and Makupa creeks, Mombasa (Kenya), revealed elevated levels of the metals copper, cadmium iron and zinc (Kamau, 2001). Yet, several other studies conducted in similar areas in Kenya revealed that overall lead and cadmium concentrations were low in the water column. A few incidents of elevated levels in sediments and some fish species were recorded, but levels of lead and cadmium in most of the fish species analysed were generally within acceptable limits (FAO/WHO, 1986). Recent monitoring conducted as part of the WIO-LaB regional monitoring programme in 2007 in the Sabaki estuary/Malindi Bay complex and Kilindini/Port Reitz Creek returned concentrations of cadmium, copper, lead and zinc in sediments well above recommended WIO guidelines (Munga *et al.*, 2007).

Extensive mangrove forests in Mombasa and Maputo have been destroyed by oil spills (Munga, 1993; Richmond, 2002). Spillage from the British tanker, Cavalier, caused considerable damage and destruction of mangrove forests in Mombasa in 1972. Since then this coastline has been subjected to five other severe spills. Such spillage has resulted in mangrove dieback, especially in Mida Creek where the effects of oil spills were still evident ten years after the last oil incident (Abuodha and Kairo, 2001). The main effects of oiling on mangrove ecosystems are complete smothering of estuarine vegetation and organisms (Abuodha and Kairo, 2001). Seagrass habitats are similarly affected and studies in Kenya have indicated cases of complete smothering of these benthic plants, as well as their associated organisms (Abuodha and Kairo, 2001). To exacerbate the problem, dispersants which are commonly used to clean up oil spills contain toxic solvents which penetrate the protective waxy cuticles of seagrass blades. This effects the biological functioning of cellular membranes and chloroplasts, thereby causing plant loss and as well as harmful effects in other benthic biota (Ellison and Farnsworth, 1996, Abuodha and Kairo, 2001).

Monitoring of pollution hotspots (Mahajanga and Nosy-Be) in Madagascar as part of the WIO-LaB monitoring programme in 2007 indicated that population pressure and associated land use activities were one of the main drivers of pollution. Heavy metals in sediments were the highest reported for the WIO region, in particular in close proximity to sewage outfall points (Mong *et al.*, 2008).

Studies conducted in Mozambique have shown the presence of heavy metals, particularly lead, in the Port of Maputo, in the discharges from the Matola and Maputo Rivers and in Nacala Bay (Fernandes, 1995; Anon Mozambique, 2006). Common pesticide residues identified in Mozambique were 2,4,5-TCB, p,p'-DDT, p,p'-DDE, p,p'-DDD, Lindane and HCB. Though DDT is officially banned in Mozambique, it is still used, as it is in neighbouring countries (Massinga and Hatton, 1997).

In Mauritius various industries such as steel mills, galvanizing, electroplating and battery factories historically released their wastes directly into rivers (Grand River North West and St. Louis River) which empty into marine systems. Estuarine habitats such as Tombeau Bay and Poudre d'Or Estuary have been exposed to such untreated industrial wastes since the 1980s (Ramessur, 2002). Heavy metals, particularly chromium (from and textile industries), zinc and lead (from industrial effluent, sewage sludge and landfill leaches) are potentially problematic (Ramessur, 2002). Despite this, coastal systems in Mauritius appear relatively unpolluted compared with more industrialised countries (Ramessur, 2004; Anon. Mauritius, 2009). Heavy metals (copper, zinc, lead, cadmium, mercury) and the pesticides atrazine, diuron and hexazinone were not detected in water samples taken from the river mouths at Grand River North West, Pointe Roches Noires, Grand River South East, Mahebourg, l'Escalier, Baie du Cap, Tamarin and Rivière Lataniers. There are however, indications of elevated levels of zinc and lead in urban estuaries, and this is cause for growing concern (Ramessur, 2004).

In South Africa, municipal and industrial wastewater discharges, including those from marine pipeline outfalls, are regulated, licensed and monitored. This appears to have had some positive influence in sustaining acceptable environmental quality, and in terms of controlling chemical pollutants, as reflected in the monitoring and assessment studies conducted in and around the offshore outfalls. Monitoring of such outfalls off Durban gives little indication of contamination by organic pollutants from municipal and industrial sources (CSIR 2004; McClurg *et al.*, 2007). Inputs of persistent organic pollutants into coastal waters from agriculture (e.g. pesticides) have not been quantified in South Africa, though pesticides have been detected in fatty tissues of seals and dolphins along the South African (and Namibian) coast (Vetter *et al.*, 1999). In general, the levels were not considered to represent a serious pollution problem. However, A recent study involving analysis of pollutants sorbed to plastic pellets from South Africa's east coast indicates very high concentrations of HCH (relative to elsewhere in the world (Ogata *et al.*, 2009). The likely source is from the use of the pesticide Lindane (Ogata *et al.*, 2009).

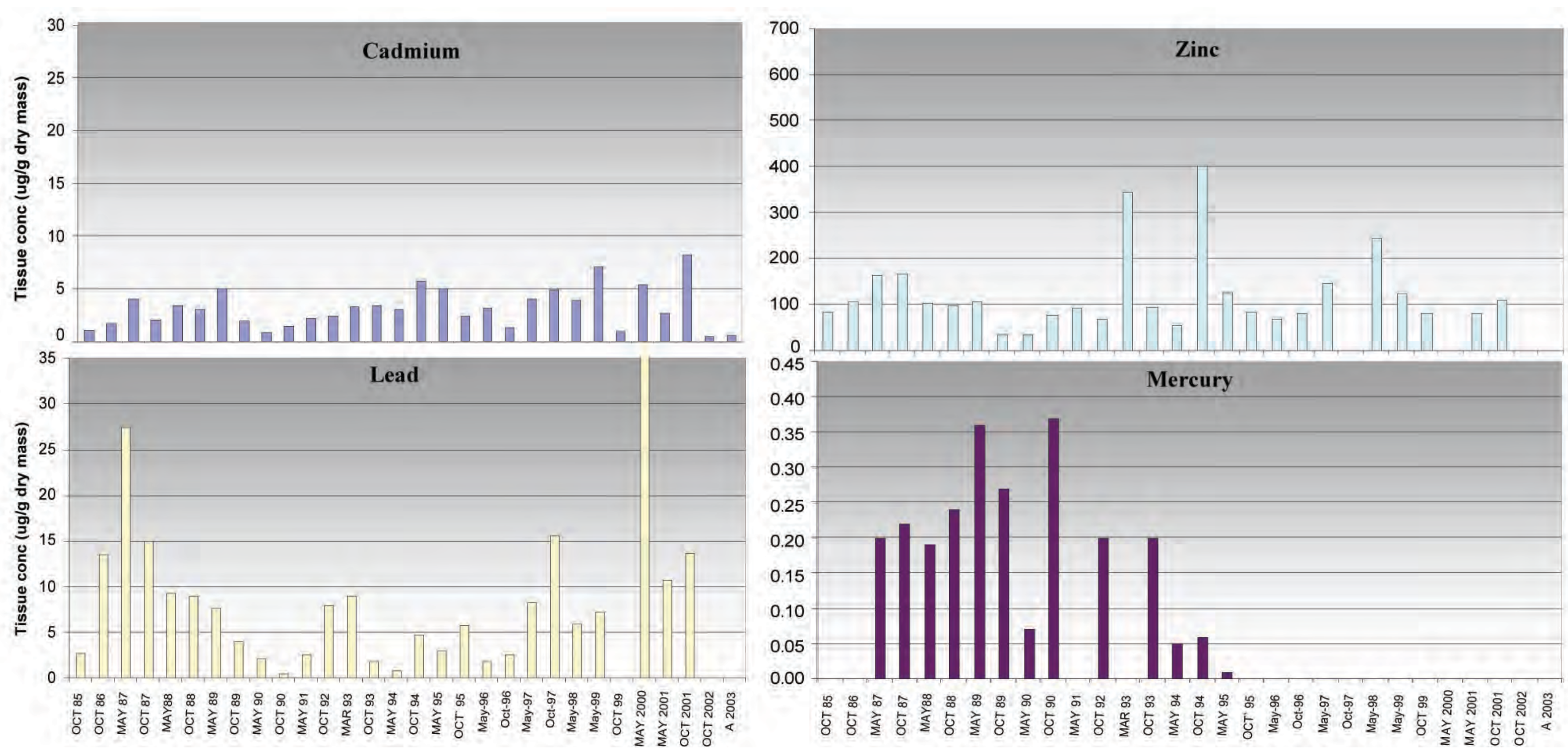
Similarly, studies investigating heavy metal accumulation in Cape Town revealed that the coastal environment is generally in a clean condition, except in localised areas such as the Port of Cape Town (Brown, 2005; CSIR, 2006a, 2006b). The fairly good state of the environment is also reflected in the results of a Mussel Watch Programme conducted along South Africa's west coast. Results for cadmium, lead, zinc and mercury do reflect inter-annual variations but, as yet, no clear long-term (increasing) trends seem to be apparent (Figure 4-7).

In Dar es Salaam, Mremi and Machiwa (2003) found significant amounts of some heavy metals in mangrove sediments and associated biota near the city. Sediment samples from the Msimbazi and Mtoni mangrove areas, which are located within the city, had higher levels of heavy metals (up to three-fold) compared to samples from mangrove forests some distance from the city at Mbweni, clearly inferring anthropogenic input to be a cause (see Table 4-10). Monitoring conducted as part of the WIO-LaB monitoring programme in 2007 also indicated that some areas around Dar es Salaam had concentrations of copper in sediments well above the guideline value recommended for the WIO region (Mohammed *et al.*, 2008).

Table 4-10 Average concentration (mg/kg dry weight) of heavy metals in mangrove sediment and biota in the Dar es Salaam area (Mremi and Machiwa, 2003), as well as the recommended environmental targets (EQTs) for sediments in the WIO (UNEP, 2009).

Heavy metal	Recommended EQTs (Sediments)	Mtoni		Msimbazi		Mbweni	
		Sediment	Crab	Sediment	Crab	Sediment	Crab
Copper	18.7	10.7	24.7	31.6	36.2	17.9	39.3
Chromium	52.3	10.1	30.0	31.7	30.0	27.1	30.0
Lead	30.2	27.8	15.0	37.5	14.3	36.8	44.1

Figure 4-7 Heavy metal concentrations (μg/g or mg/kg dry weight) measured in mussel tissue along the South African coast (Cape Town) (1985 – 2003) (Source: G Kieviets, Department of Environmental Affairs and Tourism, Marine and Coastal Management, South Africa, pers. comm.)



A ten-fold increase in heavy metal content in several algal species has been reported over a period of just seven years from different parts of Zanzibar and Dar es Salaam (Ferletta *et al.*, 1996). Another study has shown that macroalgae collected from Chapwani and Changuu Islands off Zanzibar had significant levels of aluminium and cadmium (Engdahl *et al.*, 1998), with the suggested source of these contaminants being the various industries in nearby Stone Town.

Ferletta *et al.* (1996) conducted baseline studies on the accumulation of heavy metals in algae as indicators of pollution in marine water at Dar es Salaam and Zanzibar. A comparison of the results from 1989 and 1994 revealed a significant increase in heavy metal concentrations (Table 4-11). The authors collected samples at 20 stations along Dar es Salaam and Zanzibar beaches and found zinc and other heavy metal concentrations to be highest at stations close to the city centre compared with stations in rural areas.

Table 4-11 Comparison of heavy metal concentrations measured in algae in 1989 (Wekwe et al., 1989) and 1994 (Ferletta et al., 1996) in Dar es Salaam (Oyster Bay) and Zanzibar (Mdudya Island).

Heave metal	Algea	Dar es Salaam (Oyster Bay)		Mdudya Island (near Zanzibar)	
		1989	1994	1989	1994
Cadmium	*Padina tetrastromatica*	0.12	2.3	0.14	2.6
Chromium		1.5	6.6	1.5	4.6
Copper		1.0	5.0	1.0	8.4
Iron		1190	613	1189	278
Manganese		58.5	nd	58.6	nd
Nickel		0.38	6.5	0.38	6.5
Lead		2.15	6.10	2.17	10.10
Zinc		33.4	104.6	34.0	13.4
Cadmium	*Ulva sp.*	0.3	3.3	0.3	nd
Chromium		0.8	5.5	0.8	nd
Copper		7.0	7.9	7.0	nd
Iron		230	412	230	nd
Manganese		3.5	24	3.6	nd
Nickel		0.9	7.8	0.9	nd
Lead		1.6	13.3	1.6	nd
Zinc		28	39.9	27.9	nd

nd - Not detected

An analysis of heavy metals in sediments in the inner area of Dar es Salaam harbour (Machiwa, 2000) also revealed an accumulation of certain heavy metals, notably chromium and copper (see Table 4-12). The harbour area is the recipient of large quantities of industrial waste from the city of Dar es Salaam.

Table 4-12 Average concentration (mg/kg dry weight) of total heavy metals measured in sediments in Dar es Salaam harbour and Mauritian estuaries (Sources: Machiwa, 2000; Mauritius Pollution Status Report, 2006), as well as the recommended environmental targets (EQTs) for sediments in the WIO (UNEP/Nairobi Convention Secretariat and CSIR. 2009).

Study areas	Average heavy metal concentration (mg/kg)				
	Chromium	Copper	Mercury	Lead	Zinc
Recommended EQTs (sediments)	52.3	18.7	0.13	30.2	124
Dar es Salaam harbour	33	28	0.1	21	68
Mauritius west coast estuaries	225	-	-	27	107

Another study conducted on marine sediments and biota along the coastline of Dar es Salaam (Mwevura et al. 2002) concluded that organochlorine pesticide levels in sediments might cause adverse effects on humans consuming biota directly exposed to the sediments. Biota living in the water column however, showed levels that were significantly below the FAO/WHO maximum acceptable for fish and seafood (200 mg/kg fresh weight, FAO/WHO 1986) and were safe for human consumption. Dieldrin and total DDT measured in sediments around Dar es Salaam in 2007 as part of WIO-LaB monitoring were below guideline value recommended for the WIO region (Mohammed *et al.,* 2008).

Risks/uncertainties and trends

Although several scientific studies conducted in coastal areas in the WIO region revealed elevated levels of chemical pollutants, most likely attributable to land-based sources, uncertainties remain regarding the geographical spread of chemical contamination as most studies were not designed to reflect the spatial extent of the pollution. Furthermore, scientific data on environmental impacts or socio-economic consequences directly linked to chemical pollution have not been collected in the region.

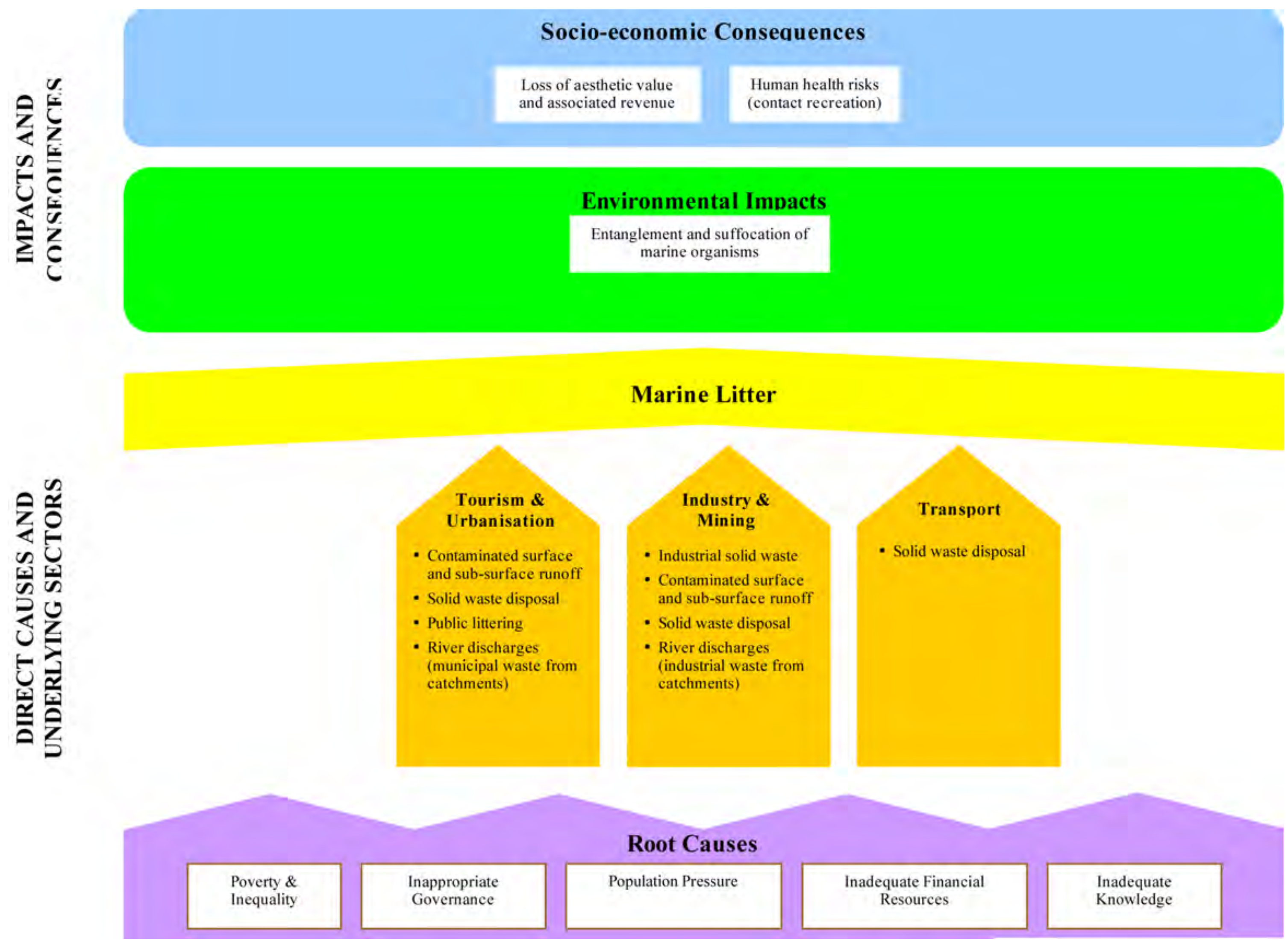
Industrialization in the WIO region remains slow relative to other parts of the world but, it is increasing rapidly. Recent history has shown that rapid development often takes place without proper environmental impact assessments or legislative controls, often leading to increased pressure on the environment, including the coastal areas. Commercial agricultural activities are also increasing in the countries of the WIO region, as are the use of agrochemicals and pesticides. Thus, chemical pollution from these sectors is likely to intensify unless they implement mitigating measures through better legislation and regulation, best practice guidance and education, and stimulation of awareness. Despite the lack of precise data, the risk of chemical pollution of coastal water from these land-based activities should not be ignored. There is a need for a timely intervention by industry managers, farmers and the government authorities responsible for regulating these activities.

4.2.5 Marine litter

Problem statement

Marine litter pollution refers to the introduction of solid waste material, which either floats or sinks, into water bodies and their coastal zone surroundings. Inappropriate disposal of solid waste represents a serious problem in most of the urban centres in WIO coastal regions. Although quantitative data are limited, known sources include waste from ports, industrial zones, urban areas and informal settlements. General littering by the populous lowers the surrounding environmental ambience and hence compromises the quality of life. It degrades the aesthetic quality of coastal areas, especially if such littering occurs along tourist routes or near resorts, cultural sites and

Figure 4-8 Problem tree: Marine litter



other popular sites. Often, such litter is also routed through rivers and transported from adjacent catchments into coastal waters.

Transboundary elements

Floating marine litter can be carried over long distances, especially considering the prevailing nearshore circulation and current systems of the WIO (see Figure 2-4). Litter at sea is known to disperse over vast distances, crossing ocean basins, and arriving at remote locations such as oceanic islands. While the full implications of the actual transboundary effects of litter in the WIO region may not have been investigated, studies from Antarctica and other parts of the world provide ample evidence of the transboundary polluting nature of floating marine litter, most certainly also common to most WIO countries (see Table 4-1). In 1989 the aircraft the SAA Helderberg crashed off Mauritius, but its flotsam was widely dispersed over the SW Indian Ocean carried by currents and gyres (Grundlingh, 1989; UNEP and WIOMSA, 2008; van der Elst *pers com*).

Root-cause analysis

The main sectors or stakeholders contributing litter to the marine environment include the urban and tourisms sectors, industry and transport, mainly linked to inappropriate facilities for the disposal of solid waste, as shown in the problem tree presented in Figure 4-8. Impacts of marine litter include ingestion by, or entanglement of, marine organisms, resulting in mortality of vulnerable species and potential loss of biodiversity (UNEP and WIOMSA, 2008). Evidence has been presented to show that litter falling on live coral normally kills the polyps in direct contact as well as those in the immediate vicinity (Schleyer *pers com*). The socio-economic consequences of littering include:

- Loss of aesthetic and biodiversity value of coastal areas; and,
- Risks to human heath through contact with contaminated waste products such as medical waste.

The consequences associated with marine litter affect stakeholders across society, from local communities to large tourist developments, compromising the aesthetic value of coastal areas and posing risks to human health. An assessment of marine litter-related issues in the WIO region revealed that environmental impacts and socio-economic consequences of marine litter are largely inferred and not adequately assessed or quantified (UNEP and WIOMSA (2008) (Table 4-7), other than in South Africa. However, the description given in South Africa's national report (Ryan, 2006) would largely be applicable to the entire region: 'Litter has numerous impacts on marine ecosystems, as well as direct and indirect impacts on humans. The main ecological impacts of floating litter are that it is ingested by, or entangles, marine organisms. Off South Africa, levels of ingestion and, perhaps to a lesser extent, entanglement, are on a par with the highest recorded elsewhere in the world. There are some encouraging developments such as the reduction in pre-processed plastic pellets ingested by seabirds, but overall the situation remains unacceptable, with several threatened species affected. Floating litter may also play a role in "rafting" invasive organisms to remote ecosystems, with potentially serious biological and commercial impacts. Litter that sinks to the seabed may impede gas exchange in bottom sediments or become entangled around sessile organisms, increasing their drag and, in shallow depths, their risk of being dislodged or washed off during large storm swells."

Risks/uncertainties and trends

The impact of marine litter on the aesthetic quality of coastal areas in the WIO region is visibly real. As was the case with microbial contamination; population growth, poverty and inequality are all factors contributing towards the root causes of marine litter. These causes are likely to intensify, posing even greater socio-economic risks to society, unless there are significant shifts in behaviour and unless those responsible for the different waste management systems intervene. Serious impacts on tourism development are likely, thereby further degrading the socio-economic standards and environmental quality of coastal regions. As economies develop and infrastructures improve, so there is a growing demand for products with a higher waste component. Paradoxically, this also offers opportunities. For example in Dar es Salaam, there has been a growing demand for empty plastic mineral water bottles for re-cycling in China, resulting in their removal from local waste dumps, roadsides and beaches (Richmond, M. *pers comm.*). The trend in Seychelles has been to ban take-away boxes, plastic bags. Grills have been placed on most river outlets and marine litter in the port area and on all of the major beaches is collected. For several years it has been illegal for stores in South Africa to give customers free plastic bags, a law that has seen an enormous drop in plastic pollution countrywide.

One really successful activity has been the "Collect-a-Can" programme (www.collecttacan.co.za) where all cans are recycled with the help of community, schools and environmental organizations, generating for these groups very substantial sources of income. This programme, initiated in 1993, now recycles 72% of all cans sold in South Africa.

4.2.6 Eutrophication

Problem statement

Eutrophication occurs when there is elevated organic matter loading in coastal waters due to the increased availability or supply of nutrients, usually as a result of inappropriate disposal of municipal wastewater or nutrient-enriched agricultural run-off. In response, this can lead to artificially enhanced primary production with excessive algal, phytoplankton and at times bacterial growth. This in turn can lower water quality and influence normal ecosystem function through chocking of living organisms, increasing biological oxygen demand (BOD) creating hypoxic conditions and in some cases introducing toxins into the ecosystem, such as in red tides. Similarly, wastewater containing high levels of inorganic nutrients, such as nitrates and phosphates, typically have a high chemical oxygen demand (COD), thus similarly depleting dissolved oxygen in the water. Eutrophication is often more apparent in closed systems and in estuaries where higher levels of organic nutrients are concentrated. While higher levels of circulation in the ocean may disperse such local organic loading, there is growing evidence that here too eutrophication may occur at certain levels in the water column, impacting on biota and contributing to harmful algal blooms.

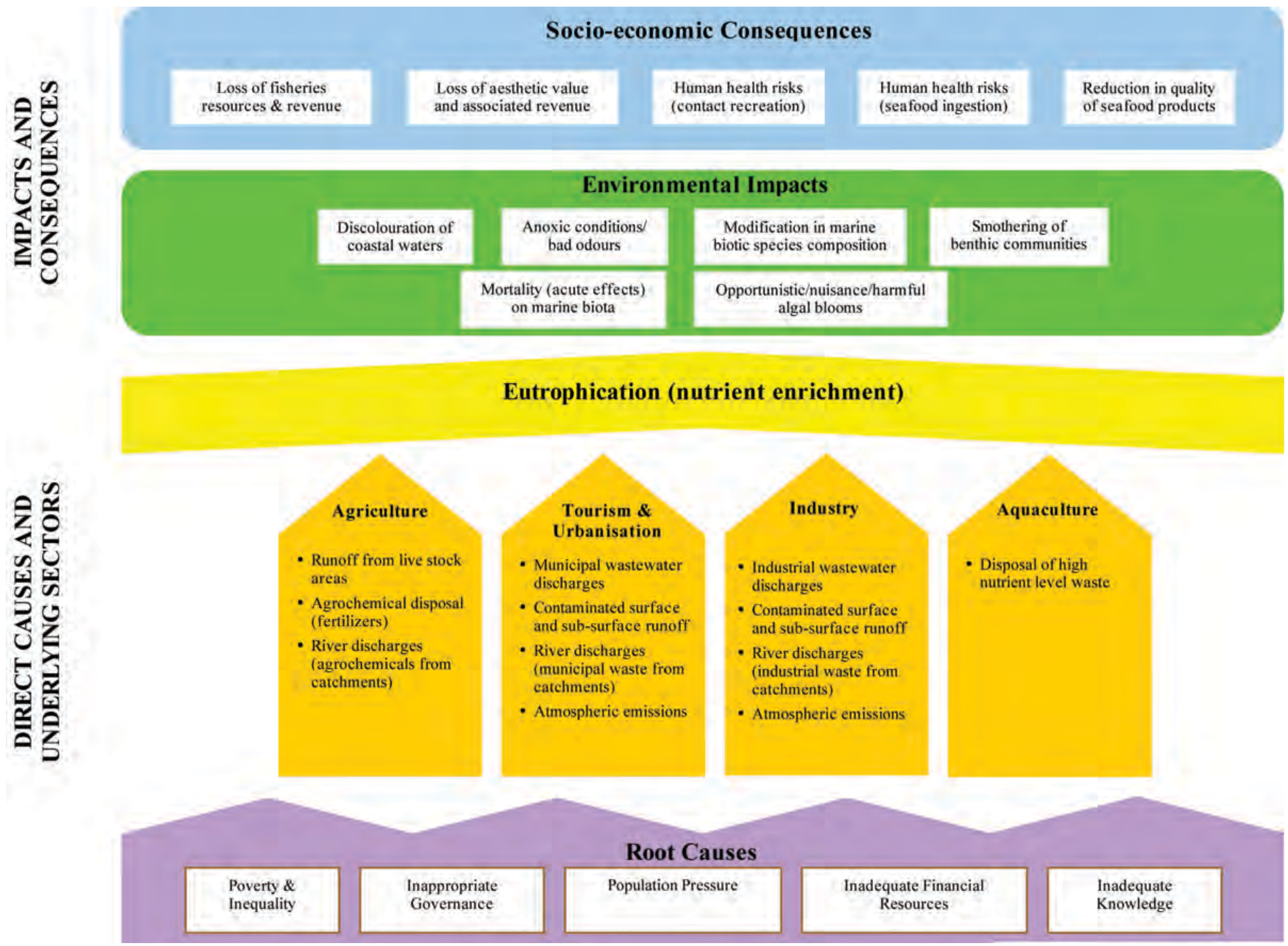
Transboundary elements

Eutrophication is a common problem in most WIO countries, albeit at a local level. The cumulative impact of eutrophication, algal blooms in estuaries, creeks and coastal lagoons, affects critical habitats for fish nurseries and reproduction, resulting in secondary impacts on regional fish stocks and biodiversity. Clearly it thus has regional, transboundary implications. While eutrophic waters may not extend readily directly across national boundaries because of greater assimilation and circulation in the open sea, the dispersal of consequent algal and bacterial blooms can range widely. In general, too little attention has been given to the study of eutrophication in the sea and hence it is not regarded a high priority in most countries (Table 4-1).

Root-cause analysis

The key sectors or stakeholders contributing to eutrophication and subsequent algal blooms in coastal waters include municipalities responsible for waste disposal, industries that generate high

Figure 4-9 Problem tree: Eutrophication and algal blooms.



nutrient loads in their wastewater and inappropriate agricultural use and disposal of fertilizers, as shown in the eutrophication problem tree (see Figure 4-9).

Environmental impacts of eutrophication and algal blooms include:

- Nuisance, opportunistic or harmful algal blooms affecting both aesthetics and biodiversity;
- Discolouration of coastal waters, affecting light-dependent benthic species;
- Smothering of benthic communities (e.g. during die off of algal blooms);
- Mortalities of marine biota (e.g. caused by anoxic conditions generated on decomposition of organic matter); and,
- Modification of marine biotic species composition.

A broad range of stakeholders are potentially affected by eutrophication, from local communities to larger sectors such as fisheries, aquaculture and tourism, which bear socio-economic consequences including:

- Loss of aesthetic value
- Risks to human health in terms of contact recreation and ingestion of contaminated seafood
- Loss of artisanal and/or commercial fisheries and aquaculture.

Wthin the WIO region, there is some evidence of anthropogenic sources of nutrient enrichment that impact on coastal ecosystems through harmful or nuisance algal growth. Along the Kenyan coast, Uku (1995, 2005) and Uku and Björk (2005) demonstrated an abundant growth of epiphytic algae on seagrass and the dominance of the green algae (*Ulva* and *Enteromorpha* sp.) in areas adjacent to dense tourism development, where epiphytic cover reaches up to 69% in the more developed areas. Nuisance algal growth, affecting the recreational (aesthetic) value of coastal resources, has also been reported in Mauritius where, for example, high nitrate concentrations introduced into lagoon systems through agricultural return flows have been associated with algal proliferation in the lagoons of Belle Mare/Palmar. As a result, many hotels have had to remove algal deposits from the shoreline on a weekly basis (Dulymamode *et al.*, 2002). At Flic en Flac, black anoxic sands, smelling of hydrogen sulphide, have been observed at the low water mark and are associated with organic enrichment from wastewater discharges (Prayag *et al.*, 1995).

Also in Mauritius, domestic sewage released to coastal waters from urban areas and poorly planned housing developments on reclaimed wetlands is a cause of eutrophication and algal blooms that lead to the smothering of coral reefs.

Inadequate solid waste management is resulting in marine litter (photo courtesy of Peter Scheren, UNEP)

Algal blooms are observed annually at Trou aux Biches and isolated cases have been reported at Bain des Dames near Port Louis. Higher levels of nitrate and phosphate associated with proliferation of algal growth have been recorded at both Belle Mare and Flic en Flac (Prayag *et al.,* 1995; Botte, 2001). Nutrient enrichment of lagoon waters also results in increased algal growth over coral, thus affecting their biology and the coral reef ecosystem as a whole (Botte, 2001). High concentrations of phosphates were reported from Mauritius (relative to other WIO countries) from sampling conducted as part of the WIO-LaB monitoring programme (Anon. Mauritius, 2009).

Jones *et al.*, (2002) identified eutrophication/algal blooms as a major issue in some of the sensitive areas around the coast of the Seychelles, although the report did not include any quantified scientific evidence of this.

Along the South African coast, estuarine systems typically act as nutrient purifying systems where, for example, nutrients from catchments are absorbed, resulting in cleaner water entering the sea. Excessive weed growth or phytoplankton blooms in estuaries provide evidence for this nutrient removal (Snow *et al.,* 2000; Taljaard *et al.,* 2000). This is particularly evident during low flow periods (dry seasons) when river runoff entering the estuaries may have high nutrients levels (for example, due to agricultural irrigation return flows). High nutrients levels in estuaries can also result from longer residence times within the estuaries, for example during weak neap tides when tidal exchange is reduced (Taljaard *et al.,* 2006).

In the Tanga area of Tanzania, proliferation of macroalgae has been reported in coastal waters due to nutrient loading from municipal wastewater and industrial discharges, particularly from a fertilizer factory (see Munissi, 1998). Munissi (2000) also demonstrated the association of *Ulva* spp. and *Enteromorpha* spp. with nutrient input from sewage pipes. In Zanzibar, eutrophication, associated with the release of inorganic nutrients from domestic sewage, has been identified as one of the main causes for a decrease in coral-reef-building algae (Bjork *et al.*, 1995). Bjork *et al.,* (1996) also showed that coralline algae are sensitive to phosphate and are disappearing from phosphate-rich areas.

Risks/uncertainties and trends

There is thus compelling evidence of impacts associated with nutrient enrichment from land-based activities, as illustrated above. At this stage the problem is mainly confined to more sheltered environments such as estuaries and creeks where weak water circulation generally limits these environments' assimilative capacity for nutrient and biodegradable organic matter. However, increased coastal urbanisation with higher municipal waste and greater agricultural and industrial activities could see a marked increase in nutrient loading, challenging the assimilative capacity of coastal regions in the WIO.

4.2.7 Stakeholder analysis

When a stakeholder matrix analysis of the five types of transboundary marine pollution problems is undertaken (Table 4-13), it becomes clear that the main sectors contributing to the problem are urbanisation, agriculture and industry. These all have broad, cross-cutting effects while aquaculture, tourism, mining, transportation and energy add further, specific types of pollution.

The stakeholders most impacted are the local communities, as well as the fisheries and tourism sector; i.e. those commercial sectors linked directly to the use of coastal and marine resources. To a lesser degree, certain mining, industrial and transportation activities may be impacted.

Table 4-13 Analysis of sectors and stakeholder groups causing (C) transboundary marine pollution problems as well as those impacted (I) by pollution.

Sector	Stakeholder	Transboundary problem									
		Micro-biological contaminants		Eutrophication (nutrient enrichment)		Marine Litter (solid waste)		Suspended solids		Chemical pollution	
Fisheries and Aquaculture	Artisanal fishers				I				I		I
	Industrial fishers				I				I		I
	Seaweed farmers				I				I		I
	Industrial prawn farmers			C	I			C	I		I
	Fish and shellfish farmers		I	C	I			C	I		I
Agriculture and Forestry	Charcoal makers			C				C			
	Small-scale loggers			C				C			
	Industrial loggers			C				C			
	Small-scale farmers			C				C		C	
	Large-scale farmers			C				C		C	
	Pastoralists	C		C							
	Ranchers										
	Poultry farmers	C		C							
	Dairy farmers	C		C							
	Beekeepers										
Tourism	Tourists		I		I	C	I		I		I
	Hotel owners/operators		I	C	I	C	I		I		I
	Small-scale traders					C					
	Tourist boat/SCUBA operators		I		I	C	I		I		I
Mining	Coral/lime miners							C			
	Sand miners							C			
	Small-scale salt producers		I		I				I		I
	Industrial salt works		I		I				I		I
	Small-scale miners							C		C	
	Industrial mining companies							C		C	
	Fuel suppliers and stations									C	
	Oil and gas production									C	
Industry	Heavy manufacturing					C		C		C	
	Light manufacturing					C		C		C	
	Agro-processing industries	C		C			I		I		I
	Oil refining									C	
Transportation	Ports	C			I	C	I		I	C	
	Dredging companies							C		C	
	Clearing and forwarding										
	Railway										
	Roads (incl. traffic)									C	
	Airports										
	Airlines										
	Shipping						I			C	

Energy production	Hydroelectric power generation										
	Power station operators										
	Renewable energy producers										
	Fossil fuel users			C				C		C	
Urbanisation	Solid waste operators	C		C		C		C		C	
	Sewage plants	C		C				C		C	
	Property developers	C	I	C	I		I		I		I
	Town planners										
	Coastal communities	C	I		I	C	I		I		I

4.3 Problem area 2: Physical alteration and destruction of habitats (PADH)

4.3.1 Overview

The world's coastal and marine habitats have been extensively modified by human activities over the last fifty years, with a consequential reduction in biodiversity and an alteration of ecological community structures in many regions (UNEP, 2006a). In the WIO region, national and regional processes and assessments such as the African Process (GEF/MSP, 2001), Nairobi Convention (UNEP, 1998b), GIWA (UNEP, 2006) as well as the WWF's-Eastern African Marine Ecoregion (WWF, 2004) have identified the need to address the loss and transformation of habitats as a priority issue for all countries in the region. Such 'physical alteration and destruction of habitats' (PADH) manifests itself among others in the form of coastal erosion, removal of vegetation cover (coastal grasslands, forests, mangroves and seagrasses), coral reef degradation and the establishment of invasive species.

The main cause of PADH is directly related to human interventions and activities in the coastal zone. Land transformations for agriculture, urban development, as well as extensive deforestation in the WIO region river basins such as Athi-Sabaki, Tana, Rufiji, Pangani, Limpopo, Betsiboka, all contribute to PADH by altering river flows, water quality and sediment loads from river basins (Arthurton *et al.*, 2002, Kitheka, 2003)[8]. Global climate change, itself attributable to human activities, is precipitating extreme hydrological droughts and flood events, sea level variability and coral bleaching further accentuating PADH. The cumulative impacts of these phenomena have seen significant physical alterations and modifications of ecological systems in the WIO region, leading to an overall decline in the productivity of many coastal and marine ecosystems, concurrently reducing their capability of providing expected ecosystem services.

The following five categories of PADH are discussed in this chapter:

1. Degradation of mangrove forests
2. Degradation of seagrass beds
3. Degradation of coastal forests
4. Degradation of coral reefs
5. Shoreline changes

8 Impacts from river-coast interaction are discussed in detail in section 4.4 of this TDA.

It is useful to note that this categorization is mainly based on the key types of coastal habitats prominent in the WIO region, as identified in Chapter 2. Because of the different basic characteristics of the individual habitats a separate analysis is needed for each. In addition, shoreline changes are defined as a separate category of transboundary problems, in light of the over-arching nature of problems related to the physical alteration of the coastal zone.

The first phase of the GEF/MSP Sub Saharan Project, commonly referred to as the African Process (GEF/MSP, 2001), provided a consolidated analysis of the PADH hotspots in the region. In the context of this TDA, hotspots are broadly defined as coastal and marine areas threatened by human activities (WGIPA-I, 2000). PADH hotspots are located at sites with important human activities, such as estuaries, islands, harbours, bays and lagoons. These sites are threatened predominantly by pollution, over-exploitation of coastal-marine resources (e.g. mangroves and fisheries) and habitat modification. An overview of the specifics of hotspots of PADH in the WIO region is presented in Table 4-14.

Table 4-14 Summary of typical PADH hotspots in WIO countries (Modified from the African Process Reports: GEF/MSP, 2001).

Country	Hotspots	Major pressure
Kenya	Malindi Ungwana Bay Vanga-Msambweni Complex Tana Delta Mida Creek	Salt works, aquaculture Upland deforestation, overfishing Deforestation, agriculture, trawling Mangrove degradation, urbanization
Tanzania	Dar es Salaam Tanga Coastal Area Zanzibar Bagamoyo	Pollution, urbanizaton Coastal development, salt works Coastal development Destructive fishing practices
Mozambique	Maputo Bay Nacala-Mossuril seascape Zambezi delta	Erosion, seagrass degradation Mangrove degradation, salt works, erosion change in hydrological cycle Mangrove degradation, erosion
South Africa	Richards Bay	Dune mining for heavy minerals, port development
Seychelles	La Digue East Coast, Mahé Anse Volbert, Praslin	Loss and modification of habitats Loss and modification of habitats Erosion
Mauritius	Rodrigues Grand Bay Flic en Flac	Deforestation Wetland transformation Shoreline change, erosion
Madagascar	Toliara Mahajanga Bay Nosy Be Hahavavy	Mangrove deforestation, aquaculture Aquaculture, sedimentation Sedimentation Mangrove degradation
Comoros	Mohéli Grand Comoros Anjouan	Over exploitation of resources Destructive fishing practices Deforestation and Ylang-ylang distillation

High levels of poverty, as well as poor governance, are amongst the most important root causes of PADH in the WIO region. Poverty forces the poor to rely on 'free' resources they can extract from the environment. Thus forests yield firewood, building poles, medicinal plants and bush meat while the sea yields fish, molluscs, sea cucumbers, ornamental products, salt, corals and a range of other resources. In many cases uncontrolled or excessive harvesting leads to PADH while in some instances the harvesting involves illegal and even more damaging activities such as dynamite fishing. Importantly, poverty lowers the urgency and commitment of communities to consider issues beyond their immediate needs, and thus to engage in natural resource conservation. The consequent over-exploitation of coastal resources has led to degradation of many habitats. For example, mangroves forests have suffered loss attributable to excessive pole exploitation, aquaculture and salt extraction. Seagrass meadows have been damaged by collection of invertebrates and use of drag nets for fishing, while intense fishing and lime extraction from coral reefs has damaged many of these sensitive systems. On land, deforestation to make way for development has also led to degradation of coastal habitats. While coastal development is to be encouraged, the inevitable higher demand for resources must also be factored in to avoid adding to the PADH problem.

The main sectors contributing to the problems of PADH in the WIO region are:

- Urbanisation and Coastal Development – Population growth is a fundamental component, accompanied by demographic changes in settlement patterns from rural to urban environments and related coastal developments. Apart from the communities themselves, specific sectors involved are property developers, town planners, operators of wastewater management facilities and solid waste operators.
- Agriculture and Forestry – This is one of the most important sectors contributing to PADH in the region. Major small-scale stakeholders include firewood collectors and charcoal burners, farmers, loggers, pastoralists and bee keepers.
- Fisheries – The sector involves both artisanal and industrial fisheries, including mariculture initiatives with shrimp, seaweeds, etc.
- Industry – Involves both small and large scale industries based in the coastal zone. These include agro-processing industries, manufacturing industry, oil-refineries and desalination plants.
- Mining – This range from coral/lime miners, sand miners, salt work producers to the mega mining operations of heavy metal extraction from dunes.
- Tourism – Encompasses hotels, tourists, tour operators and small-scale traders involved in tourism activities at the coast. In addition, large scale tourism ventures often restrict access to resources and compel poor coastal communities to change their livelihoods, switching from subsistence fishing to predominantly agriculture. This in turn requires more land, increases clearing of natural areas further away from the village, and thus expands land-use of a given habitat.
- Energy production – This sector concerns hydro-power stations, renewable energy producers and fossil fuel users.

A summary of the main threats, impacts, and the underlying root causes of PADH in the region, for each of the five categories of PADH defined above are presented in Table 4-15 and Table 4-16. The following sections present a detailed root-cause analysis of each of these problem areas.

Table 4-15 Causes, environmental impacts and socio-economic consequences of PADH in the region.

TRANSBOUNDARY PROBLEM					ENVIRONMENTAL IMPACTS
Mangroves	Seagrasses	Coral reefs	Coastal forests	Shoreline change	
X	X	X	X		Reduced biomass and cover of habitat
X			X		Reduced sequestration of greenhouse gases
X		X	X	X	Increased vulnerability to natural calamities (e.g. coastal flooding associated with Tsunamis)
X	X	X	X	X	Increased coastal erosion
X	X	X	X	X	Reduction in biodiversity
X	X				Reduced sediment and contaminant filtration/trapping capacity
X	X				Reduced water quality
X	X		X	X	Increased sedimentation and turbidity in coastal areas (estuaries, lagoons, etc.)
X	X	X			Reduced fish habitats and fisheries reproduction
X	X	X			Breakdown of inter-species relationships
			X		Lowering of ground water table resulting in drying of rivers
X				X	Sand accretion
				X	Salt water intrusion
					SOCIO-ECONOMIC CONSEQUENCES
X	X	X	X	X	Increased poverty (impoverishment of communities)
X		X			Loss of life and property
X	X	X			Reduced revenue from fisheries
X	X	X	X	X	Reduced touristic and aesthetic value
X	X	X			Reduced food security
			X		Loss of cultural heritage
X			X	X	Threats to public health
				X	Reduced land value in coastal areas

Table 4-16 Direct causes and sectors responsible for the PADH in the WIO region.

TRANSBOUNDARY PROBLEM					DIRECT CAUSES	UNDERLYING SECTORS
Mangroves	Seagrasses	Coral reefs	Coastal forests	Shoreline change		
X				X	Coastal flooding as a result of sea level rise	N/A
X	X	X			Sedimentation associated with heavy river sediment discharge	Urbanisation and Coastal Development, Agriculture and Forestry
X	X				Alteration of fresh water flow	Urbanisation and Coastal Development
			X		Salt water intrusion	Urbanisation and Coastal Development
				X	Destruction and/or degradation of wetlands	Urbanisation and Coastal Development, Agriculture and Forestry, Tourism
X			X	X	Clearance of natural vegetation for human settlement	Urbanisation and Coastal Development, Industry, Tourism
X	X	X	X		Pollution (discharge of municipal wastewater agricultural and industrial effluents, including accidental oil spillage)	Urbanisation and Coastal Development, Agriculture and Forestry, Tourism, Industry
	X	X		X	Land reclamation	Urbanisation and Coastal Development
	X				Increased sea urchin population associated with reduction in predators (due to inappropriate fishing practices or changes in environmental conditions)	Fisheries
	X				Seaweed harvesting for commercial purposes	Fisheries
		X			Increased reef activity	Fisheries, Tourism
		X			Anchor damage	Fisheries, Tourism
	X	X			Over-fishing and bad fishing practices	Fisheries
		X			Coral bleaching	N/A
X			X	X	Conversion of habitats for aquaculture/mariculture	Fisheries
X			X		Conversion of habitats to industrial zones	Urbanisation and Coastal Development, industry
				X	Mining of beach sand and removal of corals	Mining
				X	Dredging for port and harbours	Transportation
X	X	X	X	X	Alteration in freshwater flows and sediment loads due to dam construction	Industry, Agriculture and Forestry, Energy production
X			X	X	Conversion of habitats for saltworks	Mining
X			X		Deforestation to meet timber and fuelwood needs	Urbanisation and Coastal Development, Industry
	X				Seagrass beds removal for clam collection and bathers (tourists)	Tourism, Fisheries
X			X		Over-harvesting for supply of fuelwood and charcoal	Agriculture and Forestry
			X		Overgrazing associated with high cattle population	Agriculture and Forestry
			X	X	Land clearance for agriculture	Agriculture and Forestry
			X		Uncontrolled wild fires	Agriculture and Forestry

4.3.2 Degradation of mangrove forests

Problem statement

Mangrove wetlands are multiple-use systems that provide protective, productive and economic benefits to coastal communities. The forest provides timber and non timber products such as fuelwood, poles, fodder and fisheries resources to millions of people in the tropics, including the WIO region (Saenger, 2002). They buffer land from storms and provide safe havens for humans (Spalding *et al.,* 1997). Mangroves have the capacity to absorb heavy metals and other pollutants, thus controlling the quality of water reaching coral reef and seagrass ecosystems (Larcenda *et al.,* 1997). In addition, mangrove forests provide nursery grounds for a number of commercially important fish species, prawn, crabs and other animals, and enhance fishery productivity of the nearby waters (Kathiresan and Bingham, 2001).

As a dynamic zone between land and the sea, mangrove wetlands are controlled by several interacting factors such as tides, periodicity of freshwater and sediment influx, topography, soil and water salinity, temperature and sedimentation patterns. These factors are closely related to land and water use practices in the areas adjacent to and upstream of the mangrove forests. In some instances, human-induced stresses on mangrove forests range from diversion of freshwater, poor land-use in and around the forests to over-exploitation of the mangrove resources. These stresses disrupt the natural equilibrium, ultimately leading to the degradation of the mangrove wetlands which in turn not only depletes the resources within their boundaries, but also affect the productivity of the adjacent coastal and marine ecosystems.

Transboundary elements

Mangroves in the WIO countries constitute about 5% of the current global area of mangroves (see section 2.2.3). A number of these mangrove stands or their catchments are shared by several countries in the region, as are mangrove goods and services by communities adjacent to the forests (Semesi, 1998). Besides the common uses for firewood, charcoal and building materials, herbal medicine and traditional lime making are common practices in coastal communities throughout the region. Key transboundary elements as far as mangrove forests are concerned are related to the fact that mangroves provide important nursery or feeding grounds that are vital for several marine fishery resources of the entire WIO region.

Pressures on mangroves throughout the WIO countries are similar and are mostly human-induced. The area of mangrove in the WIO region that has been lost over the last century is estimated to exceed 50% of the current area (FAO, 2005c). Direct causes of mangrove degradation include tree felling for firewood and building materials, clearance of mangrove areas for aquaculture and solar salt works, urban development, and human settlement. Other causes include reduction in freshwater flow (both surface and groundwater) and heavy or increased sedimentation and pollution. The impacts of mangrove degradation are difficult to quantify for the region and more thorough analyses should consider the rate of loss brought about by each cause.

The major transboundary issues associated with mangrove degradation that affects the entire WIO region is the loss of cover, resulting in a decrease and/or loss of biodiversity, decreased fisheries productivity, shortage of firewood and building materials, and increased coastal erosion (Semesi, 1998; FAO, 2005c). These ultimately lead to loss of livelihood and increased poverty among the coastal population.

In this TDA, the quality of information to support the transboundary nature of the problems are assessed in the light of data provided by the national PADH reports of the participating countries, as well as data accessed during the preparation of this analysis. None of these issues have been well documented across the countries in the region, thereby identifying a major research or knowledge deficiency.

Illegal trade of mangrove wood products across the borders, such as between Somali and Kenya, and Kenya and Tanzania is a major transboundary concern. Apart from depleting wood resources at the Kenya-Tanzania border, over-exploitation of the Tanga-Vanga transboundary mangroves has triggered coastal erosion and sediment transport with a negative effect on fisheries in the area (Semesi *et al.*, 1999). Cross-border mangrove sites have been ranked as being of regional importance due to the unique flora and fauna they support. For example the Tanga-Vanga seascape contains some of the tallest mangroves in the region at Challe Island (Kenya) measuring up to 34 m (WWF, 2004).

Root-cause analysis

The underlying root causes of the loss and modification of mangroves in the WIO are associated with their value as an extractable natural resource as well as the multiple-use potential of the mangrove environment. As an extractable resource, mangroves are degraded or destroyed due to over-harvesting, which is a function of population density, poverty and socio-economic pressure in conjunction with resource desirability, poor resource management (i.e. ineffective governance), unequal distribution of resources. In terms of the multiple-use potential of the mangrove environment, it suffers from increased sedimentation as a result of catchment degradation and land-use changes, assimilative capacity and desirability as a substrate for siting mariculture and solar salt production facilities. In addition, climate change related factors such as sea level rise and increased sedimentation have affected the fringing mangroves in Kenya, Tanzania and Mozambique (FAO, 2001). These have led to loss of mangrove cover, shortage of harvestable mangrove products (Abuodha and Kairo, 2001; Beetje and Bandeira 2007), reduction in fisheries, shoreline change (Kitheka *et al.*, 2003), pollution (Munga *et al.*, 2007), loss of livelihood and increase in poverty (UNEP *et al.*, 2004c; WWF, 2004). Several studies have provided detailed problem analyses associated with over-exploitation of coastal and marine resources in Sub-Saharan Africa (see GEF/MSP, 2001), findings from which are presented in the problem tree for mangrove forest degradation (Figure 4-11).

According to a recent assessment of global mangrove forests, the WIO region has lost approximately 8% of its mangrove cover in the last 25 years (FAO, 2007), on average approximately 3,000 ha per year. While causes of mangrove degradation may vary from one country to another, the major causes seem to be over-exploitation of mangrove wood products, conversion of mangrove areas to other land uses and pollution. These causes are described in detailed below. The most affected countries are Tanzania, South Africa and Madagascar (see Table 4-17). No change in mangrove area has been reported in Seychelles since the 1980's, perhaps due to reduced pressure or lack of reliable quantitative information on mangrove exploitation. Successful mangrove reforestation programs in Mauritius since the 1980's have led to an increase in the extent of mangrove area in this country which nearly balanced the considerable previous net loss from the high demand for fuelwood and infrastructure development. Increased awareness of the uses and benefits of mangroves in the region is leading to other successful small-scale mangrove re-forestation activities. In Kenya, for instance, recent small-scale mangrove re-forestation activities have helped in meeting wood demand as well as controlling shoreline erosion (Kairo *et al.*, 2002 & 2008). In Mozambique, efforts are being made to rehabilitate degraded mangroves in Ilha de Mozambique district (GTA, 2007).

Table 4-17 Loss of coverage of mangrove areas in the WIO region (1980 – 2005).

Country	1980	2005	Annual loss of mangrove cover (1980 -2005)	
			Ha	%
Mozambique	402,500	390,200	492	0.1
Madagascar	330,000	300,000	1200	0.4
Tanzania	152,000	125,000	1080	0.7
Kenya	54,700	50,000	188	0.3
Seychelles	2,500	2,500	0	0.0
South Africa	3,500	3,000	20	0.6
Comoros	125	115	0.4	0.3
Mauritius	45	120	-3	-6.7
Total	945,370	870,935	2,977.4	0.3

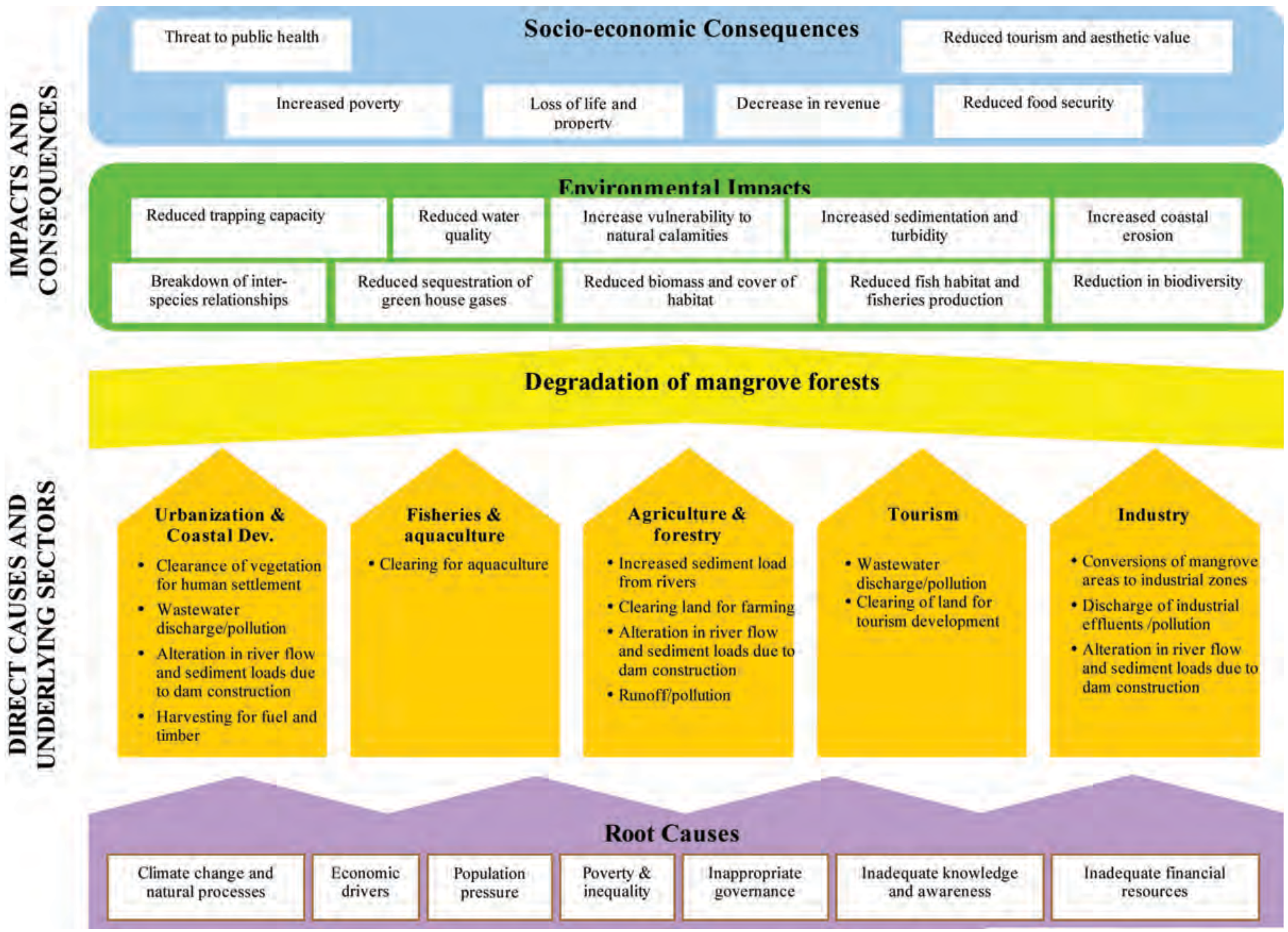
Source: FAO, (2007)

Exploitation of mangrove wood products for heating and building are widespread (Macnae, 1969; Semesi, 1998; UNEP *et al.*, 2004c). Historical records indicate that, in the 1950's, mangrove products were major export commodities from Kenya, Tanzania and Mozambique to treeless Arab countries (Macnae, 1969; Rawlins, 1957; Semesi, 1998). In the beginning of the 20th Century, export of mangrove wood products from Kenya averaged 24,150 scores, equivalent to 483,000 poles per year (Grant, 1938). Between 1941 and 1956 this export averaged 35,451 scores (Rawlins, 1957), dropping to 13,774 scores between 1991 and 1996 (Abuodha and Kairo, 2001). The commercial exploitation of mangrove products is also reported for Madagascar, where some 200,000 tons of tannins derived from mangrove trees were produced and exported to Europe in the early parts of 20th Century (Guillaumin, 1928). Apart from loss in cover associated with mangrove over-exploitation, changes in community structure of regenerating stands often occur once a forest is cleared. This has been shown in Tanzania (Semesi, 1991), Kenya (Kairo, *et al.*, 2002) and Madagascar (Radhika, 2006) whereby stands initially occupied by *Rhizophora* are re-colonized by inferior *Ceriops* species. The effects of this composition change on the general functioning of the forest have not been studied.

The growth of coastal towns and cities has greatly contributed to loss of mangrove forests in the region, through clearing for development and pollution. At least four major cities on mainland Africa, namely Mombasa, Dar es Salaam, Beira and Maputo, are located in the vicinity of mangrove forests. Between 1972 and 1990, the cover of peri-urban mangroves of Maputo decreased by 15.2 % (Saket and Matusse, 1994) and between 1991 and 2003, the loss of mangrove cover in Maputo exceeded 17%. Similar problems have been reported for Mombasa (Abuodha and Kairo, 2001); Beira (Hoguane, *et al.*, 2002) and Dar es Salaam (Semesi, 1991; Wang *et al.*, 2003).

In coastal towns in the WIO region, it is common to find garbage and solid wastes dumped at the edge of mangroves. These unsightly materials are occasionally carried into the mangrove forests by tides thus affecting the wider system. In addition, accidental oil spills are reported to have killed areas of mangrove forest in Mombasa and Dar es Salaam (Abuodtha and Kairo, 2001; Semesi, 1998).

Figure 4-11 Problem tree degradation of mangroves.



Because of their location between land and the sea, mangrove areas in many parts of the world have been converted for solar salt works, urban development, agriculture and aquaculture (Spalding *et al.*, 1997; Valiela *et al.*, 2001; FAO, 2005c). In Kenya, more than 5,000 ha of mangrove area at Ungwana Bay have been converted for solar salt work and aquaculture (Abuodha and Kairo, 2001). In Tanzania and Mozambique, extensive stretches of riverine mangroves of Rufiji and Zambezi respectively have been reclaimed during the last few decades. The major uses of reclaimed mangrove land are for agriculture and pond aquaculture (Saket and Matusse, 1994; Semesi, 1998; FAO, 2005c). A proposal to reclaim a further 10,000 ha of mangrove of Rufiji Delta was, however, halted in 2000 due to pressure from environmental groups (Bryceson, 2002).

The mangroves in the WIO do not seem to suffer a great deal from natural causes. A few cases exists, however, where mangroves have died due to massive sedimentation caused by El Niño weather and cyclones in Kenya and Mozambique respectively (Kitheka *et al.*, 2002, 2003; Hoguane *et al.*, 2002). In Kenya and Tanzania, die-back of riverine mangroves of Tana and Rufiji rivers have been reported following massive erosion of the riverbank (Kitheka, *et al.*, 2002; Semesi, 1998). Other reported natural causes of mangrove degradation in the region include pest infestation and desiccation (Semesi, 1998; Kairo *et al.*, 2002; Bandeira *et al.*, 2008).

The mangrove resources of the WIO region are abundant in ecosystem goods and services and are of great importance to the socio-economy well-being of the countries. Their importance derives both from the direct products from the forest such as timber, and from the ecosystem services provided by mangroves from within and beyond its boundaries. The main socio-economic impacts of the loss and modification of mangroves are, therefore, the loss of livelihood options provided by this habitat, shortage of mangrove wood products (provisioning services, i.e. construction, boat building etc.), decrease in revenue from forestry and fishery activities, increased coastal erosion, increased conflict caused by the desirability of diminishing mangrove goods, increased poverty, and loss of cultural heritage.

Mangrove ecosystems are important for the maintenance of the local coastal industries in the WIO countries. The majority of artisanal and commercial prawn and fish landings are from grounds in the proximity of mangroves (see section 2.2). The fishing industry in the WIO region provides direct employment for a huge workforce (Van der Elst *et al.*, 2005; SWIOP, 2006). This is particularly true for prawn fisheries in Ungwana Bay (Kenya), Rufiji Delta (Tanzania), Sofala Bank (Mozambique) and the west coast of Madagascar where the bulk of mangrove forests are found (see Spalding *et al.*, 1997). The marine fishery in Kenya alone provides direct employment to about 10,000 fishers, and indirectly supports those who are engaged in manufacturing fishing gears and marketing and sale of fish products (Ochewo, 2004).

The supporting roles of mangroves to fishery are well-documented in most parts of the world (Robertson and Duke, 1987) and recent studies on the mangroves of Mozambique and Kenya have demonstrated strong linkages between coastal fisheries and the health of adjacent mangrove ecosystem (Huxham *et al.*, 2004; Bandeira *et al.*, 2006). Non-degraded forests in the Incomati estuary in Mozambique and Ungwana Bay in Kenya support higher densities of crabs and finfish respectively (Bandeira, *et al.*, 2006). Other ecological studies have established the connections between mangroves, coral reefs and seagrass in supporting the life cycles of many coastal organisms (see Mumby *et al.*, 2004).

Although there is no comprehensive study on mangrove biodiversity in the WIO region, independent scientific studies at local levels usually associate mangrove ecosystem with high biodiversity (Little, *et al.*, 1988; Huxham *et al.*, 2004), reflected in the high number of species of mangrove trees, finfish and penaeid shrimps, among other taxa (Crona *et al.*, 2005). Most mangrove studies in the region have been carried out in Inhaca in Mozambique and Gazi Bay in Kenya, with Kenya studies showing for instance that replanting mangroves in clear-cut areas enhances biodiversity and ecosystem functions of the forest (see Bosire *et al.*, 2003; Crona and Ronnback, 2005).

Risks/uncertainties and trends

There are several risks and uncertainties related to the analysis presented in this section. These are most importantly:

- *Irreversible ecosystem change (ecological thresholds)* – There is uncertainty as to the degree to which changes that take place in the mangrove ecosystem from over-harvesting are reversible.
- *Biodiversity change* – Changes in biodiversity (genetic, species, ecosystem) may occur as a result of over-harvesting of resources or climate change, but the lack of good baseline data makes this difficult to assess. Hence the level of habitat fragmentation at which the system can still maintain its function is not known with precision.
- *Cumulative impacts* - Uncertainties exist about the regional cumulative impact from mangrove degradation on other ecosystem functions.
- *Tourism value* – The degradation of the seascape in general reduces the regional value for tourism, an aspect that has not been studied in the WIO region.

4.3.3 Degradation of Seagrass Beds

Problem statement

Seagrass beds or meadows are a critical habitat that provides a series of essential functions. Foremost is their role in primary productivity, thereby introducing nutrients into detritus pathways that in part sustain a wide range of biota and systems (Mann 1975a&b). They function as nursery grounds for fish and crustaceans of commercial importance, offer coastal protection from erosion and provide economic goods and services to coastal communities. This habitat is also the main source of food for the endangered dugong (Waycott *et al.,* 2004). Seagrass degradation in the WIO is generally evidenced by destruction and/or reduction of seagrass as a result of physical-mechanical action (Ochieng and Erfermeyer, 2003). Typically this includes clearance of seagrass beds by hotel operators (Daby, 2003), people trampling and uprooting seagrass for clam collection (Balidy, 2003; Bandeira and Gell, 2003) and destructive fisheries practices, for example the use of drag nets (de la Torre-Castro and Rönnaback, 2004; Mangi and Roberts, 2007). Unregulated coastal development, as well as dredging and land reclamation also impact on seagrass beds. All are common practice in the region.

Another direct cause of seagrass degradation is increasing pollution that reduces water quality, which negatively affects seagrass ecophysiology. Pollution from industrial activities has been documented in Mauritian coastal waters where reduction in seagrass habitat in port and jetty areas is also a common consequence of water quality degradation (Ramessur *et al.*, 1998). For example, at Inhaca Island (Mozambique), a seagrass community dominated by *Zostera capensis* was effectively destroyed in an area known to have heavy boat use (Bandeira, 2002). Climate change, through increased discharge of sediment-laden low salinity water derived from flooded river systems also could potentially affects seagrass beds (Short and Neckles, 1999; Bandeira and Gell, 2003).

The degradation of seagrass beds has a negative impact on the ecosystem’s productivity and potentially has negative environmental and socio-economic impacts across the WIO region.

Common socio-economic consequences include reduction in fishing areas and fisheries productivity with a concomitant reduction in revenue from fisheries, thus impacting on food security (Short and Neckles, 1999). Ultimately the degradation leads to a potential change loss of livelihoods and increased poverty among the coastal populations.

Transboundary elements

Due to relatively few studies on seagrass systems within the WIO, the transboundary nature of seagrass degradation is not always as evident as it is for mangrove forest or coral reef degradation. Nevertheless, the activities described above reduce seagrass habitat cover, impact on biodiversity and reduce fishing grounds and fishing productivity. Reduced seagrass cover in turn renders the habitat vulnerable to increased sedimentation which ultimately impacts on fish catches and fisheries revenue to people. These impacts are felt along the shores and across national boundaries. Finally, climate change, which brings about coastal flooding and increased sedimentation is also a common transboundary issue in several WIO countries that potentially affects seagrass beds (Bandeira and Gell, 2003).

Root-cause analysis

As described above, the degradation of seagrass beds is due to multiple causes. At the root-cause level, poorly planned coastal development, legislation and policies together with inadequate monitoring and enforcement of existing regulations are probably the most important problems that affect not only seagrass meadows but also other habitats. A lack of financial and human resources accentuates the problem while in most cases the real value of goods and services derived from seagrass beds is simply not understood.

Among the underlying sectors causing the problems, urbanization and coastal development rank highly. This, in turn, results in various other activities that affect the seagrass environment to some extent. Population growth, poverty and the growing need for natural resources to fulfil basic human needs are increasing the pressure on marine resources. The WIO region continues to experience an increase in tourism with concomitant development of tourism infrastructure often not planned and constructed as part of a strategic spatial development framework. The high density of tourist hotels in some areas has led to an increase in the discharge of untreated domestic waste to the sea, as well as negative effects caused by associated tourist activities such as boating (damage caused by boat propellers, anchoring), and physical removal of seagrasses by tourist operators in order to make beaches more attractive to tourists (Daby, 2003). The removal of seagrasses leads to environmental changes such as increased water turbidity, loss of associated fauna, decreased biomass and increased vulnerability to extreme events. These impacts in turn affect the long-term sustainability of the tourism industry itself (Daby, 2003).

Pollution is one of the direct causes of habitat degradation. A study undertaken in Mauritius at Flic en Flac and Grand River North West, during the period 1996-1997, have shown that chromium and lead concentrations had exceeded the permissible limits; the main sources attributed to tourist hotels and industrial activities (Ramessur *et al.,* 1998). Heavy metals are absorbed into seagrass leaves and vascular tissue from either the water column or the sediment (Lyngbay *et al.,* 1982; Brinx and Lyngbay, 1982). Contamination by heavy metals is harmful to seagrasses, interfering with the photosynthetic apparatus and affecting CO_2 fixation at different levels. Copper, zinc, cadmium, mercury, and lead can reduce chlorophyll content because these elements interfere with the pigment biosynthesis, although the damage is not necessary permanent (Catriona *et al.*, 2002; Lewis *et al.*, 1997). More information on the status of pollution in WIO region is presented in section 4.2.

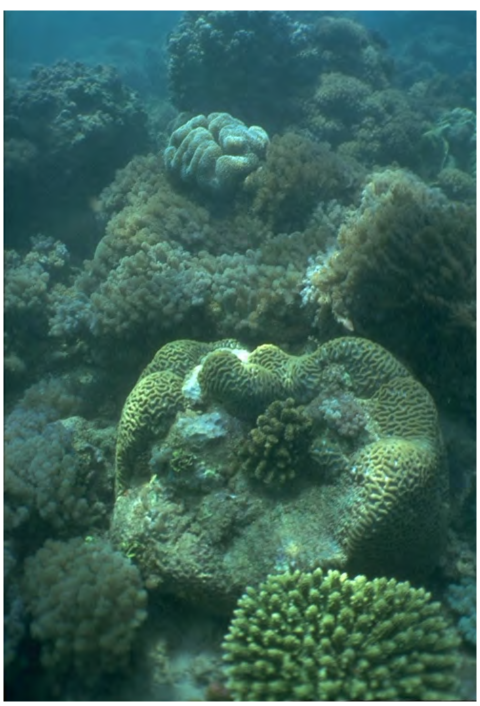
Coastal communities use seagrass meadows as fishing grounds, yest another factor that may impact on seagrass degradation (Bandeira and Gell, 2003; de la Torre-Castro and Rönnaback, 2004; Eklöf *et al.*, 2005). Different fishing gears are used in seagrass meadows and includes as drag-nets, basket traps, harpoons and hand lines. Destructive practices such as drag-nets, dynamite, poisons, harpoons and nets with smaller mesh size, exacerbate the negative effects of over-fishing in seagrass bed areas (Mangi and Roberts, 2007).

Coastal communities also collect a diversity of invertebrates from seagrass beds. At Inhaca Island sea cucumber and seahorse harvesting for commercial purpose has increased in the last few decades and this has led to a significant decline in the availability of invertebrates (Pereira, M., *pers. comm.*). Digging in *Zostera capensis* beds and surroundings seagrass areas for the collection of edible bivalves has also led to the destruction of the seagrass beds at Bairro dos Pescadores near Maputo (Balidy, 2003; Bandeira and Gell, 2003). Almost 14 km^2 of seagrasses, notably *Z. capensis* beds, were lost in the period 1989-2002 due to the intense collection of bivalves. This was aggravated by river flooding in 2000 where heavy sediment loads deposited on seagrass beds resulted in extensive smothering and die-off.

Among the underlying sectors causing the problems, urbanization and coastal development rank highly, accompanied by various other activities that to a lesser or greater extent also affect the seagrass environment. Population growth, the need for infrastructure development, higher levels of tourism that are not consistent with planned coastal development are all contributing factors. High concentration of tourist hotels generate more waste, increases damage caused by motor boat propellers, anchoring and often lead to physical removal of seagrasses by tourist operators in order to make beaches more attractive to tourists (Daby, 2003). The removal of seagrasses leads to environmental changes such as increased water turbidity, loss of fauna, decreased biomass and increased vulnerability to extreme events. In particular the loss of primary production may have serious consequences for the energy budget of a host of species that are dependent on the seagrass ecosystem. These impacts in turn affect the long-term sustainability of the tourism industry itself (Daby, 2003).

Aquaculture in general and seaweed farming in particular, are two activities that potentially affect seagrass beds. Seaweed farming has been implicated in the reduction of seagrass cover, reduction of macrofauna biomass and changes in community structure. It potentially also results in changes in sediment composition, including texture and organic content (de la Torre-Castro and Rönnaback, 2004; Eklöf *et al.*, 2005).

Climate change is also a potential agent of seagrass bed degradation. The effects of climate change includes the alteration of growth rates and physiological functions, changes in distribution and reproduction patterns, changes in plant community structure and loss of some key species (Short and Neckles, 1999). In the WIO, the best examples of climate impacts on seagrasses are those from Mozambique, a country with cyclones and floods nearly every year. Heavy floods in Mozambique in 2000 caused smothering of 24 km^2 and 10 km^2 of seagrass beds in southern Mozambique and Inhassoro,



Reefs recovering from bleaching may be colonised by the soft coral Cespitularia (Photo courtesy of Michael Schleyer, ORI) respectively (Bandeira and Gell, 2003). Other areas where seagrass beds were lost included those off Pemba town, Moçambique Island, Inhambane Bay and Inhaca Island. It is estimated that close to 28 km^2 of seagrass beds was lost due to sediment smothering associated with flooding of the Incomati and Govuro rivers (Bandeira and Gell, 2003). Harbour development, sewage disposal and coastal development in areas of southern Mozambique have further diminished seagrass area (Bandeira and Gell, 2003),

Excessive harvesting of some fish species that feed on sea urchins can lead to uncontrolled and rapid growth of sea urchin populations which in turn can seriously affected the seagrass communities. This has been reported from the Diane-Chale lagoon, the Malindi-Watamu Marine National Park and Reserve (Uku et al., 2005) and other places along the Kenya coast. There has also been a significant loss of seagrasses along the Kenya coast as a result of anthropogenic activities. More than 50% of the Diane-Chale lagoon's seagrass bed cover was lost, and in most of the cases, the degraded sites were found to have a density of more than 37 sea urchin individuals per m2, a very high number when compared to the 4 individuals/m2 in healthy sites (Uku et al., 2005).

In Mauritius, seagrass beds are threatened by eutrophication caused by the organic fertilizer run-off from sugar cane plantations (Ramessur and Jarvis, 1998). Furthermore, the dredging of channels for swimming and water skiing has also resulted in degradation (Daby, 2003). Other factors that have impacted on the seagrass beds of Mauritius include sedimentation, disposal of sewage and sand mining (Ramessur, 2002). In Seychelles, sedimentation, reduced salinity and decreased water quality associated with effluent discharge have adversely affected seagrass beds (Ingram and Dawson, 2001).

In the Seychelles, the East Coast reclamation project and the December 2005 Tsunami has had a serious effect on the degradation of seagrass beds found in shallow areas inside the reefs. Large areas of seagrass beds were destroyed by the reclamation (Bijoux *et al.*, 2003) and the Tsunami caused seagrass beds at Baie Ternay Marine Park on the north-west coast of Mahé to be covered with a thick layer of sand that has still not cleared (Obura and Abdulla, 2005). Also, sedimentation associated to effluent discharge has caused salinity and water quality to reduce, affecting adversely seagrass beds (Ingram and Dawson, 2001).

The consequence of these various impacts is a severe reduction in seagrass bed coverage, lower species diversity and ecological degradation. For example, in Mauritius, the disappearance of some seagrass species is reported from areas such as Albion (Halodule uninervis) and Poudre d'Or, Mont Choisy and Poste Lafayette (Syringodium isoetifolium), though the actual areas lost is unknown. Similarly, areas covered by Zostera capensis in estuaries in KwaZulu-Natal are believed to have been seriously depleted by periodically heavy flooding in the northern parts of South Africa.

Risks/uncertainties and trends

There are several risks and uncertainties related to the analysis presented in this section. These are most importantly:

- *Biodiversity change* – Changes in seagrass biodiversity (genetic, species, ecosystem) may occur as a result of over-harvesting of resources, but the lack of good baseline data makes this difficult to assess.

- *Habitat destruction* – The degree to which over-harvesting affects habitats through impacts on dominant invertebrate species is unknown and baseline data are lacking.
- *Level of seagrass degradation* – Precise data on regional distribution and degradation of seagrass beds and their species composition within the WIO are scarce.
- *Future trends* – Seagrasses are fast-growing plants that can rapidly replenish denuded seabed areas, provided the physical damage to the habitat is minor or reversible. Future scenarios could include (i) natural recovery of seagrasses occurring in areas were water quality is maintained despite physical alteration of the habitat; (ii) the continuous depletion of seagrass beds in areas of intense impact (e.g. collection of invertebrates or intense tourism that leads to clearing of beaches) and (iii) seagrass rehabilitation in areas where intense habitat destruction has been alleviated and re-colonisation is assisted by propagation.

4.3.4 Degradation of Coral Reef Ecosystem

Problem Statement

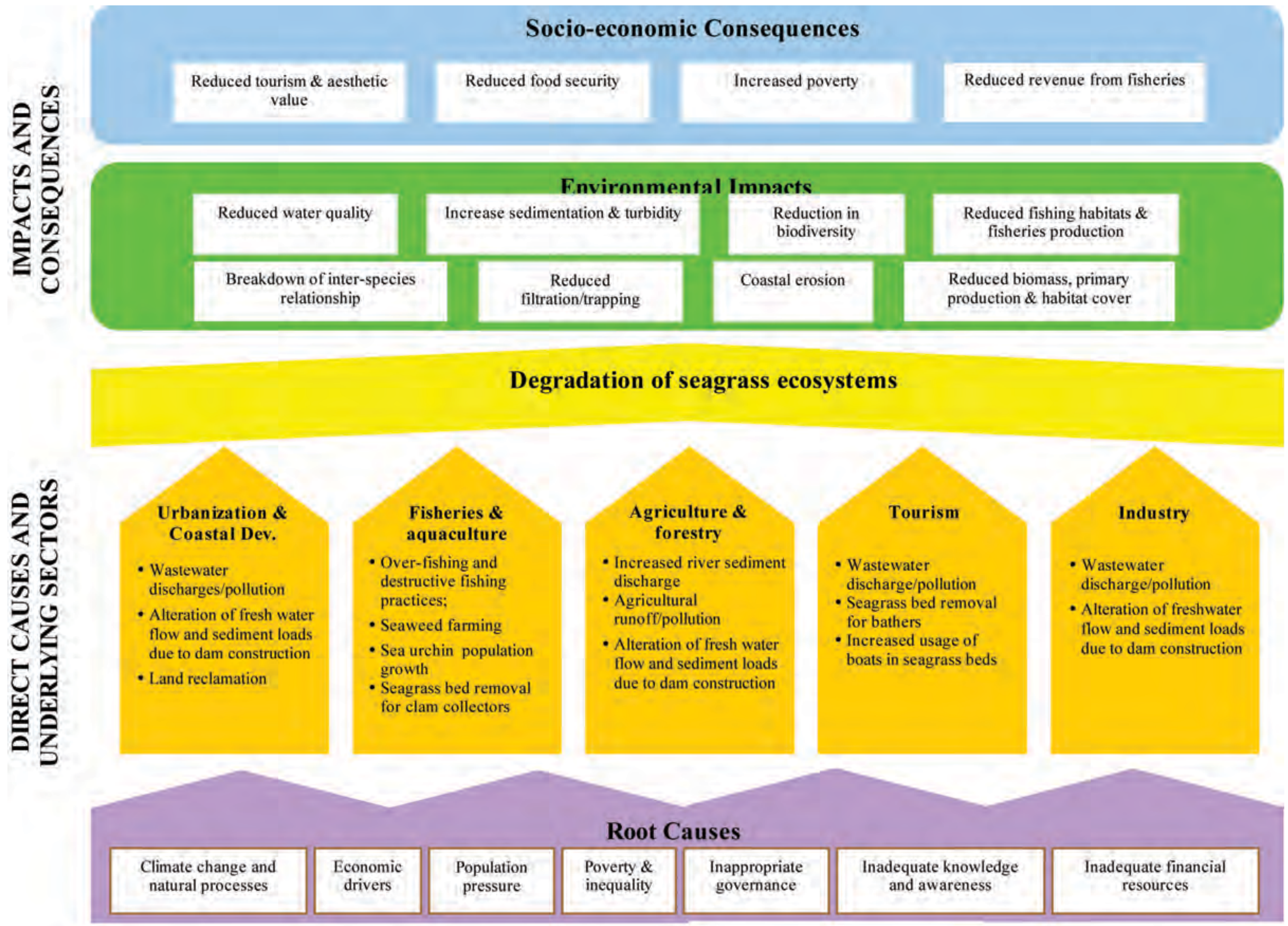
Coral reef ecosystems face various types and levels of impact across the WIO. In addition to anthropogenic threats, are included those associated with climate change, which led to severe coral bleaching during the 1997-98 El Niño Southern Oscillation, degrading reefs throughout the WIO region (Sheppard, 2003; McClanahan *et al.*, 2005; Obura, 2005; Graham *et al.*, 2006). Poverty and socio-economic drivers impact reefs mostly at local levels, particularly activities associated with the use of destructive fisheries practices that lead to reef degradation (Edinger *et al.*, 1998). In the recent past, it has been shown that the lack of effective governance, such as effective policies, laws and regulations and inadequate institutional capacity for coral reef management, have precipitated increased degradation of reefs throughout the region. This continuous degradation and resultant diminishment of coral reef biodiversity ultimately impacts on the socio-economic well being of coastal communities, because destruction of reef ecosystems leads to reduction in fisheries productivity that eventually impacts on livelihoods and incomes, ultimately leading to increased poverty levels (Souter and Lindén, 2000; Sheppard *et al.*, 2005).

Transboundary elements

The transboundary issues associated with coral reef degradation include a decline in productivity and biodiversity, lower reef fish catches, reductions in coastal tourism and impacts on threatened migratory species like marine turtles. Information to support the transboundary relevance of these issues is generally well-documented for areas that were involved in the Coral Reef Degradation in the Indian Ocean (CORDIO) project, which involved all the WIO countries. There is sufficient information to suggest that degraded reefs in the region have incurred a loss in percentage coral cover, decline in biodiversity and reduction in fish catches and other wildlife (CORDIO, 2002; ICRAN, 2004). In Diani, Kenya, McClanahan *et al.*, (1997) have shown the reduction in species diversity of reef fishes together with a decline in fish abundance as a consequence of over-exploitation. Similar results have been reported from Tanzania, Mozambique and island states in WIO (Wilkinson *et al.*, 1999).

Any threats to fringing reefs of the WIO are transboundary because of strong ecological linkages between the reefs in the region, resulting from the high biodiversity they support, which notably includes massive numbers of both planktonic and adult forms of marine life that move freely through the region, transported for weeks at a time drifting on the ocean currents or actively swimming or migrating thousands of miles. The seasonal monsoon winds and oceanic currents provide connections between north and south of the WIO. Kaunda and Rose (2004) have hypothesized that planktonic larvae of many coral reef biota from northern Mozambique may recruit to the

Figure 4-12 Problem tree: Degradation of seagrasses.



fringing reefs of Tanzania and Kenya, and vice versa, depending on the direction of water circulation. Endangered migratory species such as some turtles are reported to nest in a number of localities around WIO and move freely between several site and coral reefs areas. Through tagging recoveries, migration patterns for a number of them are being documented, confirming the transboundary nature of coral reefs.

Root-cause analysis

The underlying root causes of coral reef degradation in the region can be grouped into three broad categories that include: a) global climate change and natural processes; b) socio-economic conditions, including lack of alternative livelihood options and c) inappropriate and ineffective governance. In most cases more than one of these drivers is responsible for any observed degradation on coral reefs thus making the determination of root causes a complex issue (Payet *et al.,* 2005). The sections that follow describe the problem of coral reef degradation from this perspective, highlighting the three underlying root causes.

Underlying root cause 1: Global climate change and natural processes

One of the most important underlying root causes of coral reef degradation in the WIO is coral bleaching brought about by higher temperatures, likely to be linked to climate change. The first noticeable impact of climate change to the coral reefs in the WIO was observed in 1997 when most reefs witnessed unprecedented coral bleaching and eventual death four months later (Wilkinson *et al.*, 1999). The immediate cause of this event was a warm water episode linked to the 1997-98 El Niño, which raised the sea surface temperatures over wide areas of the region (Wilkinson *et al.*, 1999; Spencer *et al.*, 2000; Celliers and Schleyer, 2008). The severity of this event is thought to have been further exacerbated by the background increases in sea surface temperatures (SSTs) linked to global climate change (Hoegh-Guldberg, 1999). Bleaching-related damage in the WIO region was variable. For instance, in Kenya, mortality ranged between 50-95% (Wilkinson, 1999, 2000) whereas in the Seychelles mortality was close to 95% on most reef sites of the inner islands. On the other end of the scale, countries such as Mauritius recorded less than 10% coral bleaching (McClanahan *et al.*, 2005) with most of bleaching occurring in the bleaching sensitive genus *Acropora* (Pillay *et al.,* 2002).

Sein netting causes great physical impact to coral reefs (photo courtesy of Rudy v.d. Elst, ORI)

A number of factors may be responsible for the differential bleaching that has been observed across the region such as the presence of clouds or storms (Turner *et al.*, 2000), geography and temperature histories (Berkelmans *et al.*, 2004), the coral taxa involved (McClanahan, 2004; McClanahan *et al.*, 2005), the dominant algal symbionts on the reefs (Baker *et al.*, 2004) and water flow (Nakamura and van Woesik, 2001). Recovery of coral reefs from the impact of the 1998 coral bleaching event has been variable. Strong recovery has been recorded in the Comoros (Ahamada *et al.*, 2004) while slow recovery is being recorded in the Seychelles (Payet *et al.*, 2005) and patchy recovery is being observed in Kenya (Obura, 2002).

Ten years after the first regional significant bleaching event in the WIO, there appears to be a shift in species composition of fish communities, local extinction of certain fish and coral species, a reduction in the structural complexity of reefs (Graham *et al.*, 2006), a breakdown of commensal relationships between corals and other reef inhabiting species, a decrease in the ability of coral reefs to dampen wave action (Sheppard *et al.*, 2005) leading to increased coastal erosion, and population explosions of plague organisms. However, very few studies have been able to detect any impact on fish catches. It has been predicted that many coral species in the WIO would be extinct by the year 2050 (Sheppard, 2003). The increase in ocean acidity observed in other regions of the world (Kulshrestha *et al.*, 1999) should also be a cause for concern for coral reef managers and users in the WIO. Such a change in water chemistry is likely to result in the need for corals to expend more energy to the mineralization of their calcium carbonate skeletons, consequently devoting less energy for colony expansion and reproduction.

A global survey of reefs at risk carried out by Bryant *et al.* (1998), in the wake of the circum-tropical mass coral bleaching event of that year, found that 25% of coral reefs in the Indian Ocean were at high risk from human activities (equivalent to 36,100 km^2) whereas 29% were of medium risk (or 16,600 km^2) and 46% (or 36,100 km^2) were at low risk. Monitoring results from throughout the countries of the WIO have indicated that many reef sites are taking a long time to recover and that human pressures are further exacerbating coral reef degradation.

Freshwater input, discharged as a result of surface runoff, is known to be one of the major influences controlling coral reef distribution in the WIO region. Heavy sediment discharge at Malindi Bay (from Athi-Sabaki River) is affecting the coral reef system at Malindi–Watamu Marine National Park and Reserve (Blorn *et al.*, 1985; McClanahan and Obura, 1995; Obura, 2002; Kitheka *et al.*, 2003a-b, 2005; Arturton *et al.*, 2006). As a result of heavy river discharge of sediments and freshwater, coral reefs are absent in the extensive swampy coast of central Mozambique (Bandeira *et al.*, 2002). In Madagascar, sediment-laden rivers such as Betsiboka are known to have been responsible for degradation of coral reef ecosystem. In addition to sedimentation associated with river discharge, coastal currents and winds have been known to be responsible for the increased sedimentation of coral reefs at Ponta Torres, Inhaca Island, Mozambique (Kalk, 1995). Change in rainfall pattern could increase the amount of freshwater and sediments discharged from river catchments areas/basins to coral reefs throughout the WIO region. This would cause further stress, phase shift and degradation on coral reefs.

Outbreaks of plague organisms such as crown of thorns starfish (COTS), black-spined sea urchins (BSU) and coral-eating snail *Drupella* have been recorded on many coral reefs where they have grazed live corals causing death of the colony which has lead to reduction in live coral cover and collapse of the reef matrix through increased bio-erosion (Schleyer, 1998; Carreiro-Silva and McClanahan, 2001; Spencer and Viles, 2002; Celliers and Schleyer, 2006). The population outbreak of black-spined sea urchin is of particular relevance to our region as recovery on many reef sites is being retarded by their grazing habits (Carreiro-Silva and McClanahan, 2001).

Underlying root cause 2: Socio-economic drivers, including poverty and alternative livelihoods

Poverty is one of the main underlying root causes of widespread degradation observed on coral reefs throughout the region. Over-fishing and destructive fishing practices are very common in Tanzania (Francis *et al.*, 2002), Comoros (Ahamada *et al.*, 2004), Madagascar and Kenya. Coral mining is still practiced in many countries of the region as a source of construction materials, leading to habitat degradation and also an increase in the amount of coral rubble on the reef which in turn easily moved about by wave action, often resulting in further physical damage to the remaining live coral community. Coral mining also holds implications for the stability of the near-shore marine zone as it tends to deepen the reef flat thereby increasing the volume of water and the height of the waves impacting the shore which leads to increased coastal erosion. Reef trampling is similarly a very important cause of destruction of the reef flat community throughout most of the region where there are many fishers and collectors operating, notably those involved in the octopus, sea cucumbers and shell fishery.

Although it is technically illegal in many countries, except Mozambique, seine netting is still practiced in most of the continental WIO states as well as in Madagascar and the Comoros. This type of fishing involves dragging a weighted net over the reef which causes great physical impact to the reef structure as well as to the benthic reef community. As the mesh seize of the net are often very small, this type of fishing method is responsible for capturing a large number of juvenile fish. Over-harvesting of marine resources is widespread in reef areas, often driven by increased external market demands such as sea cucumbers, seafood for tourist resorts and ornamental shells and curios. In continental countries, demographic changes resulting in net migration to the coast has also fuelled over-harvesting of marine resources. Marine resources that are presently being targeted from coral reef areas include large coral reef fishes, especially large groupers and snappers, lobsters, octopus and sea cucumbers.

While Marine Protected Areas (MPAs) can offer protection to coral reef systems, poaching in MPAs is widespread. The overall effect is that most MPAs are not effective in acting as coral or fisheries reserves nor as a source of larvae and mature individuals to be recruited to the more exploited reefs beyond their boundaries. Poaching of MPAs also has an indirect impact on the tourism industry as it removes large fishes that are one of the main sources of attraction for tourists. This loss of large fish impacts on the pristine nature of the MPAs and willingness by tourists to pay to enter into the MPAs (Jennings *et al.*, 1996; Kaunda-Arara and Rose, 2004).

The level of reliance of coastal communities on coastal ecosystems such as coral reefs is closely related to a range of external factors. Often, harvesting inshore resources is a source of employment of last resort in the absence of other opportunities. In times of drought or during internal conflict, there may be a greater dependence on the marine environment, and thus higher pressure. Although alternative livelihoods have often been seen as a panacea for these problems, in reality many schemes have involved the tourist curio trade and not lifted the coastal communities out of real poverty. Innovation and investment will be needed to shift the non-sustainable dependence on coral reef systems to more substantial alternative livelihoods.

In addition to poverty and inequality, there are also a number of other economic drivers operating in the region which are underlying root contributors to coral reef degradation. These include industrial development, tourism, economic and social growth of countries, accompanied by increases in market demand, and factors such as government budget limitations. The increasing need for "flat" land for industries, urban development and the creation of harbours has led to reclamation and dredging in some parts of the region, notably Seychelles. Here, the need for development land has led the government to reclaim large expanses of the reef flats and seagrass beds on the east coast of Mahé Island.

Tourism development has also been linked to degradation of coral reefs through increased discharge of municipal wastewater from high-density beach tourist sites (Edinger *et al.*, 1998; Fabricius, 2005), trampling (Hawkins and Roberts, 1993; Brown and Taylor, 1999) and increased demand for marine products such as seafood and marine curios. Tourism-associated SCUBA diving has destructive potential when in high concentration from boat and diver damage (Schleyer and Tomalin, 2000), yet conversely tourism may boost conservation efforts and the creation of MPAs that protect coral reef areas.

Underlying root cause 3: Inappropriate governance and/or ineffective governance

Poor governance, including institutional influences and other aspects that contribute to coral reef degradation in the WIO comprise (i) inappropriate and/or outdated legislation; (ii) failure to monitor and enforce existing legislations, (iii) lack of appropriate coastal development policies and associated planning, (iv) inadequate institutional capacities and (v) poor stakeholder or community participation. These underlying issues contribute to the problem of coral reef degradation by failing to prevent destructive practices in the coastal zone such as discharge of untreated municipal wastewater and run-off, poaching in MPAs, use of destructive fishing gears and physical damage caused by anchors, trampling and sedimentation. An in-depth analysis of governance-related issues is presented in Chapter 5 of this TDA.

The combined impacts of all the drivers of coral reef degradation are most visible as decreased coral cover, decrease in coral recruitment, reduction in reef structural complexity, loss of nursery areas, breakdown of inter-species relationship, reduction in coral biodiversity, decreased reproductive output of reef organisms, reduction in wave dampening leading to coastal erosion, and loss of fishing grounds. These primary impacts have a cascading effect, causing secondary impacts in the form of collapse in reef structure, reduced pristine nature and aesthetic value, and reduction in coastal fisheries productivity (Sheppard, 2003). In turn these lead to the loss of livelihoods and increased poverty among coastal communities.

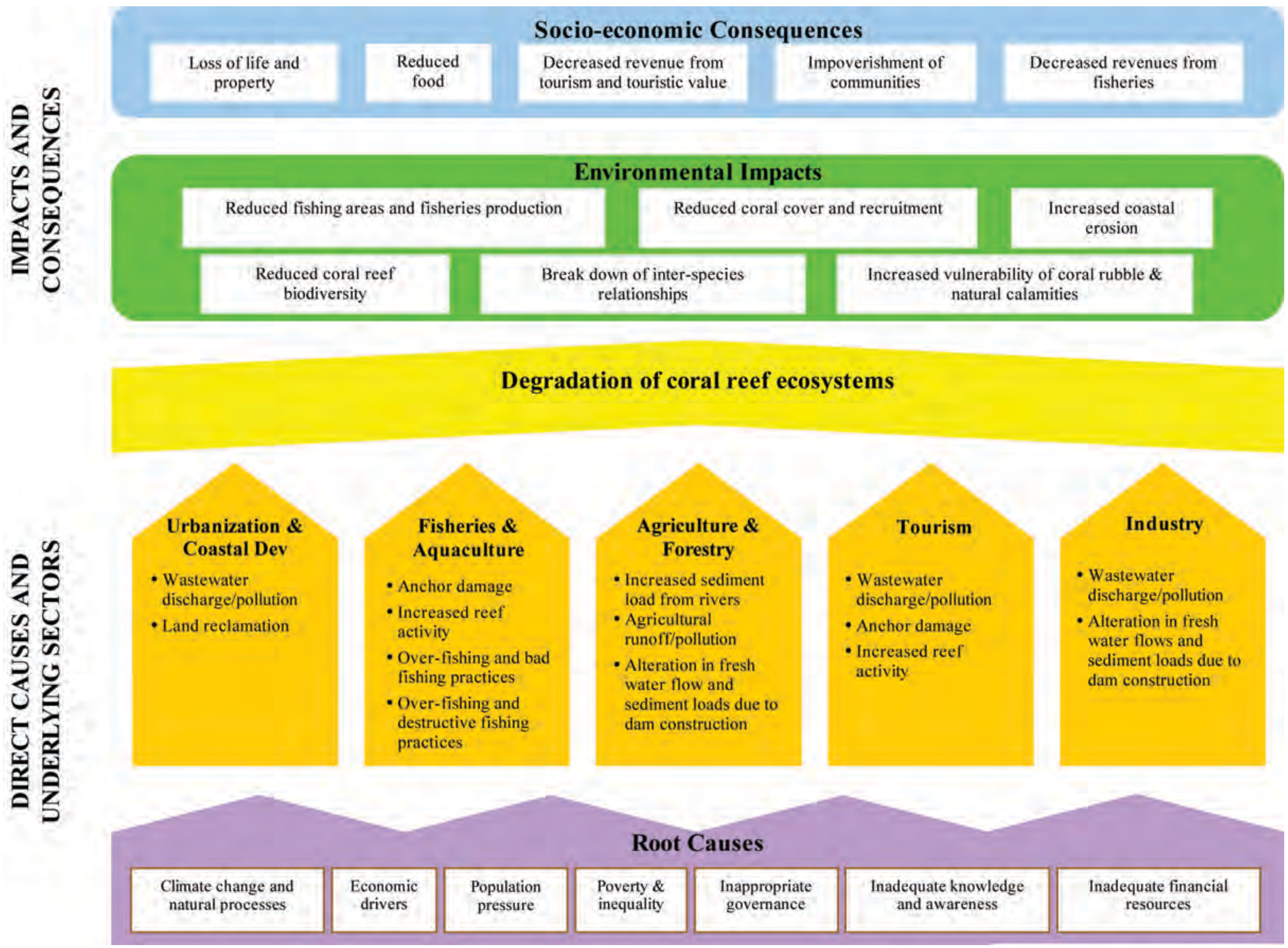
As more people migrate to the coast and as the world population continues to grow, it is expected that reef-based activities will continue to increase and that greater pressure will be exerted on the coral reef ecosystem. However, it is also encouraging to note that patchy recovery of coral reefs from impacts are being reported from many countries in the WIO region (Obura, 2002; Motta *et al.*, 2002; Linden *et al.*, 2002; Wilkinson, 2004; Payet *et al.*, 2005; Souter and Linden, 2005).

Risks, uncertainties and trends

There are several risks and uncertainties related to the analysis presented in this section. These are, most importantly:

- *Inadequacy of data* - The lack of data on the detailed spatial distribution and associated current status of coral reefs in the WIO hampers a better prediction of the actual trends of coral reef degradation and recovery in the region.
- *Uncertainties in trend* – Over-fishing seems to be a major cause of coral degradation in the region. Without alternative livelihoods, the region is likely to continue experiencing reef degradation. A positive trend could be the establishment of community-based fisheries organizations that may play a role in promoting good fisheries practices throughout WIO countries.
- *Trend* - Climate change impacts on coral reefs are becoming an important risk issue and threatening coral reefs in the WIO, though considerable uncertainties remain as to the ability of reefs to recover from impacts such as raised sea surface temperatures and bleaching.

Figure 4-13 Problem tree: Coral reef degradation.



4.3.5 Degradation of Coastal Forests

Problem Statement

Coastal vegetation generally comprises an assemblage of special plant species, ranging from unique coastal grasslands to large indigenous climax forests, some centuries old. Degradation of coastal vegetation and especially forests is predominantly the result of physical-mechanical activities in the form of land transformation through intense clearing for agriculture, mining, human settlement and coastal development, including tourism. There is also degradation and destruction associated with an increased demand for forest products such as timber and firewood. Increased populations in coastal areas are an exacerbating factor. Transformation of coastal forests impacts on the coastal environment through a reduction of plant and faunal diversity, resulting in soils prone to erosion, reducing recharge of groundwater aquifers and negatively affecting the development infrastructure. (Dubinsky and Stambler, 1996). Ultimately, these impacts change the dynamics of both sediment and water exchange in the coastal zone.

Transboundary elements

The transboundary context of coastal forest degradation in the WIO region is mainly attributed to the problem being shared, with only a few boundary areas supporting forests that are truly transboundary, such as parts of the Mozambique-South Africa and the Mozambique-Tanzania borders. In such situations, deforested areas can result in soil erosion adding sediment loads of rivers which are subsequently carried to coastal waters and beyond, increasing turbidity of waters of neighbouring countries. The single major shared problem is that most of the countries in the WIO region have to a certain extent experienced deforestation of coastal forests with considerable impacts on biodiversity.

Root-cause analysis

Most of the impacts on forests are as a result of clearing in order to open land for agriculture. human settlement, livestock grazing, supply of timber and fuelwood, urban and infrastructure developments (Brouwer and Falcão, 2004). Such degradation and loss of coastal forests and associated species is widespread. An estimated 60% of coastal forests in eastern Africa have already been converted over time to farmland and human settlement (Burgess and Clarke, 2000). Moreover, 75% of the remaining coastal forest areas have been flagged as to be highly or very highly fragmented (Younge *et al.*, 2002). According to WWF (2006), the major direct threats to the coastal forests are in ranked order:

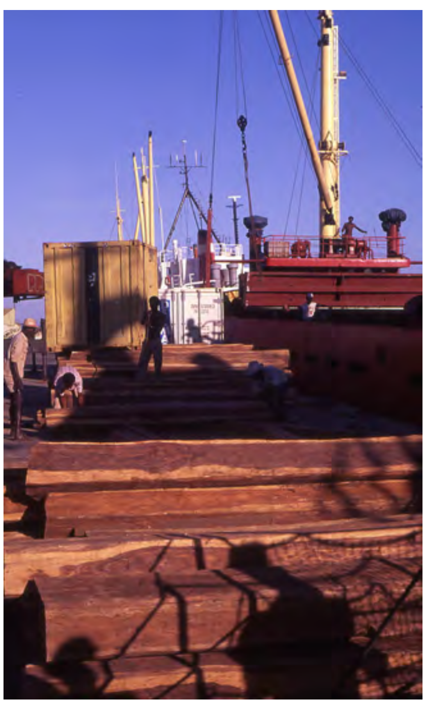
- expanding agriculture
- charcoal burning and firewood collection
- uncontrolled wild fires
- illegal logging
- unplanned settlement
- destructive mining practices

Agriculture is the major threat facing coastal forests. As the soils of coastal forests are generally poor and cannot easily support permanent agriculture, the type of farming practiced by most subsistence farmers at the coast is shifting agriculture, concentrating on food crops such as tomatoes, cassava, maize, millets, along with pawpaw, banana and citrus fruits. The high poverty status of the traditional coastal communities, as well as growing population pressures, tend to decrease the length of the fallow period (Younge *et al.*, 2002), thus the same piece of land is cultivated year after year leading to soil degradation and impoverishment. Plantations of sisal, coconut, cashew nuts and fruit trees have claimed a considerable area of coastal forests in WIO countries; particularly in Kenya's Arabuko-Sokoke (Githitho, 2004), Tanga and Pungu in Tanzania (Dallu, 2004) and northern Mozambique (Kanji *et al.*, 2004; Burgess and Clarke, 2000; Bandeira *et al.*, 2007b). In Kwa-Zulu Natal, South Africa, extensive areas of the Maputaland centre of endemism have been converted into exotic timber plantations (van Wyk and Smith, 2001). However, there is a trends to allow natural vegetation to return once timber harvesting has been completed. In the island states such as Mauritius and Madagascar, the native flora is being transformed and replaced by non-indigenous plantations such as sugarcane.

Fuelwood is the major source of energy for rural people in eastern Africa and charcoal is the preferred fuel in peri-urban areas (Brouwer and Falcão, 2004; Burgess and Clarke, 2000). The increased demand for fuelwood and charcoal in urban areas has led to an increase in deforestation of coastal forests (Burguess and Clarke, 2000;, Brouwer and Falcão, 2004). Although not well-documented, the business of charcoal production has heavily impacted forest areas of Arabuko-Sokoke and Ganze in Kenya, Pungu-Kazimzubwi (Tanzania) as well as northern Mozambique area (Younge *et al.*, 2002). Commercial logging of coastal forests occurs in Madagascar, northern Mozambique and remote areas of Tanzania and Kenya; with many forests intensively logged (Burgess and Clarke, 2000). Heavy exploitation for hardwood export has recently occurred in coastal forests of Rufiji, Kilwa and Lindi districts in Tanzania (Dallu, 2004) and similar logging for export to the Far East continues in the northern and central area of Tanzania (Kanji *et al.*, 2004).

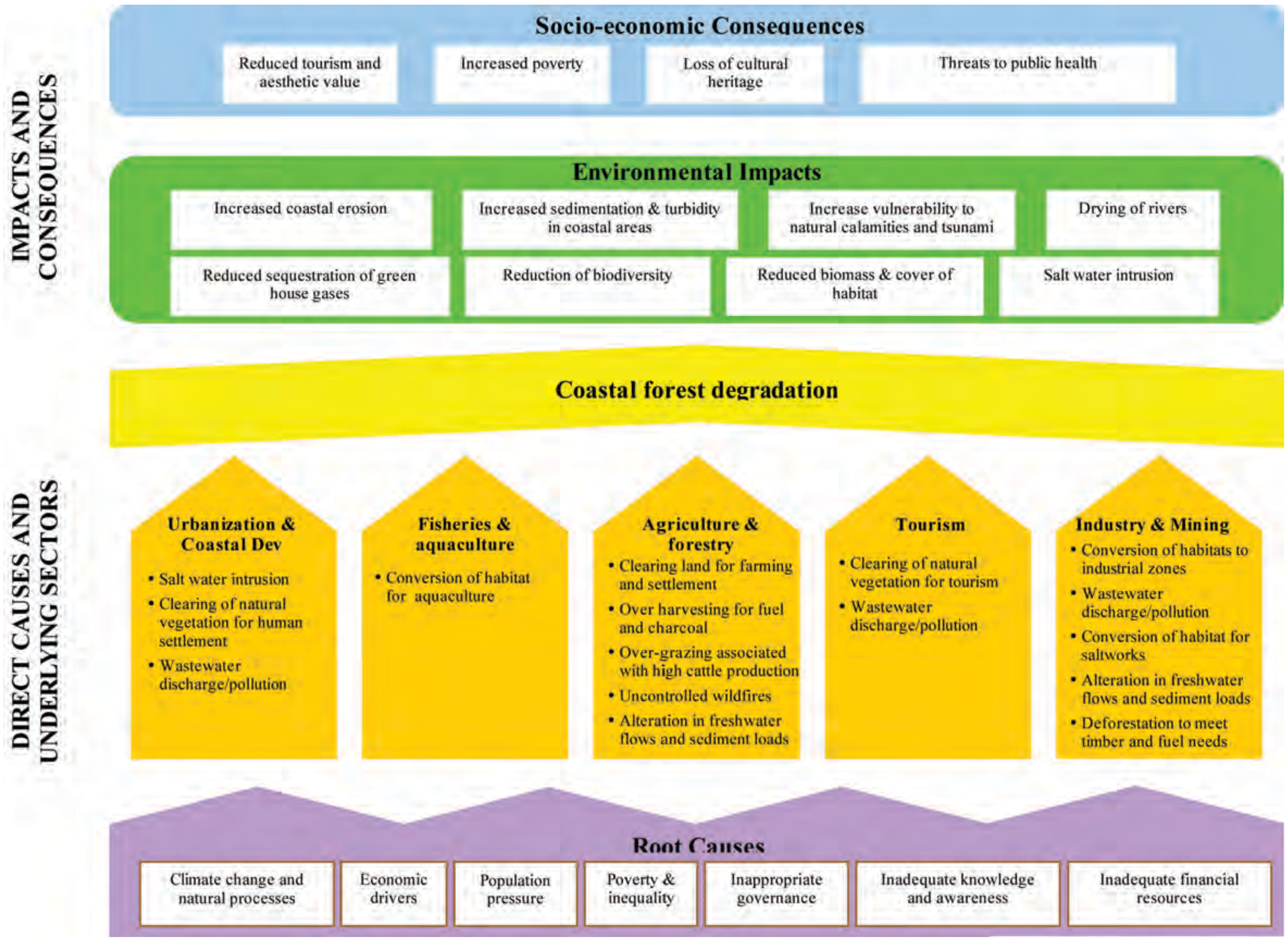
Coastal areas of the WIO region are endowed with huge deposits of mineral resources. Mining of iron ores, aluminium, titanium, gemstone, limestone, coral rag and silica has for example already destroyed large areas of natural habitats (Younge *et al.*, 2002). Future exploitation of these and other minerals present a threat to remaining coastal forests and grasslands. In South Africa, north of Richards Bay, extensive mining for heavy metals in coastal dunes that are clad in climax forests has resulted in extensive loss of indigenous coastal forests. In some instances rehabilitation is possible, as demonstrated by the Bamburi Cement quarry rehabilitation initiative in Kenya (Wass, 1995). At Richards Bay, extensive replanting of previously mined dunes with pioneer vegetation has proven successful, although full rehabilitation is likely to take at least 40 years.

Tourism development indirectly causes the degradation of coastal forests through increased demand for wood materials used for curios, in the construction of tourist hotels and also through increased demand for agricultural products. For local communities, the loss of livelihoods and cultural values associated with forests further increases their poverty. Additional socio-economic impacts include the reduction in the touristic value of the forest due to deforestation that physically reduces forest areas. These communities become further vulnerable to natural calamities such as droughts or floods. Destruction of coastal forests and climate change also affect large animal communities that live in forests. The coastal forests of eastern



The exploitation of forests for the export of tropical hardwood is an important cause of coastal forest degradation (photo courtesy of Rudy v.d. Elst, ORI)

Figure 4-14 Problem tree: Coastal forest degradation.



Africa are recognized as being of global importance, earmarked as of the 25 world's hotspots of biodiversity due to the high concentrations of endemic plants and animal species in exceptionally small areas (Bruton and Cooper, 1980; Burgess and Clarke, 2000).

Deforested areas experience high rates of soil erosion leading to high sediment loads of rivers and subsequent heavy sedimentation in coastal waters. The discharge of sediments from degraded lands leads to an increased turbidity of coastal waters with consequent impacts on the productivity of critical coastal ecosystems such as mangroves, seagrass beds and coral reefs. These impacts negatively reduce coastal and marine biodiversity. The reduction in the recharge of groundwater aquifers due to increased surface run-off from cleared areas leads to lowering of ground water table, drying of rivers and increased intrusion of saltwater.

Risks/uncertainties and trends

There are several risks and uncertainties related to the analysis presented in this section. These are, most importantly:

- *Habitat destruction, biodiversity change and impacts on marine habitats* - The lack of good baseline data makes it difficult to assess real changes in biodiversity and impacts on marine life due to coastal forest degradation.
- *Governance issues* – Uncertainty surrounds the responsibility for maintenance of the current levels of pristine coastal forests in the WIO region.
- *Extent of coastal forests* - The precise area of coastal forest in each country remains to be determined. A standardized assessment across the WIO region is needed to develop an agreed baseline assessment. The potential for rehabilitating coastal forests and grasslands needs to be evaluated.
- *Relationship to coastal ecosystems* - The importance of coastal forests to other ecosystems, especially coastal and marine systems remains to be better understood.
- *Economic value* - The economic value of coastal forest goods and services have not been clearly established.
- *Uncertainties in trends* - Coastal forest encroachment as a result of the development of settlements and tourism is already an ongoing process. Further reduction of coastal forests is foreseen over the next 20-50 years.

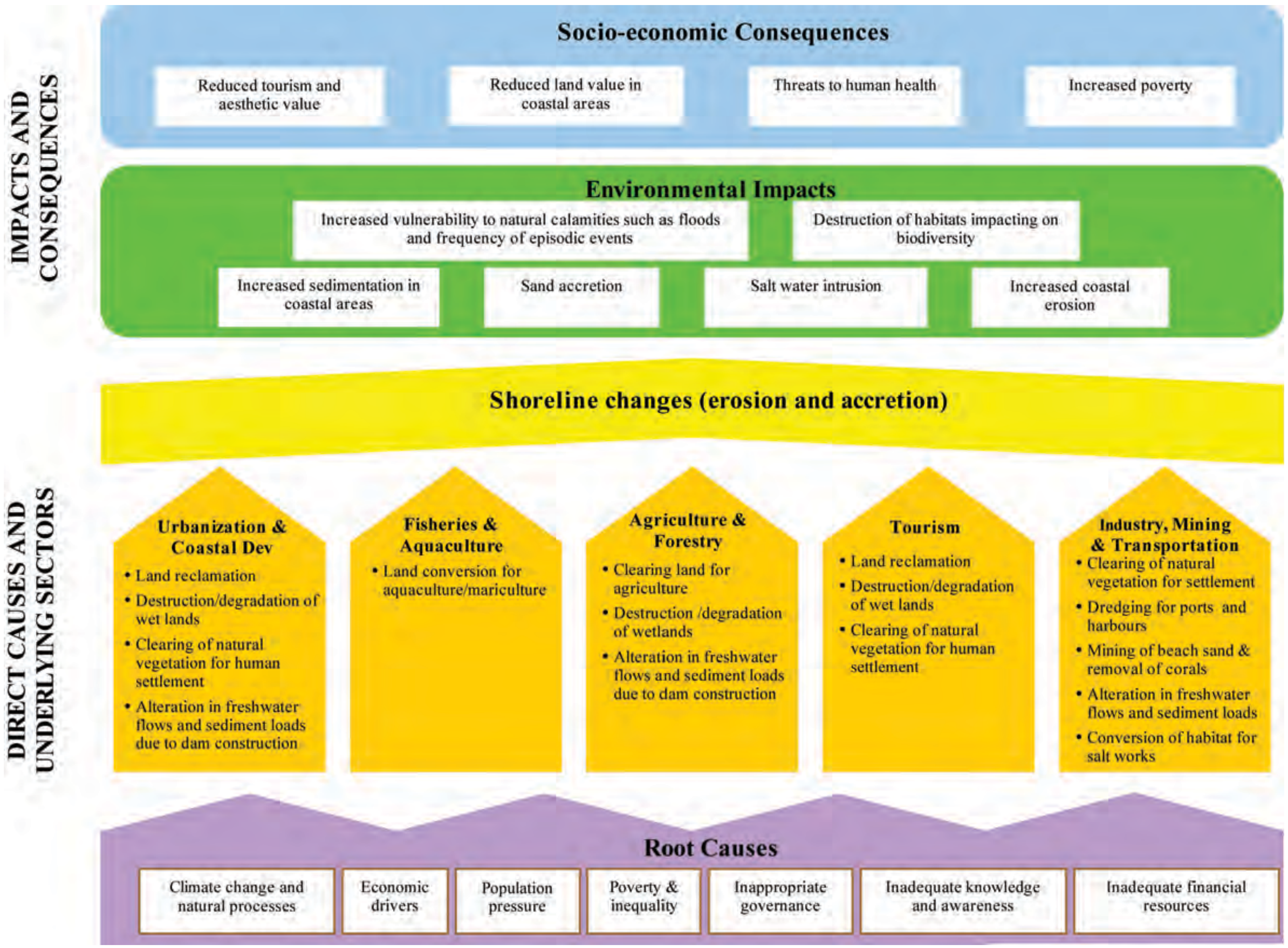
4.3.6 Shoreline changes

Problem statement

Shoreline changes, particularly those resulting from coastal erosion, pose serious threats to the coastal ecosystems and infrastructure development in the WIO (UNEP/GPA and WIOMSA, 2004e, IOC-UNEP-WMO-SAREC, 1994; Kairu and Nyandwi, 2000). Sedimentation and/or accretion of the coastline results in shoreline changes, generally from two sources: first, terrestrial sediments are carried to the sea by rivers, often derived from poor agricultural practices in the hinterland as well as deforestation, and secondly, re-suspension of benthic sediments by rough seas, vigorous longshore currents and at times through trawling over soft substrates.

In many parts of the WIO, coastal areas are dominated by loose sand and sediments which can erode rapidly. In some cases this has led to loss of land for agriculture, human settlement, infrastructure development as well as damage to coastal infrastructure, such as roads and buildings (Kairu and Nyandwi, 2000). Increased water turbidity, due to re-suspended sediments, interferes

Figure 4-15 Problem tree: Shoreline changes (erosion and accretion)



with the amount of light reaching corals and seagrass beds and, as the suspended sediments settle, they smother corals and seagrasses leading to loss of productivity, ultimately impacting on the system. In addition, coastal erosion has contributed to loss of critical ecosystems such as mangroves in Kenya, Tanzania and Mozambique through burial of their breathing roots leading to suffocation and eventually death of the trees. The socio-economic impacts of coastal erosion have serious repercussions on the livelihood and incomes of coastal communities.

Sea level rise is an additional problem of concern for low lying coastal areas, as is the case of the swampy coasts in central Mozambique, the west coast of Madagascar, and the Tana and Rufiji deltas. The Intergovernmental Panel on Climate Change (IPCC, 2001) has predicted that sea level will rise between 20 and 80 cm over the next century as a result of global climate change. Under this scenario, the low-lying coastal settlements are considered to be at risk, as the expected coastal inundation will displace a large segment of the coastal population and lead to major impacts on the socio-economic well-being of the coastal populations.

Transboundary elements

The most common transboundary issues associated with shoreline changes include modification and/or loss of habitat, increased coastal erosion/sedimentation, loss of property and increased poverty. The impacts of shoreline changes, either through sedimentation or erosion, are significant in all the countries in the WIO. The problem is most prevalent in Malindi –Mambrui area in Kenya (Abuodha and Kairo, 2001; Abuodha, 2003); NW coast of Madagascar (Joottun *et al.*, 1994); Beira and Macaneta Peninsula in Mozambique (Lundin and Linden, 1996; Kairu and Nyandwi, 2000) and Unguja Islands (Zanzibar) in Tanzania (Shaghude *et al.,* 1994). Some of the affected marine and coastal ecosystems, for example Tanga-Vanga and Lindi-Ruvuma systems, are cross-border areas. The silting of Mahajanga Port in Madagascar, as further discussed in section 4.4, can be viewed as a transboundary problem as the port was rendered useless thus affecting regional trade in terms of loss of revenue and livelihood. In this example, the transboundary issue is firstly economic in nature rather than environmental.

Root cause analysis

The main root causes of shoreline change in the region are high population pressure, poor and unregulated coastal development, restricted livelihood opportunities due to poverty, and increased economic growth in the coast areas, as shown in the problem tree presented in Figure 4-15. Climate change, which manifests itself in the form of increased episodic events, prolonged drought, desertification and flooding, exacerbates the transboundary impacts of shoreline change in the region. Natural processes contributing to shoreline change in the region include, among others, the combined action of waves, low coastal topography and nature of sediments, tides, winds and currents, variations in sea level, tectonic movement, precipitation and storms (Kairu and Nyandwi, 2000). Coastal erosion leads to loss of beach area, agricultural and settlement land, damage to coastal property or infrastructure, and destruction or degradation of important ecosystems. The principal sectors leading to shoreline change are urbanization and coastal development, fisheries and aquaculture, agriculture and tourism. Large scale dredging activities and port developments also contribute to changes in coastlines.

Increased population density along the WIO coastline has led to increased demand for food and shelter. For instance, around the Tana River (Kenya) and in central Mozambique, thousands of hectares of wetlands have been reclaimed for agriculture and human settlement in order to accommodate an increasing population. In addition to population pressure, shoreline change in the region is being caused by economic growth and increased demand for products and services. This is leading to the obstruction of natural nearshore tidal, current and sediment flows through the erection of coastal structures on beaches, such as those used by tourist hotels, marinas, harbours and beach jetties, many leading to accelerated shoreline changes (Kairu and Nyandwi, 2000).

In most of the WIO countries, there is little understanding among policy makers of the complex human-environment interactions, which provides an inadequate basis for sound policy making. For this reason, mangroves and catchment deforestation including destruction of wetlands; mining of beaches and sand dunes for construction materials and minerals, and the dredging for ports and harbours are proceeding without clear guidelines, causing land transformation and accelerated shoreline change.

The most obvious changes to shorelines are those resulting from changes in sedimentation, either as accretion or erosion of soft sediments. The Tana and Athi-Sabaki rivers in Kenya carry extensive terrestrial sediment to the sea (Kitheka, 2002a&b; Kitheka *et al.*, 2004). The increased discharge of these terrigenous sediments to the coast has caused accretion systems, as in the Athi-Sabaki estuary near Malindi (Kitheka, *et al.*, 2003 & 2005; Arthurton *et al.*, 2006). As a result, shoreline change has been particularly severe in the Malindi-Mambrui area. Between 1976 and 2003, the beaches at Malindi have widened by about 500 m due to this sedimentation processes (Kairu, 2003). Tanzanian waters also have zones of accretion, especially in relation to the Rufiji River which carries massive quantities of terrestrial sediments to the sea (Kairu and Nyandwi, 2000).

Conversely, eroding shorelines are reported from other sites, such as the Kenyan beaches of Kanamai, Shanzu, Nyali, Likoni, and Tiwi (Aboudha, 2003). In Tanzania, coastal erosion problems have been reported from parts of the mainland and the shores of Unguja Island (Zanzibar) (Shaghude *et al.*, 1994; Mohammed and Betlem, 1996). The most seriously affected sites include the Dar es Salaam coast (Msasani to Kunduchi); Tanga (Mwambani, Kigombe and Pangani delta); Mtwara (Mikindani) and Unguja (Jambiani – Bwejuu, Maruhubi).

Areas experiencing severe coastal erosion in Mozambique include Beira, Nacala, Macaneta Peninsula and Maputo Bay (Lundin and Linden, 1996; Kairu and Nyandwi, 2000). Historically the Zambezi River carried significant quantities of sediment to the ocean (Hoguane *et al.*, 2003), but for the past 40 years, the Zambezi delta has been experiencing erosion of about one metre per year (Kairu and Nyandwi, 2000). Maputo city and the surrounding areas experienced severe coastal erosion during the 2000 floods (Bandeira and Gell, 2003).

Coastal erosion poses serious threats to coastal ecosystems and infrastructure alike (photo courtesy of Rudy v.d. Elst, ORI)

Coastal accretion is observed in many areas on both the east and west coasts of Madagascar. These areas include Morondova, Mahajanga Port, at the mouth of the Betsiboka River, received 100 million cubic metres of sediment from upstream sources, killing mangroves and rendering the port inoperative (Rasolofoharinoro *et al.*, 1997; Kairu and Nyandwi, 2000). Beach-sand mining has led to erosion in the Comoros, while in Mauritius erosion has been documented in Flic en Flac, Le Morne, Riambel-Pomponette, Belle Mare and Grand Baie (Joottun *et al.*, 1994). In Seychelles, coastal erosion is more pronounced on the island of La Digue, Bird Island and Praslin as well as the East Coast of Mahe Island (Shah, 1994).

Table 4-18 Examples of eroding/accreting shorelines.

Site	Geology	Comments
Comoros Grande Comoros	Low volcanic rock cliffs and narrow coastal lowlands	Removal of beach sands for construction has reduced beach areas (Kairu and Nyandwi, 2000).
Kenya Malindi	Sandy beaches	Major beach accretion of micaceous sand has occurred since the 1960s.
Madagascar Morondova	Wide low-lying area	In 1953, the Morondova city lost 100 m of shoreline due to the swell and storm events (Kairu and Nyandwi, 2000).
Mauritius Flic en Flac	Sandy beaches are the most common and exposed basaltic cliffs in the northern end	Between 1980–1994, the position of high water mark at Flic en Flac moved inland by a distance of 8 m (Jootum et al., 1994). The ridge complex zone which runs parallel to the shoreline, stretching over 600 m and attaining 5 m high in some regions, has been mined for its good quality sand.
Mauritius Belle Mare	Sand beaches	Beaches receded by about 5 m in 1988 due to tropical cyclones (Jootum *et al.,* 1994).
Mozambique Beira	Sandy beaches, and coastal swamps	According to Lundin and Linden (1996), apart from natural causes, coastal erosion could be attributed to: inadequate maintenance of the buttress and sand retention wall, destruction of the dunes, mangrove and casuarina tree removal; removal of sand for construction, and building on beaches. Dam construction has also starved the coast of sediments.
Mozambique Maputo city	Sandy beaches	Floods, cyclones and swells accelerated erosion of the coastline north of Maputo, and the 2000 floods divided the small Chefina and Grande Island into two.
Seychelles Bird Island	Low-lying coralline island	Its south-western shoreline shift and recede naturally while, north-eastern shoreline is accreting (Shah, 1994).
Tanzania Mwambani,Tanga	Cliff erosion	Mwambani shoreline is characterized by a fringing reef platform bordered by a line of cliffs. The stretch is a high wave energy environment and fine sediment is lacking.
Tanzania Maziwi Island	Sandy island	The island disappeared in 1977/1978, attributed to sea level rise (Fay, 1992) and clearance of all vegetation (Shaghude *et al.,* 1994).
Tanzania Nungwi, Zanzibar	Sandy beaches	An erosion regime that threatened the village of in the early 1990s has been replaced by accretion.

Risk, uncertainties and trends

There are several risks and uncertainties related to the analysis presented in this section. These are, most importantly:

- *Uncertainties with regard to the extent of shoreline changes* – The problem of shoreline change in the WIO region has been studied and reported widely for some countries more than others.
- *Governance issues* - There is at present no comprehensive set of strategies (policies, legislation and regulations) in the WIO which is specifically geared towards addressing problems of shoreline change. Also, most countries in the WIO lack key government mechanisms such as Integrated Coastal Zone Management Programmes, guidelines or codes of conduct to address shoreline change. Consequently, there is large uncertainty as to what extent mitigation of shoreline changes will be implemented at least in the near future.

4.3.7 Stakeholder analysis

Various stakeholders were identified for all natural ecosystems discussed in this TDA. For most habitats, the main stakeholders were those involved with coastal resource use such as local communities and management authorities. Those identified for PADH are fisheries and aquaculture, agriculture and forestry, tourism, mining industry, management authorities, NGO's, local communities and scientists. The principal stakeholders involved at the root of each problem, were the resource users and management authorities, whereas at the impact level, the most affected include again the resource users especially the tourism and local community sectors. Several stakeholders were both at the root cause of the problems and were also affected by the degraded ecosystems (see Table 4-19).

Table 4-19 Analysis of sectors and stakeholder groups causing (C) PADH as well as those impacted (I) by such.

SECTOR	STAKEHOLDER	TRANSBOUNDARY PROBLEM									
		Mangroves		Coral Reefs		Seagrasses		Coastal forests		Shoreline change	
Fisheries and Aquaculture	Artisanal fishers		I	C	I	C	I				
	Industrial fishers		I		I		I				
	Seaweed farmers					C					
	Industrial prawn farmers	C	I								
	Fish and shellfish farmers	C	I			C	I		I		
Agriculture and Forestry	Charcoal makers	C	I					C	I		
	Small-scale loggers	C	I					C	I		
	Industrial loggers							C			
	Small-scale farmers							C	I		
	Large-scale farmers	C	I					C	I		
	Pastoralists							C	I		
	Ranchers							C			
	Poultry farmers							C			
	Dairy farmers							C			
	Beekeepers		I						I		
Tourism	Tourists		I	C	I		I		I		I
	Hotel owners/operators	C	I	C	I	C	I	C	I		I
	Small-scale traders	C	I	C	I	C	I				I
	Tourist boat/SCUBA operator		I		I		I				I

Mining	Coral/lime miners			C	I						I
	Sand miners							C	I	C	I
	Small-scale salt producers	C	I								
	Industrial salt works	C		C		C					
	Small-scale miners							C		C	I
	Industrial mining companies	C				C		C		C	I
	Fuel suppliers and stations										
	Oil and gas production	C		C		C					
Industry	Heavy manufacturing										
	Light manufacturing										
	Agro-processing industries										
	Oil refining							C		C	
Transportation	Ports	C		C		C		C		C	
	Dredging companies			C		C				C	
	Clearing and forwarding										
	Railway							C		C	
	Roads (incl. traffic)							C		C	
	Airports							C			
	Airlines										
	Shipping										I
Energy production	Hydro-dam operators										
	Power station operators										
	Renewable energy producers										
	Fossil fuel users		I		I		I		I		I
Urbanisation	Solid waste operators					C					I
	Sewage managers	C		C		C				C	
	Property developers	C	I	C	I	C	I	C	I	C	I
	Town planners	C	I	C	I	C	I	C	I	C	I
	Coastal communities	C	I	C	I	C	I	C	I	C	I

4.4 Problem Area 3: Alteration in freshwater flows and sediment loads from rivers.

4.4.1 Overview

One of the key areas of concern is the zone of interaction between river basins and the coastal and marine environment where the alteration and/or modifications of freshwater flows, of sediment loads, water quality and pollution are primary considerations. The seriousness of this concern is underscored by among others the Land Ocean Interaction in the Coastal Zone (LOICZ) Global Change Assessments and Synthesis of River Catchment – Coastal Sea Interaction and Human Dimension of African Basins (see LOICZ Reports and Studies No. 25, 2002) as well as the preliminary Transboundary Diagnostic Analysis for the WIO region (UNEP, 2002).

Around much of the region many of the coastal issues are linked to human activities and climatic variability that are distant, often far removed from the coast. Such up-country pressures have altered the nature of the drainage through the river systems – large and small – impeding the flow of freshwater, terrigenous sediment and organic matter. They have also affected the quality of the water, mainly through the addition of nutrients and pollutants from domestic sewage and industrial and agricultural chemicals (Crossland *et al.*, 2005).

The focus of this section of the TDA is on the main rivers flowing into the south-west Indian Ocean. The overview will cover information on hydrology, environmental issues such as water quality, flow alteration, sediment loads, etc. It will highlight main current environmental impacts related to freshwater flows, and analyse their drivers and impacts. For the purposes of this section of the TDA, the area of interest is the outflow of the river – where it transforms from being a freshwater system via an estuary into the saltwater marine environment. Thus, the issues may vary in different parts of the basin, but cumulatively there is an impact in the outflow area – be it a delta, estuary or a linear river mouth.

There are two key problem areas, and a number of associated issues, analysed in this section of the TDA:

A. Alteration of river flow and degradation of water quality:

- a) Quantity of water at river mouth
- b) Timing of the flows at the river mouth
- c) Quality of water at river mouth

B. Alteration in river sediment loads:

- a) Increase in sediment load at the river mouth
- b) Decrease in sediment load at the river mouth

Associated causes

The most important transboundary environmental impacts associated with alteration of river flow and degradation of water quality, as well as the most important causes and sectors associated with such problems are summarized in Tables 4-20 and 4-2 respectively. From these summary tables, it is apparent that there are several problems that contribute to a specific impact or consequence and *vice versa*. There are also several direct causes linked to each specific transboundary problem. These can roughly be attributed to six key underlying sectors, namely:

- Urbanisation
- Agriculture and Forestry
- Industry
- Mining
- Transportation
- Energy production

Each of the above sectors has potential impacts on one or a combination of river flow, water quality and sediment loads. Southern and eastern Africa is becoming increasingly urbanized, with some of the largest cities in the region located in basins included in this study – such as Nairobi in the Athi-Sabaki and Johannesburg and Pretoria in the Limpopo basins. Increased urbanization leads to an increase in paved areas, reducing infiltration of rainfall to the soil. A reduction in the holding capacity of the terrain leads to flash-floods during periods of intense rainfall, with possible increases in soil erosion in the lower reaches of catchments. Urbanisation results in an increase in water consumption. To accommodate this, large-scale water storage and transfer infrastructure has been constructed, with dams, impoundments and weirs altering the flow regime of rivers as well as trapping sediments.

Much of the population in the WIO region, especially in the hinterland of the upper-reaches of the basins in the study, is heavily dependant on agriculture and forestry. These activities are associated with heavy water consumption – both through interception of rainfall (thus leading to a drop in groundwater levels) as well as through the evapo-transpiration of irrigated water. Intense or inappropriate farming techniques, such as planting on steep slopes or deep drainage furrows, can also lead to an increase in erosion with sediments reaching the main flow of the river. Furthermore, the return flows from fields frequently have elevated levels of nitrates, phosphates, salts and other pollutants such as herbicides and pesticides, which could impact river water quality.

Accompanying, and in some cases driving, the increased urbanization is industrial development in various parts of the river basins of the region. From these industries there is the potential for organic and inorganic pollutants to reach the lower reaches of the rivers, while the increase in water use also raises the possibility of reducing the dilution capacity of the rivers.

Mining is a mainstay of economic development in much of the region. Although precautions are generally taken to ensure that environmental impacts from mining activities are minimized, there exists the potential for the contamination of water resources from mine water runoff. This has already become an issue in the headwaters of the Limpopo River where acid mine drainage from decommissioned gold mines on the Witwatersrand has found its way into the groundwater (Coetzee *et al.*, 2005). In addition to large-scale mining activities, there are in several parts of the basins of the region small-scale, unregulated or illegal, mining activities. These lead to erosion of river banks during the digging and panning process, increasing the sediment load and turbidity of the rivers. Numbers of these on a single system result in significant effects particularly in lower catchments and can irreversibly alter ecological goods and services afforded by estuaries.

The transportation sector has impacts on river basins in areas where road networks have been covered with impermeable surfaces. This reduces water infiltration to top soils leading to increased runoff and less tolerance to heavy downpours and flash floods, causing soil erosion and an increase in sediment loads. Dirt roads, through their construction as well as long-term use, may also increase soil erosion, conversely by exposing bare soil (cleared of vegetation) to the rain.

Several countries in the region rely extensively on energy produced by hydro-electric power schemes – important for Kenya, Tanzania and Mozambique. Much like dams constructed for water-supply these hydro-power dams alter the flow regime of rivers and trap sediments. The Cahora Bassa Dam on the Zambezi River has had an impact on its delta area by encouraging coastal erosion and reducing the nutrient supply carried downstream by floods (Turpie, 2006; Brown and King, 2002). In South Africa, large amounts of water are taken from rivers for wet cooling of thermal power stations, impacting particularly the Limpopo and Incomati rivers once the warmed effluent is returned to the rivers.

At the root-cause level, seven common factors contribute to environmental problems related to river-coast interaction in the WIO region:

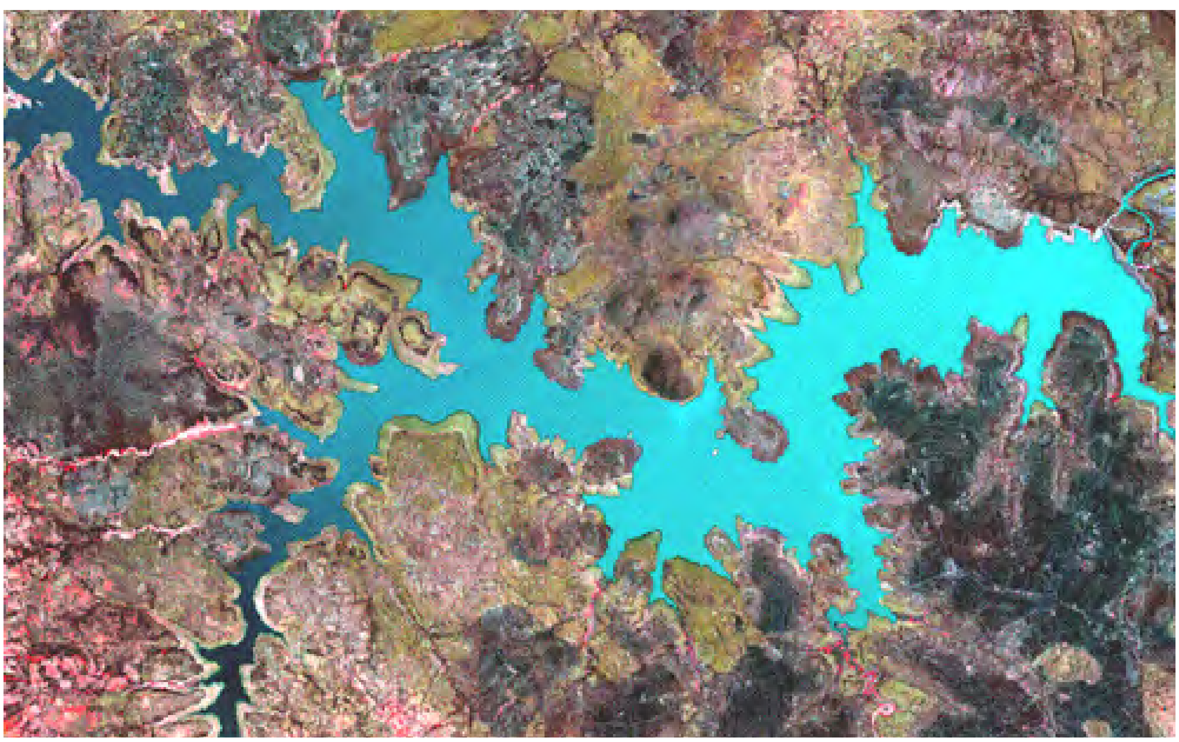
- *Climate change and natural processes* – Climate change and natural events to an important extent influence river flows, turbidity and sediment transport. For example, Mozambique has in recent years had several severe floods impacting on the floodplain and the delta in the lower reaches of the Zambezi and Limpopo rivers. Most of the region is characterized by large spatial as well as temporal variations in rainfall. Year-on-year variation around the long-term norm for various parts of the region is as high as 30–35% (Earle and Malzbender, 2007). This natural climatic variability is exacerbated by human induced climate change. Temperature increases of between two and six degrees by the end of the 21st Century have been predicted by the IPCC (2005) for much of the region, though the exact impact is more difficult to predict, with some areas experiencing an increase and others a decrease in rainfall. What seems likely though is that there will be an increase in what is termed "extreme events" – floods and droughts following on from each other (UNEP, 2005). This is likely to increase stress on the river systems in the region by increasing soil erosion and sedimentation and, in places, increasing pollution concentrations where average water volumes decline. It is also likely that there will be decreased freshwater flows to the coast in times of drought.

- *Economic growth* - Increased demands for limited water resources due to economic growth in the region results in growing competition over the resource between different sectors and the construction of more dams on rivers. Several countries in the WIO region have, over the past half century, experienced high levels of economic development, with a commensurate increase in water use in river basins for industry, mining, urban development, agriculture and energy production (TPTC, 2001; Arthurton *et al.*, 2002; van der Zaag and Carmo Vaz, 2003; Hoguane et al., 2009). This trend is likely to continue with several countries in the region already experiencing electricity shortages due to the increase in demand from industrial users. The response in South Africa has been to plan the construction of new power stations, such as the dry cooled Medupi plant in the Limpopo River basin. With electricity production currently the largest user of water in that country, and forecast to grow, this will likely lead to increased demands for water on the resources of the Limpopo and Incomati rivers.
- *Population pressure* – The increased demand for water resources by growing populations can change river systems irreversibly. For example, in the Pangani River basin (Tanzania) where increased water use of the Luengera and Mkomazi rivers, which were historically perennial, has now led to only seasonal flow (PBWO/IUCN, 2007). All of the countries in the region are experiencing medium to high rates of overall population growth, which in the context of a finite supply of water resources, equates to ever greater demands on existing supplies (Hirji *et al.*, 2002).
- *Poverty and inequality* – Due to limited resources, people engage in unsustainable land-use practices, such as over-stocking of cattle leading to over-grazing and therefore increased run-off of nutrients and soil erosion. Other harmful practices are the inefficient application of fertilizers and use of (often cheap) harmful pesticides leading to compromised river water quality. Poverty and inequality are also at the base of large-scale deforestation for fuelwood and building materials in many areas at the coast, which is at the root of increased soil erosion and sediment load to rivers.
- *Inappropriate governance* - The lack of inter-sectoral coordination, notably little or no involvement of different water-use sectors, with different sets of priorities in the management of the resource, leads to the misuse of the resource. This is widespread in the region, often with no, or inadequate, intervention and governing regulatory instruments. The inclusion of stakeholder views, knowledge and interests is also limited. The lack of information and data in some areas of the nature, causes and impacts of environmental problems, and weakly enforced legislation, compounded by the lack of harmonised legal and institutional frameworks for the management of transboundary rivers has allowed the deterioration of river and adjacent coastal areas. Fortunately, these issues are increasingly being addressed,

with a more detailed analysis of governance related issues presented in Chapter 5, section (5.3.6) with particular relevance to river basin management structures.

- *Inadequate knowledge and awareness* – This concerns two important factors:
  - Shortcomings in information and data (in some areas) of the nature, causes and impacts of environmental problems. For example, in the Pangani River the melting of glaciers on Mount Kilimanjaro has increased streamflow at certain periods in some of the tributaries, making it difficult to determine whether increased water abstraction has had an impact on overall streamflow or not (PBWO/IUCN, 2007).
  - Lack of awareness of stakeholders of the impact of their activities on other stakeholders and the ecosystem as a whole. For instance, in the Incomati River water is abstracted for cooling power stations and for use in irrigated agriculture, with the result that there is an increase in salt water intrusion from the marine environment into previously freshwater reaches of river systems (TPTC, 2001).
- *Inadequate financial resources and human capital* – There is limited financial and human resource capacity for effective implementation and monitoring of agreements and comprehensive water management regimes.

The impacts on the coastal and marine environment of changes in river flow and sediment load from rivers of the WIO, results in physical alteration and destruction of habitats, the degeneration of water quality and a combination of these issues. In particular these changes impact on the many estuaries of the region and which represent enormously important habitats for sustaining mangroves, seagrass beds and nurseries or refugia for a wide range of important fish and crustacean resources. In other words, the actual effects relate back to the two main categories of transboundary problems that were analyzed in sections 4.2 and 4.3. For this reason, the secondary environmental impacts and related socio-economic consequences related to river-coast interactions are not dealt with in this section, but for further analyses on these aspects, the reader is referred to the respective sections of this TDA.



In most major rivers in the WIO region multiple dams have been constructed for the creation of water reservoirs and the generation of hydropower (photo Landsat image of Masinga dam and reservoir on the Tana River)

Some of the main specific issues related to each of the twelve river basins are introduced below:

Tana River

Since the development of the hydropower dams on the Tana River there has been a 56 % decline in sediment load to the Tana Delta (Kitheka *et al.*, 2004d). This drop has led to the erosion of beaches along the Tana Delta/Ungwana Bay (Otieno and Maingi, 1983; Kitheka *et al.*, 2002b;, 2003d & 2005) and a loss of wetlands and mangroves in the delta (IUCN, 2003). The flow regime is highly variable, both year on year as well as seasonally. Some studies suggest that there is a long-term increase in runoff from the basin – however the reliability of the data cannot be confirmed (Kitheka *et al.*, 2004 & 2005). Although there has been an increase in the use of agro-chemicals in the Tana Basin, expected to lead to increased nutrient levels (Davis, 2000), the chemical water quality at the Delta has not reflected major deterioration although nutrients levels are generally high at the Tana Delta (Kitheka *et al.*, 2004).

Athi-Sabaki River

The Athi-Sabaki River has over the past five to six decades experienced a major increase in sediment load at the estuary (van Katwijk *et al.*, 1993; Kitheka *et al.*, 2002b, 2003a, 2003c & 2004). One of the prime causes of this is poor land-use patterns in the catchment, with intensive agriculture (both small-scale as well as large-scale farming, including livestock and wildlife over-grazing) leading to soil erosion (van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007). This has been coupled with an increase in rainfall in the catchment as well as a reduction of rainfall infiltration – all contributing to an increase in soil weathering and erosion (Snoussi *et al.*, 2004; Kitheka *et al.*, 2004). There is evidence that this increase in sediment transport started at the time of British colonial settlement in the central highlands of Kenya, when there was a shift from traditional subsistence agricultural practices to more intensive land use (Champion, 1933; Dunne, 1974 & 1975; Dunne and Ongwenyi, 1976; Fleitmann *et al.*, 2007). The consequences of this large increase in the sediment load from the river include the siltation of Malindi Bay, deposition of sedimentary matter and debris on beaches rendering them unappealing to tourists, and the degradation of nearby coral reefs and seagrass beds through suspended solid settlement and decreased water clarity (van Katwijk *et al.*, 1993; Snoussi *et al.*, 2004; Kitheka *et al.*, 2004; Fleitmann *et al.*, 2007).

Pangani River

According to the Pangani State of the Basin Report the "main causes of (Pangani) river degradation are: changes to the flow regime; changes to the channel and riverbed, including the extent of inundated areas such as floodplains; changes to water quality due to pollution; and the presence of alien plants and animals" (PBWO/IUCN, 2007). In the Pangani catchment, power production at the Nyumba ya Mungu Dam relies on storage of water during rainy seasons and a constant release of water through the turbines (PBWO/IUCN, 2007). Regulation at the dam also results in a relatively even flow through the year to the downstream power stations at Hale and New Pangani. The Nyumba ya Mungu Dam on the Pangani River and Kalimawe Dam on the Mkomazi River thus have the effect of smoothing-out the flow regime experienced at the estuary, significantly changing the natural hydrographic pattern (Lugeiyamu, 2002). In the dry season, the low flows are still present due to constant dam releases, but any higher flows are withheld by the dams. In the wet season, large floods still move down the system but smaller floods and a proportion of the low flows are trapped by the dams between floods. Thus, the flow is lower than natural (PBWO/IUCN, 2007). The quality of the water in the river generally deteriorates from upstream to downstream (Lugeiyamu, 2002), and most of the lower reaches of the river are classified by the State of the Basin Report as being "largely modified[11]" for parameters such as water quality, stream morphology and aquatic life. Poor quality is mostly related to increased levels of dissolved salts, nutrients, faecal coliforms, decaying organic material and turbidity in various parts of the system (PBWO/IUCN, 2007). Dissolved oxygen levels in the estuary are very low, especially in the upper reaches before the diluting effect of seawater plays a role.

Rufiji River

The Rufiji River, like the Athi-Sabaki River in Kenya, is one of the last undammed rivers (on the main stem) in the region (Shaghude, 2004). This makes it an interesting system to study, providing a valuable baseline against which to compare the situation after any future dam construction – such as the proposed hydro-power dam at Stiegler's Gorge. At present there is some degree of water quality degradation in the Delta region, mainly as a result of DDT applied by rice farmers to combat freshwater crab damage to seedlings (Kulindwa *et al.*, 2001) though contamination is at a low levels and seems to be locally confined. Nutrient flows from agricultural activities upstream in areas around Mbeya and Iringa are high, but again, most of this is broken down or absorbed by the ecosystem prior to it reaching the delta (Mwalyosi, 2004). The flow of water and sediment also appears to be stable, with no significant changes noted. Building of dams, such as the one proposed at Stiegler's Gorge, would have the main impact of trapping sediments being transported downstream – preventing them from reaching the delta. Reduction of the fine sediments means reduction in the average supply of nutrients to the floodplain and delta. This is expected to have significant consequences to agriculture and the deltaic and offshore ecology (Shaghude, 2004).

Ruvuma River

The hydrology of the Ruvuma River has not been systematically studied, thus little is known of changes in flow rates or quantities or about sediment load (Francis *et al.*, 2002; DNA, 2004; Lerise, 2006). Floods and a high sediment load seem to be a natural part of the flow regime, with no evidence of anthropogenic drivers (DNA, 2004). The remoteness of the river and relatively low population densities in the catchment has meant that some of the best preserved mangrove forests along the coastline are found in the estuary (Kyewalyanga, 2004).

Zambezi River

The construction of the Kariba and the Cahora-Bassa dams has had the dual impact on the Zambezi Delta of reducing sediment load and reducing the seasonal variability of flow (ZRA, 1998; Beilfuss, 1999; Chenje, 2000; Brown and King, 2002; Turpie, 2006). According to a study by Gammelsrød (1996), as cited by the ZRA (1998) report, "in the case of the Zambezi River the construction of Cahora Bassa Dam in Mozambique has had a significant impact on fisheries, particularly along the Sofala Bank at the River mouth". This has bearing to the shrimp *Fenneropenaeus indicus (previously Penaeus indicus)*, for example, there is a close relationship between river runoff and abundance. Regulation of river flow has two main impacts on this shrimp: (a) increased runoff during the dry season is likely to set up currents heading offshore strong enough to prevent the larvae from entering nursery areas and (b) after having developed to a juvenile state in the nursery areas, a strong rainy season runoff facilitates high levels of recruitment to the fisheries - because higher runoff flushes a larger area and creates a stronger offshore current" (ZRA, 1998).

11 Ecological state: Severe modification with major disruptions in ecosystem functioning; mostly tolerant species remaining, often to pest proportions; alien species common; plants and animals may be diseased (PBWO/IUCN, 2007).

The economic losses from reduced fisheries landings, due to the reduction in nutrients entering the Indian Ocean at the Sofala Bank fishery (Arthurton, 2002), following alterations to the Zambezi River freshwater flows has been estimated at between 10 and 20 million USD (Turpie, 2006). In addition, there has also been a large reduction in the extent of the mangrove forests, due to desiccation following reduced freshwater flows (Beilfuss, 1999), while the reduced sediment load has led to increased coastal erosion.

Pungwe River

The Pungwe River has experienced a large increase in abstraction of water for use in agriculture, urban areas and industry (Van der Zaag, 2000; Hoguane *et al.*, 2002). This abstraction is taking place at various points throughout the basin, including the headwaters in Zimbabwe and the mid and lower reaches in Mozambique. No comprehensive studies have so far been carried out to assess whether there is a substantial change in the flow regime received at the Pungwe Delta (Van der Zaag, 2000; Hoguane *et al.*, 2002) thus no pressing issues have been identified related to the freshwater flow of this river into the ocean, other than the fact that coastal erosion in the area does seem to be increasing (Hoguane *et al.*, 2002).

Limpopo River

The water of the Limpopo River is heavily used by the four basin states (Botswana, South Africa, Mozambique and Zimbabwe). Agriculture (large and small scale), mining, industry, energy production and urban water use are all significant water consumers. The large number of dams in the basin (over 40), coupled with direct abstractions, has reduced the annual flow of the river significantly (Arthurton *et al.*, 2002; Louw and Gichuki, 2003; Anon Mozambique, 2006). The reduced flows in the lower reaches of the river have lowered the potential for the river to absorb pollutants. Thus water quality degradation, emanating from the sources above, is a problem, with high concentrations of chromium, copper, iron and manganese found in the gills, liver, muscle and skin of freshwater fish in the river (Louw and Gichuki, 2003). There has also been an increase in seawater intrusion into the floodplains in Mozambique, negatively affecting agriculture (Arthurton *et al.*, 2002). The Limpopo reaches the Indian Ocean cutting through a coastal dunes belt by a narrow river mouth lacking any deltaic features. This partly indicates the prevalence of natural ocean forces over the river mouth in creating the physical environment of the narrow coastal zone whereby typical river-ocean interrelations are confined to a relatively small coastal and marine area (Louw and Gichuki, 2002). The most significant direct impacts to reduced freshwater flows are the intrusion of the ocean saline water into the river course during high tides and the spread of sediment in the nearshore sea, particularly suspended particles which on extreme floods may be transported long distances by longshore currents.

Incomati River

Due to the heavy utilisation of its water resources, the flow regime of the Incomati River is significantly altered. Water quality has decreased in some areas (Hoguane *et al.*, 2009) but at present, flow alteration due to impoundment and abstraction from those impoundments has the biggest impact on the system and the estuary. The estuary has suffered from reduced freshwater inflows and sediment deposition (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009), leading to salt intrusion and sediment deficit, and consequently erosion. Hoguane (2000) observed salt intrusion up to about 40 km upstream. There are currently numerous dams in the system and further dams are planned, which would potentially aggravate the described impacts on the estuary (TPTC, 2001).

Table 4-20 Overview of common environmental impacts and socio-economic consequences associated with alteration of river flows, quality and sediment loads.

TRANSBOUNDARY PROBLEM				COASTAL IMPACTS
Alteration of river flow	Water quality degeneration	Increased sediment loads	Decreased sediment loads	
				IMPACTS ON COASTAL HABITATS AND SHORELINES
X				Increased salinisation of agricultural land (flood plain agriculture) due to lack of flooding
X	X	X	X	Modification of ecosystem (riverine and estuarine) community structure and dynamics
X				Loss of wetlands due to lack of flooding and erosion
X	X	X	X	Decreased natural productivity due to changes in habitats, nurseries and spawning areas (e.g. vertebrate and crustacean fisheries)
X				Changes in habitats of terrestrial fauna including birds
X	X	X	X	Reduction of available natural living resources (fauna and flora)
X				Loss of natural estuarine/river mouth riparian habitat resulting in human encroachment onto floodplain and subsequent loss of buffering benefits to flooding from upstream and sea storms
X	X	X	X	Loss of biodiversity
		X	X	Shoreline changes (erosion/accretion)
		X		Coral reef degradation
X			X	Mangrove forest degradation
				IMPACTS ON WATER QUALITY
X	X			Water quality degeneration due to decreased absorption capacity
	X			Water quality degeneration due to increased pollutant loads from rivers or decreased dilution factor through reduced flows
X				Increased salt water intrusion into downstream end of rivers
		X		Increased turbidity, siltation and at times eutrophication of estuarine and coastal waters

Table 4-21 Overview of common causes and sectors associated with alteration of river flows, quality and sediment loads.

TRANSBOUNDARY PROBLEM				IMMEDIATE CAUSES	UNDERLYING SECTORS
Alteration of river flow	Water quality degeneration	Increased sediment loads	Decreased sediment loads		
X	X		X	Damming of rivers, construction of off-channel impoundments, weirs	Energy, Agriculture and Forestry, Urbanisation
X	X			Direct water abstraction for urban water supply, irrigated agriculture and wet process mineral mining	Agriculture, Urbanisation, Mining
X			X	Inter-basin water transfer	Energy, Urbanisation
X				Hydrological variability	N/A
	X	X		Poor land-use	Agriculture
	X			Agricultural runoff of nutrients and pesticides	Agriculture
	X			Wastewater discharges	Urbanisation, Industry, Mining, Energy
	X			Stormwater runoff	Urbanisation
X		X	X	Changes in vegetation types and patterns (including afforestation)[9]	Agriculture and Forestry
X		X	X	Alteration of climatic conditions	N/A
		X		Unsustainable agricultural techniques (e.g. slash and burn)	Agriculture
		X		Deforestation	Agriculture and Forestry
		X		Encroachment on river banks[10]	Urbanisation
		X		Mining of sand and aggregates[10]	Mining
		X		Road development	Urbanisation
			X	Canalization and impoundment of river reaches for navigation purposes[10]	Transportation

9 Includes also direct abstraction by large-scale non-indigenous plantations.
10 Note: to some extent, such causes may even lead to alteration in river flow. However, generally such consequences are relatively limited and localized and therefore not highlighted in this analysis.

Table 4-22 Overview of the main issues related to freshwater flow in the basins

River	Flow Issues	Quality Issues	Sediment Issues	Main Issues
Tana	Variable (Kitheka et al., 2002b, 2003b-d & 2005)	Stable (Kitheka *et al.*, 2005)	Decrease – but not critical (Snoussi, 2004; Kitheka *et al.*, 2003b&d)	• Reduction in sediment load due to construction of the HEP dams in the Upper Tana Basin (Ongwenyi, 1979 and 1983; Dunne and Ongwenyi, 1974 and 1976; Kairu, 1997; Kitheka *et al.*, 2003c). • Salt water intrusion and erosion of the mangrove colonised delta (Kitheka et al., 2003b&d)
Athi-Sabaki	Variable, possible (Fleitmann et al., 2007, Kitheka *et al.*, 2002b & 2003c)	Stable – slight decrease (Kitheka *et al.*, 2004)	Increase (Fleitmann *et al.*, 2007, Kitheka *et al.*, 2002b, 2003a&c & 2004)	• Increased siltation of the estuary and Malindi Bay resulting in degradation of the coral reef ecosystem at Malindi (van Katwijk et al., 1993; Kitheka *et al.*, 2004)
Pangani	Decrease (PBWO/IUCN, 2006a).	Decrease (PBWO/IUCN, 2006a).	Small Increase (PBWO/IUCN, 2006a and (PBWO/IUCN, 2007).	• Reduced freshwater flows resulting in increased sea water intrusion in the estuary (PBWO/IUCN, 2007). • Reduced water quality, particularly increased oxygen demand (PBWO/IUCN, 2007).
Rufiji	Stable – small increase (Shaghude, 2004)	Stable	Variable	• Limited water quality degradation due to agricultural runoff including nutrients and pesticides (Shaghude, 2004; Kulindwa et al., 2001)
Ruvuma	Stable	Stable	Small Increase	• Destructive fishing practices have led to a drop in biodiversity, negatively affecting seagrass beds (Francis *et al.*, 2002)
Zambezi	Decrease and less fluctuation (Turpie, 2006; Brown and King, 2002)	Stable – slight decrease	Decrease (Turpie, 2006; Brown and King, 2002)	• Drop in sediment loads has led to landward erosion of the delta and sea water intrusion into the lower catchment. • Size of delta has reduced from 18,000 km2 in 1977 to around 15,000 in 1998 (Chenje, 2000). • Decreased variability of seasonal flow negatively impacting fisheries (Turpie, 2006; Brown and King, 2002).
Pungwe	Small Decrease (Hoguane, *et al.*, 2002 and Anon Mozambique, 2006)	Stable	Stable	• Decrease in riverflow, due to increased abstraction upstream, is accelerating coastal erosion and salt-water intrusion through the estuary (Anon Mozambique, 2006; Van Der Zaag, 2000)
Limpopo	Decrease (Arthurton, *et al.*, 2002)	Decrease – not critical (Louw and Gichuki, 2003)	Decrease – not critical (Louw and Gichuki, 2003)	• Streamflow reduction, nutrient depletion, biodiversity loss and salinisation receive impact codes of between 6 and 9 out of 10 in the LOICZ study (Arthurton *et al.*, 2002)

Table 4-22 Overview of the main issues related to freshwater flow in the basins

Incomati	Decrease (Hoguane *et al.*, 2009; TPTC, 2001; Van der Zaag and Carmo Vaz, 2003)	Decrease (Hoguane *et al.*, 2009; TPTC, 2001)	Decrease (Hoguane et al., 2009; Van der Zaag and Carmo Vaz, 2003; TPTC, 2001)	• Streamflow reduction due to heavy abstraction upstream resulting in salt water intrusion through the estuary. • Reduction in sediment loads impacting mangrove vegetation (TPTC, 2001; Hoguane *et al.*, 2009; Van der Zaag and Carmo Vaz, 2003)
Maputo	Small Decrease	Decrease (Fernandes, 1995)	Stable	• River is increasingly polluted due to industrial and urban wastes (Hoguane *et al.*, 2002)
Thukela	Decrease (DWAF,2004; DWAF, 2004a)	Decrease	Decrease (DWAF, 2004)	• High risk of increased pollution and further flow and sediment reduction, particularly for prawn and fish nursing grounds (DWAF, 2004); Risk of decrease if further impoundments/ transfers reduce dilution capacity (DWAF, 2004a)
Betsiboka	Stable (Chaperon *et al.*, 1993)	Stable	Increase (Autrand, 1997)	• High sediment loading of river outflow (IWMI, 2006) • Accretion in the Bay hindering the of Mahajanga harbour shipping activities (Autrand, 1997) • Increase in area of basin affected by bush fire practice leading to increasing runoff and heavy sediment loads
Tsiribihina	Stable (Chaperon *et al.*, 1993)	Stable	Increase (Salomon, 1987)	• Continual accretion in the delta that could impact on mangrove ecosystem e.g. species dominance related to growth condition (salinity, type of soil etc)
Mangoky	Stable (Chaperon *et al.*, 1993)	Stable	Increase (Salomon, 1987)	• Continual accretion in the delta but seems to be mitigated by strong oceanic currents bringing marine sediments to certain areas • Marine sediments not conducive to optimal conditions for mangrove growth.
Fiherenana	Variable (Chaperon *et al.*, 1993)	Stable	Increase (Salomon, 1987)	• Displacement of delta due to violent flood inundating the city of Toliara. • Heavy sediment loads into the Bay of Toliara damaging the barrier reef (Vasseur, 19971967)

Key: Issues deemed "critical" or "important" by consulted studies are highlighted

Maputo River

The main issue on the Maputo River is the discharge of agricultural, industrial and urban wastes into the river shortly before it flows into Maputo Bay. The Bay has seen a general degradation in its water quality – partly caused by the discharge it receives from the Maputo River, but also from direct discharges from Maputo City (Hoguane *et al.*, 2002).

Thukela River

An increasing number of dams and inter-basin transfer infrastructure, such as pipelines and canals, has manifested itself in the flow and sediment load conditions of the Thukela and its estuary, which had until recently, remained relatively stable (DWAF, 2004a; DWAF, 2004b). The effect of the dams on floods and sediment dynamics at the estuary has over the past decade become an issue of increasing concern, with the estuary now closing for days at a time, whereas historically the system was permanently open to the sea. (DWAF, 2004a). While in the past the overall water quality was considered stable (DWAF, 2004a), there are now increasing pockets and stretches of river where water quality problems are more significant, for example in the upper reaches where acid mine liquid waste enters the river as well as lower reaches where municipal and industrial waste enters the system. Water quality at the estuary deteriorates whenever flow rates are reduced, such as during the winter dry season, which has seen an increase in water quality standard transgressions in terms of human health and ecosystem integrity. The Thukela Water Project, comprising the construction of the Jana and Groot Mielietuin Dam, has been deemed feasible (DWAF, 2001) but the approval to construct has not yet been given. If the Thukela Water Project does proceed, it might not become operational before 2020, possibly even later if Lesotho and South Africa go ahead with Phase 2 of the Lesotho Highlands Water Project (DWAF, 2004a). Though the estuary sediment dynamics have in the past been shown to be in a dynamic equilibrium state, some simulations of a post-dam scenario suggest that a dynamic equilibrium similar to the current conditions could prevail (DWAF, 2004b). However, the proposed Thukela Water Project is set to draw large volumes of water from the Thukela for industrial use in inland regions, effectively redistributing a large water flow from the Thukela to other catchments, the implications of which are not fully understood. Moreover, the reduced water flow is likely to accentuate the pollution problems increasingly being experienced.

Betsiboka River

Although there are two dams in the upstream part of the Ikopa River (a main tributary), flow regime issues seem not to be associated with dams, but rather from changing climate affecting the whole basin. Despite the absence of current data on climatic conditions in Madagascar, studies have reported increasing periods of drought, mainly in the south-western region, coupled with mostly irregular rainfall which often causes violent erosive flows downstream. Betsiboka River basin is much more affected by poor land use along its course. Bush fires and slash-and-burn practice are the main causes of the basin's degradation every year, leading to heavy sediment load transport into the Bay of Mahajanga. There is evidence that this problem began before independence in 1960. It was reported by Autrand (1997), during a study of the western coast potential for shrimp nursery, that the accretion in the Bay has reduced the water depth from 70 to 40 m. This process is thought to have transformed the former bay into a lagoon system (Autrand, 1997). Nowadays, shipping activities are the first affected by the changes but the water quality may also worsen from the reduced circulation combined with the continual and direct discharge of untreated municipal wastewater. Finally, some kilometres north, at Antrema, local coral reefs have also been impacted by the higher turbidity associated with the sediment load Maharavo (2003).

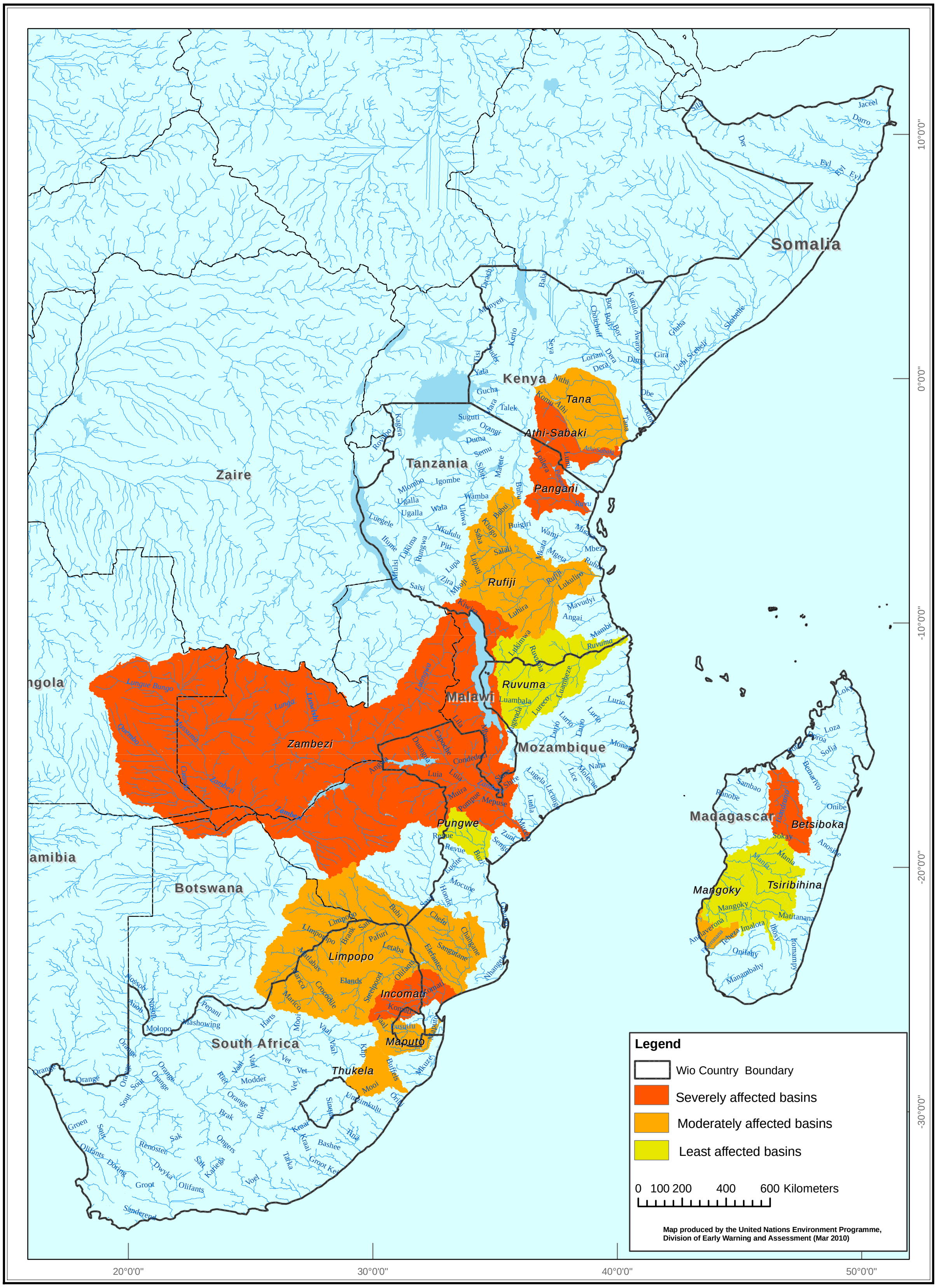


Figure 4-16 Map showing key hotspot areas for rivers of the WIO region

Tsiribihiny, Mangoky and Fiherenana rivers

The three south-western rivers, Tsiribihiny, Mangoky, and Fiherenana, located in a semi-arid zone have experienced the same problem of increasing sediment load due to: the irregular occurrence of violent storms concentrated at the start of the rainy season; the relatively steep and long slopes in the crystalline zone of the river courses; and a catchment area in which the destruction of the vegetation cover has resulted in the erosion of topsoil. All of these impact, to varying degrees, on the mangrove ecosystem at the delta and the surrounding coral reef ecosystem, such as the Grand Recife in the Bay of Toliara, heavily impacted by siltation from the Fiherenana River. The current agricultural policies of government, encouraging and facilitating the use of chemicals and fertilizers, are likely to have an impact on the quality of freshwater downstream and subsequently on the fragile nearshore ecosystems such as coral reefs. The expansion of mining and petroleum investment and activities in the country, particularly in the western part, could have a severe impact on water use and quality and should not be overlooked.

Based on the above descriptions it may be concluded that all of the twelve rivers covered in this review have been modified by human activities to some degree. In certain cases, the modification is significant, such as Pangani, Zambezi and Incomati, as highlighted above. In others, the degree of impact is relatively low – such as the Ruvuma and the Rufiji. Again, when discussing the degree of modification for this transboundary impact study, it is the situation at the outflow of the river which is of interest and direct relevance to transboundary issues.

The degree of impacts of land and water use activities in the basins concerned is difficult to quantify and compare. This is due to the fact that no empirical studies using standardised methodologies have been carried out on all the rivers. A subjective categorisation of the degree of impact on the rivers has been performed by the authors of this TDA, largely based on citations from the literature consulted, whereby the rivers have been divided into three classes – severe, moderate and little affected (by human activities). Essentially, if studies have flagged an issue in a basin as "severe", "pressing", "important", or "critical", it has been classified under the "severe" heading in the present analysis. Likewise, "little affected" rivers or similar are those which the literature indicates there is low human impact at the mouth of the river. The remainder of the basins are placed in the "moderate" category – indicating either that the various studies consulted have concluded, on the basis of empirical evidence, that the impacts are moderate (or a similar description) or that studies and data are inconclusive. The final categorisation of the degree of impact severity on the rivers is thus, as follows:

- *Severe*: Pangani, Athi-Sabaki, Incomati, Zambezi, Betsiboka
- *Moderate*: Rufiji, Limpopo, Maputo, Fiherenana, Tana, Thukela
- *Little affected*: Ruvuma, Pungwe, Mangoky, Tsiribihina

The majority of the main rivers of the WIO region are thus either moderately or little affected, while only four of the rivers appear severely modified – with measurable impacts on the immediate marine ecology associated with them (Table 4-24). The latter may therefore be considered as the main 'hotspots' in the region, as it comes to issues related to river-coast interaction. It should be noted, however, that even for rivers classified as "moderately affected" there are some issues which either currently are posing an environmental threat or have the potential to develop into one in future.

This situation, whereby most WIO rivers are little or moderately affected could change if economic and social development pressures in the basins increase. Table 4-23 provides an overview of the existing and proposed dams and inter-basin transfers (IBTs) for the main river basins. The planned dams are ones for which there is some likelihood that they will be constructed (or at least that construction will begin) in the next 15 years or so.

As the economies of the region develop and populations grow, so will the pressures on the freshwater ecosystems increase, with a commensurate decrease in the quantity, quality and timing of flows into the coastal marine ecosystem.

Table 4-23 Overview of dams and inter-basin transfers in the WIO region – existing and planned

River	Current significant Dams[12]	Potential/Planned significant Dams	Inter-basin transfers
Tana	Masinga, Kamburu, Gitaru, Kindaruma, Kiambere (Kitheka et al., 2003c & 2005; IUCN, 2003)	Mutonga Grand Falls, Usueni, Adamson's Falls, Kora Hills (Kitheka et al., 2003c & 2005; IUCN, 2003)	Transfer to the Athi river Basin through water supply to the City of Nairobi (Snoussi et al., 2004)
Athi-Sabaki	None (Snoussi et al., 2004 ; Kitheka et al., 2004)	Yatta, Munyu and Ndarugu (Kitheka et al., 2004 citing GOK-TARDA, 1981a-c)	Transfer from the Tana River to supply Nairobi (Gupta, 2001; Snoussi et al., 2004)
Pangani	Nyumba ya Mungu, Kalimawe, Mabayani, Kihansi, Hale	Possible new hydro-power dams	None
Rufiji	Mtera	Stiegler's Gorge (Shaghude, 2004, Richmond et al., 2002; Mwalyosi, 2004)	None
Rovuma	None	None	None
Zambezi	Kariba, Cahora Bassa, Kamuzu barrage, Itezhitezi, Kafue Gorge, Sebakwe, Mazvikadei, Manyame, Chivero	Mepanda-Uncua, Batoka, Mupata, Baroma, Lupata, Mutarare (ZRA, 1998; Turpie, 2006; Beilfuss, 1999; Pallet, 1997)	Matabeleland Zambezi Water project – to Bulawayo (Chenje, 2000)
Pungwe			Transfer to the Save basin to supply Mutare in Zimbabwe (Van der Zaag).
Limpopo	Macarretane, Massingir, Hartebeespoort, Eerstepoort, Loskop	Rehabilitation and raising of Massingir dam	Currently IBTs from the Orange-Senqu and the Incomati basins
Incomati	Maguga, Driekoppies, Nooitgedacht, Vygeboom, Mbambiso, Kwena, Ngodwana, Witklip, Klipkopje, Da Gama, and Corumana Dams (TPTC, 2001)	Corumana (raising), Moamba, Mountain View, Boekenhoutrand and New Forest Dams (Van Wyk, pers comm., 2007; TPTC, 2001)	Currently several IBTs to the Limpopo Basin in RSA (TPTC, 2001)
Maputo	Small earth dams only (less than 6m in height) DNA, 1994		
Thukela	Woodstock, Spioenkop, Ntshingwayo (previously Chelmsford), Zaaihoek, Wagendrift (DWAF, 2001; DWAF, 2004a)	Jana, Mielietuin (DWAF, 2001; DWAF, 2004a & 2004b) Feasible but not yet decided on	Currently four IBTs into neighbouring catchments (DWAF, 2004a)
Betsiboka	Mantasoa and Tsiazompaniry (IWMI, 2006)		

12 These are dams on the main stem or important tributaries of the river which have an impact either due to their storage capacity or due to being located close to the mouth of the river, thus affecting sediment transport

Based on the earlier assessment of problems and issues related to the main river basins in the WIO region, the sections that follow provide a further systematic analysis of the two main problem areas related to river-coast interaction in the WIO region:

A. Alteration of river flow and degradation of river water quality

B. Alteration in river sediment loads

4.4.2 Alteration of river flows and water quality

It should be noted that issues related to river flow alteration and the degradation of water quality, while seemingly different in nature, are strongly interconnected. This is because the eventual effect of pollution inputs on water quality depends on the assimilation capacity of rivers. This capacity is directly related to the flow of rivers. For the purpose of this TDA, therefore, these two issues are analysed in an integrated manner.

Problem statement

The alteration (changes in quality, quantity or timing of flow) of the natural river flow occurs to different degrees in many of the major river basins in the WIO region. The four most frequent reasons for flow alterations are due to: (i) consumptive uses, (ii) increase of river surface area along sections because of impoundment, (iii) changed seasonal flow patterns (e.g. releases for hydropower-generation during the dry season), and (iv) increased floods due to wetland losses (loss of water retention capacity) (Hirji *et al.,* 2002). These are coupled with the large-scale realities and uncertainties brought about as a consequence of climate change, with some basins predicted to receive more rainfall than the historic mean, and others less (Bailey and Scholes, 1999; Hulme *et al.,* 2001; IPCC, 2001; Hirji *et al.,* 2002; Cave *et al.,* 2003; Kitheka *et al.,* 2004; UNEP, 2005; Earle and Malzbender, 2007).

Transboundary elements

The problem of flow alteration is specific to the rivers mentioned above, notably the Pangani, Zambezi, Limpopo, Incomati and Maputo. Although the impacts are relatively localized, the cumulative impacts of flow alteration are such that the effects on coastal communities and marine ecosystems are of considerable significance within the regional context. This is particularly the case when several rivers terminate in close proximity, as is the case in Maputo Bay where the Incomati and the Maputo rivers end. Individually, the water quality of these rivers is not considered critical (Anon Mozambique, 2006) but combined with increased pollution directly from the city of Maputo, the water quality of the Bay has deteriorated significantly (Fernandes, 1995; Arthurton *et al.,* 2002; Anon Mozambique, 2006).

Root-cause analysis

The main sectors linked to the immediate causes of river flow alteration and degradation of water quality are:

- Agriculture, in particular extensive farming and forestry
- Urbanisation
- Mining
- Energy Production
- Industry

Each of these sectors is associated with the abstraction of water from rivers, with or without damming. The consequent drop in river flows can lead to a wide range of impacts on the marine environment, both in terms of destruction of coastal habitats and shoreline changes as well as on water quality modifications. These issues are presented in the problem trees for river flow alteration in the WIO region (Figure 4-17) and degeneration of water quality (see Figure 4-18). An overview of direct causes, impacts and affected stakeholders for the major river basins in the WIO region, based on currently available data, is shown in Table 4-25.

Aerial views of the permanently open Sundays River Estuary in the Eastern Cape, South Africa, showing the extensive flood tidal delta inside the mouth (photo Alan Whitfield, Guy Bate, Brian Colloty and Ricky Taylor)

Figure 4-17 Problem tree: Alteration of flow at river outflow

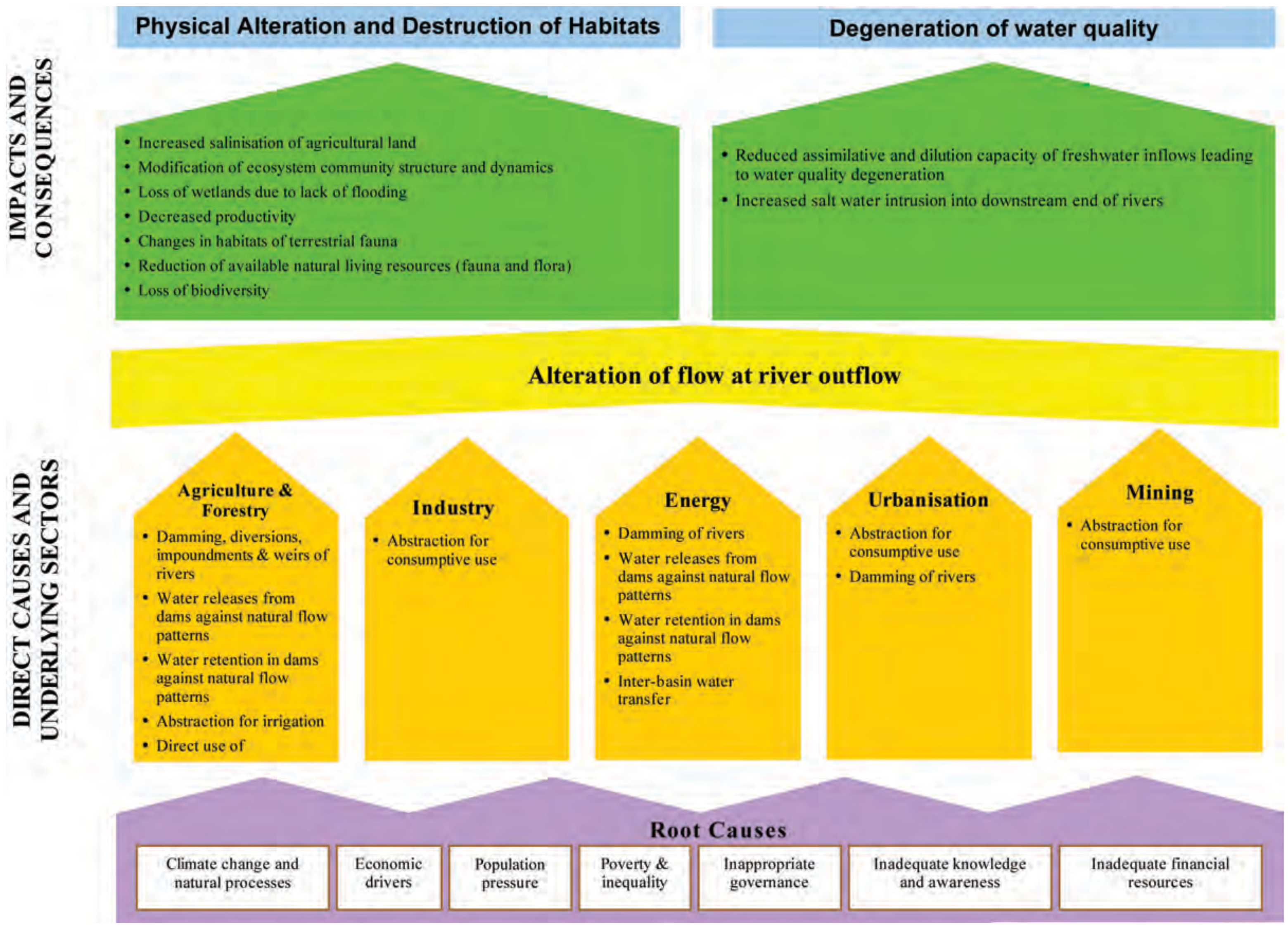


Figure 4-18 Problem tree: Decrease of water quality at river outflow

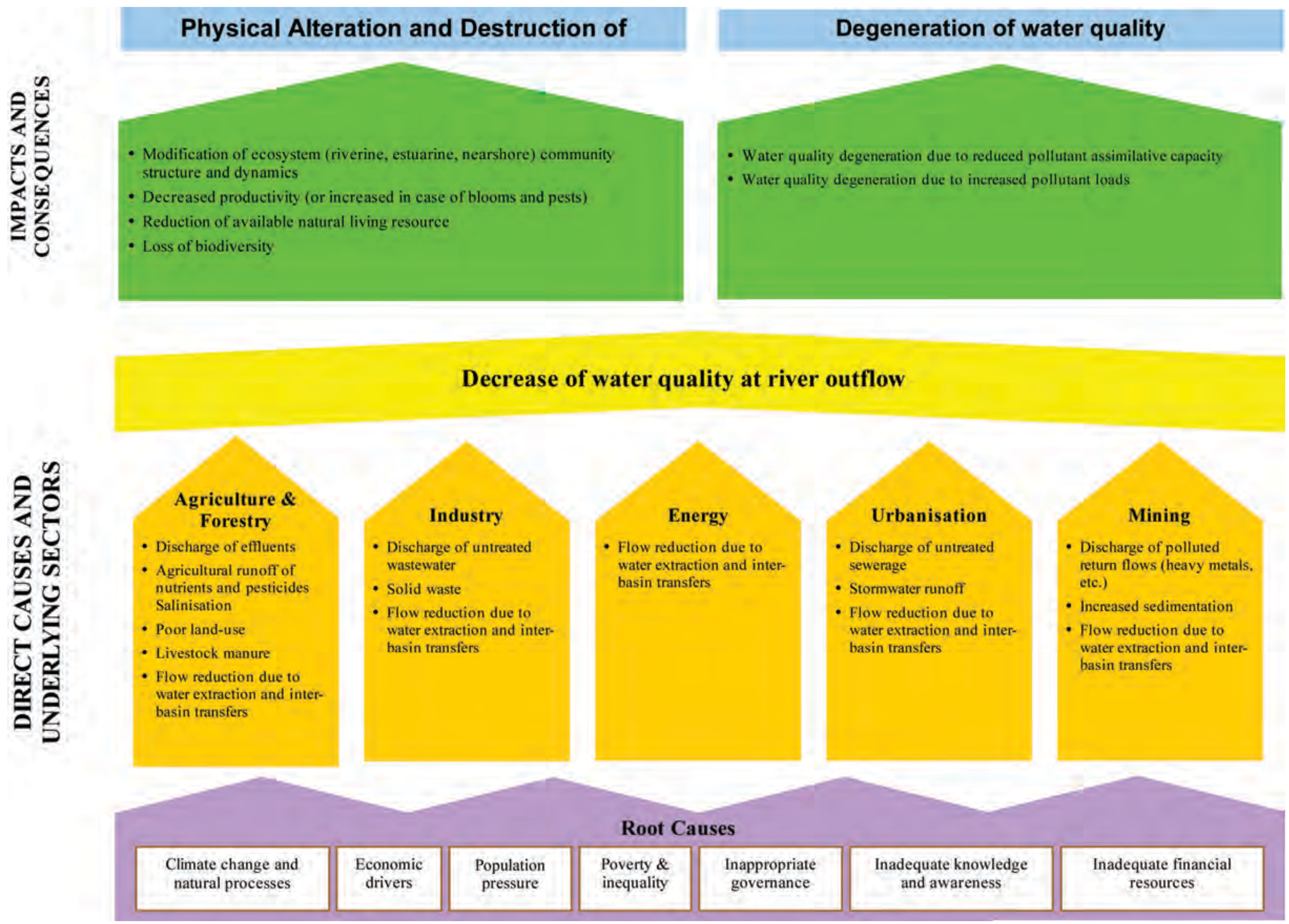


Table 4-24 Overview of the key problems, impacts and direct causes related to alteration of freshwater flows and degradation of water quality in the main river basins of WIO region

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSE
	Alteration of freshwater flow	Degradation of water quality		
Tana	X	X	• Decrease in the extent and frequency of flooding (IUCN, 2003). • Increased turbidity of coastal waters in Ungwana Bay. • Increased seawater intrusion and erosion of the delta leading to loss of mangroves and other important habitats such as riverine forests.	• Damming of river for hydro-power generation • Direct abstraction for urban water supply and irrigated agriculture • Hydrological variability • Poor land use
Athi-Sabaki	X	X	• High flow variability (Kitheka et al., 2004; Fleitmann *et al.*, 2007) • Increased flash of flood events due to reduced percolation of rainfall (Snoussi *et al.*, 2004). • Increased turbidity of water in Malindi Bay (Kitheka *et al.*, 2004) • Impacts on coastal habitats particularly coral reef ecosystem	• Poor land use • Wastewater and stormwater runoff from urban settlements • Hydrological variability
Pangani	X	X	• Smoothing-out of the annual-flow hydrograph leading to reduced flooding downstream (Lugeiyamu, 2002; PBWO/IUCN, 2007) • Low oxygen levels in water entering estuary associated with a heavy pollution load (Lugeiyamu, 2002; PBWO/IUCN, 2007) • Increased salt water intrusion at estuary	• Damming of river for hydro-power generation • Direct abstraction for irrigated agriculture and urban water supply • Agricultural runoff • Wastewater and stormwater runoff from urban settlements • Hydrological variability
Rufiji		X	• Limited and localised water quality degradation (Shaghude, 2004; Arthurton *et al.*, 2002)	• Agricultural runoff and pesticides
Ruvuma	–	–	• Very little development in the basin, resulting in insignificant impacts	
Zambezi	X		• Reduction in inter-seasonal flow variability resulting in the decrease in mangrove forest cover, decrease in fish and shrimp catches. • Reduced colonisation of sandbanks in delta by riverine plants (Turpie, 2006; Brown and King, 2002; Beilfuss, 1999; Chenje, 2000; ZRA, 1998)	• Damming of river (to supply water for hydropower generation and irrigated agriculture) • Land use change
Pungwe	X		• Increased water abstraction upstream of the estuary has lead to a reduction in streamflow and increase in coastal erosion (Van der Zaag, 2000; Hoguane *et al.*, 2002)	• Water transfer out of the basin • Direct abstraction for agriculture and urban water supply • Exotic forest plantations consuming more water

Key: Highly impacted basins are highlighted

Table 4-24 Overview of the key problems, impacts and direct causes related to alteration of freshwater flows and degradation of water quality in the main river basins of WIO region

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSE
	Alteration of freshwater flow	Degradation of water quality		
Incomati	X		• Reduced streamflow leading to reduced sediment load and sediment deposition; increased sea water intrusion; reduction in fish and shrimp catches (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009)	• Damming of River to supply water for irrigation and cooling of power generation stations, (TPTC, 2001) • Direct abstraction for irrigated agriculture, inter-basin water transfers (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003)
Maputo		X	• Reduction in water quality associated with increased anthropogenic activities; Reduction in the water and sediment quality in Maputo Bay; Reduced aesthetic/recreational values of Maputo Bay	• Increased direct discharge of industrial effluents. • Increased water abstraction for urban water supply
Betsiboka	X		• Slow shift of the Bay of Mahajanga to lagoon system (Autrand, 1997) • Inter-seasonal high variability of salinity	• Harsh climate • Bush fire and slash and burn practice • Steeply and long slope • Irregular and intense rainfall
Tsiribihina	X		• Increased salinisation and regression of mangroves area at the delta	• Harsh climate and expansion of drought • Bush fire for grazing purpose • Steeply and long slope • Irregular and short-lived intense rainfall
Mangoky	X		• Increased salinisation and regression of mangroves area at the delta	• Harsh climate and expansion of drought • Bush fire for grazing purpose • Steeply and long slope • Irregular and short-lived intense rainfall
Fiherenana	X		• Severe flooding affecting the riverine plain and the city of Toliara (Chaperon *et al.*, 1993)	• Harsh climate and expansion of drought • Bush fire for grazing purpose • Steeply and long slope • Irregular and short-lived intense rainfall

Key: Highly impacted basins are highlighted

For most of the rivers in the region, pollution of the marine environment from freshwater flows is not significant, although (as described earlier) various studies undertaken in the Pangani, Limpopo, Incomati and the Maputo rivers show that there has been some reduction in water quality and that the spatial-temporal distribution of such reduction is usually significant. In a few hotspot areas however, where there are changes to the estuarine environment due to increased pollution levels, reduced flows and changed sediment deposition patterns have severely affected fish and shrimp catches (for example, at the Zambezi Delta), confirming that the estuaries' function as fish and prawn spawning areas, nurseries and feeding habitats is compromised. The reduction in flow, and especially the flood events, has led to the physical alteration and destruction of habitats (PADH) of the lower delta, mainly through salt-water intrusion, impacting on important spawning grounds for fish and shrimp (ZRA, 1998). The other PADH impact on the Zambezi Delta area is the reduction in mangrove forests coverage. Similar trends, leading to reduced fish catches linked with alteration of flow and drop in water quality, have been observed for the coast off the Incomati River mouth (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and off the Pangani River mouth (PBWO/IUCN, 2007). The Maputo River has experienced high levels of chemical and biological pollution emanating from industries and from effluent from neighbouring towns, threatening seagrass beds (Fernandes, 1995). The combination of increased pollutants from the city of Maputo and a reduction in freshwater flows from the Incomati River which leads to salt-water intrusion, threatens mangrove forests and seagrass beds in the vicinity of Maputo Bay (Hoguane *et al.*, 2002). Increased demands for water in the region, coupled with possible drops in rainfall due to climate change, could lead to further problems.

In Mozambique, alteration of river flow from impoundments and water abstraction e.g. the Incomati River has led to the Delta suffering from an increase in the salt-water intrusion, extending upstream for about 40 km. This is accompanied by an increased erosion of the Delta, due to reduced sediment loads and consequent reduction in mangrove forest areas (Hoguane *et al.*, 2004).

The growing demand for water and unsustainable land use practices are often coupled with limited awareness at grassroots levels of the cause-impact relationships as well as weak legal and institutional frameworks and capacity to address the problems. Poor enforcement of water use licenses, such as in the Pangani basin (PBWO/IUCN, 2007), limited knowledge of environmental water requirements, such as in the Incomati basin (Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and lack of financial and human resources to effectively mitigate and adequately manage causes and impacts are common problems throughout the WIO region.

Governance is specifically related to flow alterations from the damming of rivers through dam operating rules. Hydro-power and water supply dams aim to provide maximum hydraulic pressure at times when power is needed most and store wet season runoff for use in the dry season respectively. The net impact is a reduction in the natural flow variability of the river, leading to loss of biodiversity and habitat destruction. For instance, the construction of the Cahora-Bassa Dam and its operation and its impact on the downstream fisheries has been mentioned above. The same is true for the Pangani River where hydro-power reservoirs upstream have an impacted the flow regime at the estuary (PBWO/IUCN, 2007).

Addressing the underlying root causes requires cooperation between countries as solutions often cannot be developed on a national basis. The transboundary nature of the resource renders national or local responses, often in isolation, ineffective at addressing the described environmental problems. These can only be solved if they are addressed throughout entire basins, some requiring harmonisation of legal instruments on a regional level beyond the basin scale. Increased cooperation between sectors is also needed to overcome management interventions that are mainly sectoral in nature with little coordination between sectors. Further analysis of the governance-related problems related to river flows and quality is presented in Chapter 5.

Risks, uncertainties and trends

Increasing demands for water (for irrigation, industry, mining and domestic use) due to population growth and economic development, coupled with changing rainfall patterns and greater climatic variability increases the pressure on the water resource. Although the problem of flow regime alteration (and its impact on the marine environment) does not occur in all rivers of the region, there exists the possibility for it to increase as economic development continues.

One of the biggest challenges faced is to obtain reliable hydrological data for most of the rivers. Records which do exist tend to be incomplete due to failure of gauging stations and reporting procedures for a variety of reasons. Additionally, the quality of the data is questionable, being measured by different types of instruments, often mixed and corrupted. Several countries in the region have plans for new large-scale water infrastructure and use (see Table 4-23) thus it will become increasingly necessary to be able to understand the impact of such developments on downstream users and ecosystems. Without sound data on which to base decisions, it is likely that damage to other users and the ecosystem will continue to increase.

4.4.3 Alteration of sediment loads

Problem statement

A number of factors, such as changing climatic conditions, land use practices and dam construction, have led to changes in the sediment load transported by some of the rivers in the WIO region. Broadly, the alteration of sediment loads manifests itself in three ways:

1. *Increased sediment loads* – The Athi-Sabaki and the Pangani rivers, among others, suffer from increased sediment loads (e.g. van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007; PBWO/IUCN, 2007). The increase in the sediment load of the Athi-Sabaki River has a negative impact on the marine environment, through the degradation of the coral reef ecosystem in Malindi Bay (van Katwijk *et al.*, 1993; Kitheka *et al.*, 2004).
2. *Decreased sediment loads* – The Tana, Zambezi, Limpopo and Incomati rivers are all experiencing decreases in their sediment loads, important for downstream ecosystems (e.g. Kitheka *et al.*, 2003; Turpie, 2006; Hoguane *et al.*, 2009) According to the literature consulted, the issue of decreased sediment load is having a negative impact on the marine environment in the Zambezi and the Incomati rivers. The size of the Zambezi Delta has decreased from 18,000 km^2 in 1977 to around 15,000 km^2 in 1998, due to the construction of the Cahora-Bassa Dam (Chenje, 2000). In the Incomati Delta, there is an increase in salt-water intrusion (up to 40 km upstream) and increased erosion of the delta due to a decrease in the sediment load. The result is a reduction in mangrove area (Hoguane *et al.*, 2004).
3. *Variable sediment loads in different parts of the basin* - In some rivers, both increased sediment loads, from erosion in upstream areas, and reduced sediment transport downstream of dams, following the trapping of the sediments behind the dam wall, are observed. The latter situation could affect more rivers in the WIO region, as more dam development projects are planned. Even where rivers are dammed, the sediment load reduction immediately downstream of the dam can at times is off-set by sediment load increases caused by bad land use practices on the river stretch between the dam and the river mouth. It is difficult to judge what the impacts of such an altered situation will be on the marine ecology, with no studies found covering the issue.

The combination of direct anthropogenic causes such as erosion with changing climatic conditions (e.g. changing rainfall patterns) makes it difficult at times to determine the exact contribution of a specific factor to the problem of sediment load alterations.

Transboundary elements

A common problem in the WIO region is poor land use practices (e.g. over-grazing, deforestation) which are often aggravated by increased population pressure. Poor land use practices can lead to problems of large-scale soil erosion (and resulting increase in sediment load), which may severely impact river floodplains. Combined with reduced or significantly altered flows, detrimental effects can be felt at the estuaries (e.g. Dunne and Ongwenyi, 1976; Kitheka *et al.*, 2004; Turpie, 2006) Natural phenomena such as climatic extremes (violent rainfall) coupled with slash-and-burn practices to clear land for grazing is a common cause of wide-scale soil erosion. An example is the western sedimentary zone of Madagascar, with resulting dramatic increases in sediment load in affected rivers. Salomon (1987) measured the average rate of specific degradation of south-western Malagasy river basins reporting 3,000 tonnes/km^2/yr, a value significantly higher than those of other major rivers.

Sediment load alterations can be found to some degree in most rivers of the WIO region (Table 4-22), be they transboundary or rivers flowing through only one country. However, as described above, the impact of sediment load alterations on the marine environment emerges as a major problem only for the following five river basins:

- Athi-Sabaki (increase)
- Zambezi (decrease)
- Incomati (decrease)
- Tana (decrease)
- Betsiboka (increase).

Changes in sediment loads have been observed for some of the other basins in this study, with no apparent negative impact on the marine environment, but no conclusive studies exist to confirm these observations. Where rivers are shared between countries, the factors causing sediment load alterations usually occur in all countries with poor land use practices that lead to erosion being a typical example. Effectively addressing transboundary environmental problems such as sediment load alterations would significantly benefit from harmonised legislation and institutional frameworks.

In the case of sediment load reductions as a result of river impoundment – dams being a major contributor to sediment flow reduction – the effects occur downstream of the dam, hence making downstream countries more vulnerable to the impacts. However, under the SADC Protocol on Shared Watercourses (relevant to all continental WIO countries except Kenya) major infrastructure development requires notification of the other riparian states as well as data and information exchange. The implementation of major water infrastructure development thus needs to be on the basis of transboundary cooperation.

Root-cause analysis

It becomes clear from the range of potential impacts that alteration of sediment loads in rivers can trigger negative impacts both when levels drop too low and when they are too high as shown in the problem trees of Figures 4-19 and 4-20 for increases and decreases in sediment loads from rivers, respectively. In the context of assessing the impact of sediment load alterations on the marine environment it is thus not accurate to draw generic conclusions from the occurrence of contributing factors in a river basin. Instead, the exact combination of factors and specific location of activities resulting in sediment load alterations need to be assessed on a case by case basis. It needs to be emphasised that for most rivers assessed in this study the data is very limited and often outdated. More detailed studies are required in order to determine likely impacts and to what extent the respective rivers are affected. Several sectors contribute to changes in sediment load in the basins in the region. For the basins with documented evidence for sediment load changes (e.g. Athi-Sabaki, Zambezi, Incomati, and Betsiboka) the main underlying sectors causing these changes include: (i) Agriculture and Forestry, (ii) Urbanisation, (iii) Transport, (iv) Energy Production and (v) Industry.

Large dams such as the Kariba dam on the Zambezi River are a main cause of the decrease of sediment loads to the coastal environment

Figure 4-19 Problem tree: Decrease in sediments.

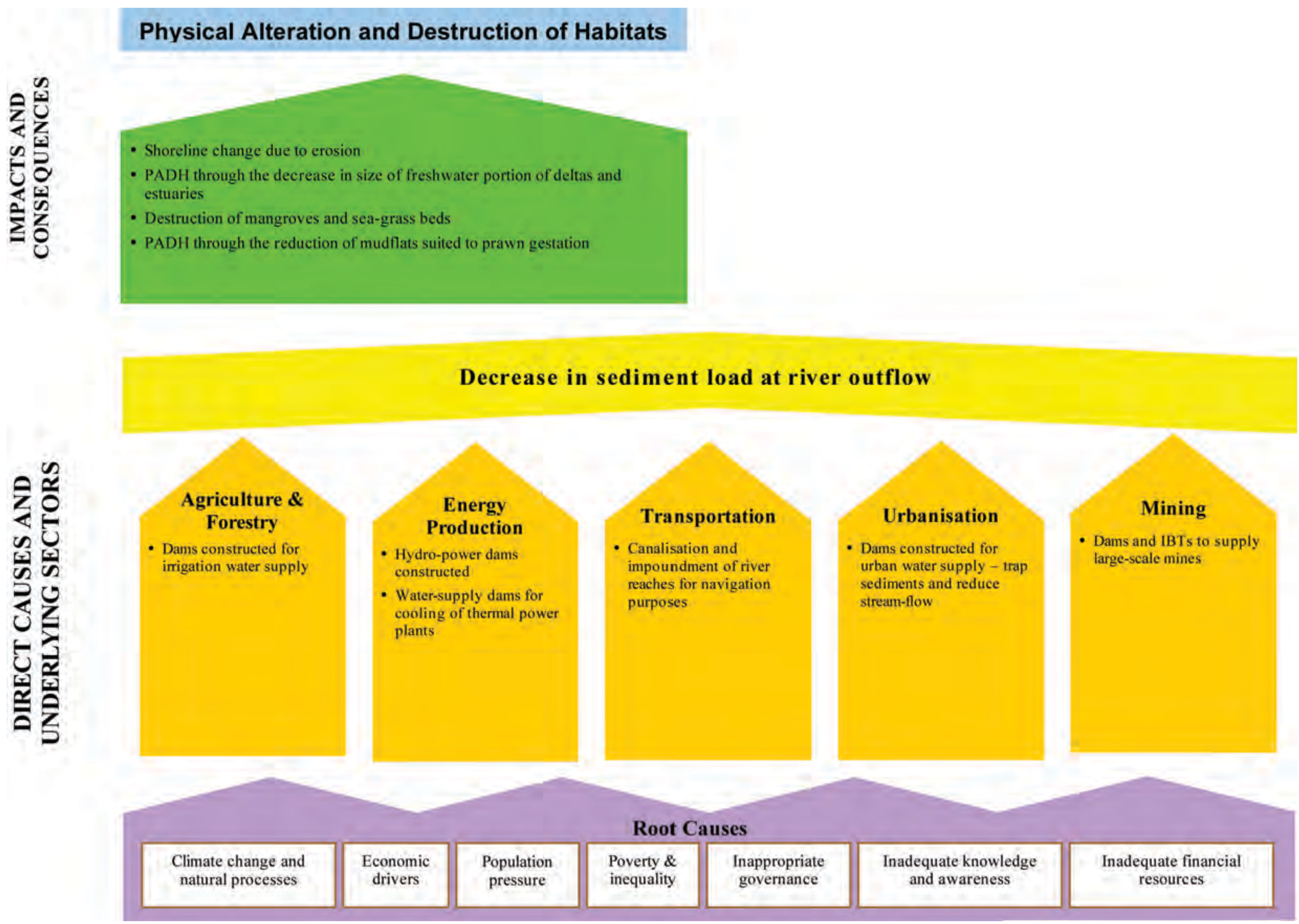


Figure 4-20 Problem tree: Increase in sediment loads at river outflow

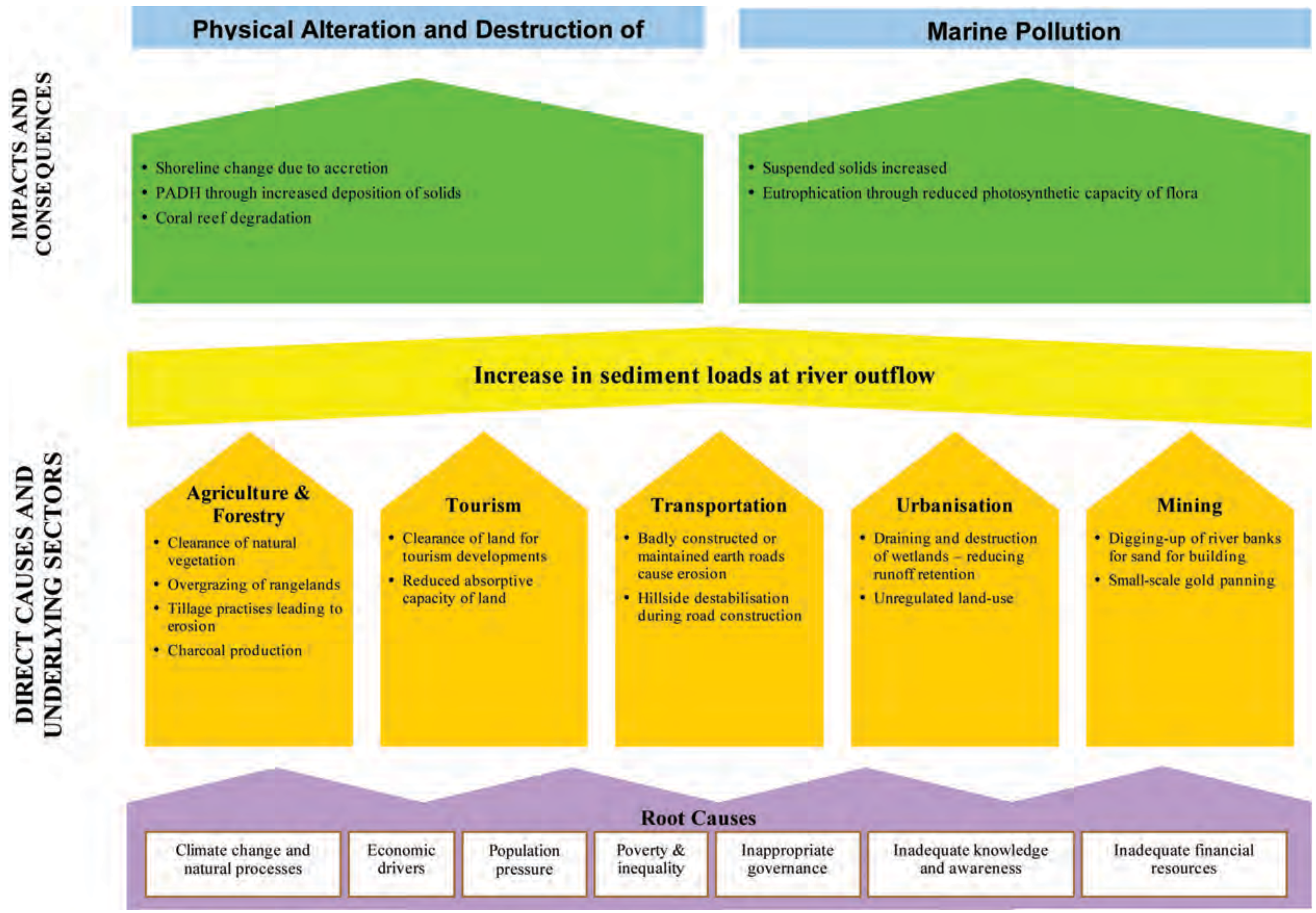


Table 4-25 Overview of the key problems, impacts and direct causes related to alteration of sediment loads in the main river basins of WIO region.

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSES
	Increase sediments	Decrease sediment		
Tana		X	• Erosion of the Tana delta and the Ungwana Bay coastline leading to loss of biodiversity (NB. the sediment load has dropped from 12 x 10^6 tons.yr^{-1} to about 6.8 x 10^6 tons.yr^{-1} (Ongwenyi, 1979; 1983; Otieno and Maingi, 1983; Dunne, 1974; Dunne and Ongwenyi, 1976; Kitheka *et al.*, 2005). • Reduced spatial extent of mangrove forests and associated impacts on coastal fisheries and biodiversity. • Changes in the morphology of the Tana Delta and associated estuaries. • Increased turbidity of water impacting on the productivity and fisheries of Ungwana Bay.	• Damming of river for hydropower generation • Direct abstraction (weirs) for irrigated agriculture
Athi-Sabaki	X		• Siltation of Malindi Bay limiting the use of port facilities such as jetties. • Deposition of sedimentary matter (and debris) on beaches thus reducing the aesthetic and recreational values of Malindi Bay beaches. • Increased turbidity of water impacting on the productivity and fisheries of Malindi Bay. • Degradation of the coral reefs sea-grass beds off the shoreline and in particular at Malindi Marine National Park (van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007; Snoussi *et al.*, 2004; Kitheka *et al.*, 2002b, 2003a & 2004). • Accretion creating new grounds for colonisation by mangroves and other coastal vegetation.	• Poor land use - increased cultivation and livestock grazing. • Deforestation • Rural roads and other constructions • Urban development • Hydrological variability
Pangani	X		• Increased water turbidity that impacts on the productivity of the coastal waters.-excess phytoplankton concentrations (Akitanda and PBWO/IUCN, 2007). • Changes in the morphology of the Pangani Estuary due to increased scouring of the channel.	• Poor land use – increased cultivation • Encroachment on river banks • Deforestation • Rural roads and other constructions • Sand mining
Rufiji	–	–	• No major changes in sediment loads at the mouth mentioned in the literature consulted	• No major changes in sediment loads at the mouth mentioned in the literature consulted
Rovuma	–	–	• No major changes in sediment loads at the mouth mentioned in the literature consulted	▪ No major changes in sediment loads at the mouth mentioned in the literature consulted

Table 4-25 Overview of the key problems, impacts and direct causes related to alteration of sediment loads in the main river basins of WIO region.

Zambezi		X	• Reduction of nutrients supply to Sofala Banks leading to reduced productivity and reduced fisheries. • Erosion of the delta and the coastline leading to loss of valuable land and biodiversity. • Loss of mangrove forests at the Zambezi delta	• Damming of river (to supply water for hydropower generation and irrigated agriculture)
Pungwe		X	• Increased coastal erosion leading to loss of land and valuable biodiversity.	• Water transfer out of the basin • Direct abstraction for agriculture and urban water supply • Exotic forest plantations consuming more water
Limpopo	–	–	• No sediment studies in the estuary have been carried out – increased erosion in the headwaters is countered by dams (Louw and Gichuki, 2003)	• No sediment studies in the estuary have been carried out – increased erosion in the headwaters is countered by dams (Louw and Gichuki, 2003)
Incomati		X	• Reduced fish and shrimp catch (Hoguane *et al.*, 2009; Van der Zaag and Carmo Vaz, 2003) • See the summary prepared by Hoguane	• Damming of river (TPTC, 2001) • Landuse change – increased agriculture and other rural activities such as charcoal production • Climate change
Maputo	–	–	• No major changes mentioned in the literature consulted	• No major changes in sediment loads at the mouth mentioned in the literature consulted
Thukela		X	• The decrease in flood peaks from natural to present day conditions is estimated at 8% and the impact of the reduced sediment on the estuary is minimal (DWAF, 2004).	• Damming of river; inter-basin transfers (DWAF, 2004a)
Betsiboka	X		• Siltation of Mahajanga Bay hindering the shipment activities • Confinement of the Bay leading it to shift into lagoon system (Autrand , 1997) • Weak development of coral reef around (Maharavo, 2003) • Red-coloured water up to few miles of the coast	• Poor land use leading to the degradation of the basin • Irregular intense rainfall
Tsiribihina	X		• Siltation at the delta	• Poor land use leading to the degradation of basin • Irregular intense rainfall
Mangoky	X		• Siltation of rice growing field • Siltation of the delta	• Poor land use leading to the degradation of basin and agriculture • Irregular intense rainfall
Fiherenana	X		• Subsurface flow due to accumulation of sand and silt in the river bed (Vasseur, 1997) • Siltation affecting the Great reef barrier in the Toliara Bay	• Poor land use, agriculture and rush mining

Key: Highly impacted basins are highlighted

Risks/uncertainties and trends

One of the prime challenges faced is the general lack of reliable, long-term hydrological data. For most of the basins in the study there was less data available on sediments (rates, fluxes, variation, etc.) than on water flow. The future dams planned for the region will certainly have a noticeable impact on the amount of sediment reaching the ocean from these rivers. Without a good long-term understanding of sediment transport dynamics it will not be possible to develop and implement mitigating strategies for such dams.

4.4.4 Stakeholder analysis

There are important differences between stakeholders involved in the various problem categories, for example, between stakeholders causing water quality degeneration and those causing flow alteration or sediment flux. Also, the nature of the problems related to the different river basins differs considerably. An obvious example of this is the difference between rivers with large dams, such as Tana, Pangani, Zambezi, Incomati and Thukela, and those without. For this reason, the stakeholder analysis presented in this section warrants a case-by-case scrutiny.

As the region is still heavily reliant on farming as a principal economic activity, the bulk of stakeholders causing as well as being impacted by flow alteration and water quality issues derived from this sector include small-scale farmers, large-scale farmers, pastoralists and loggers. However, in several of the basins, the actions of light manufacturing industries as well as hydro-electric dam operators are having an increasing impact. Most impacted by upstream activities are the artisanal and industrial fishers. Table 4-26 provides a tabular overview of the main sectors and stakeholder groups causing flow alterations and degeneration of water quality, as well as of sectors negatively affected by such issues.

The sectors mostly responsible for causing impacts from sediment flux alterations, as well as the most affected by the impacts are agriculture and forestry. On the whole the impacts which they cause are due to many and diffuse activities – small dams, run-off and erosion from fields. While these collectively represent substantial impacts, the largest impacts are caused by the hydro-dam operators due to trapping of sediments behind reservoir walls. Artisanal fishers and coastal communities tend to be most negatively impacted by the upstream activities. Table 4-27 provides a tabular overview of the main sectors and stakeholder groups causing sediment load alterations and those negatively affected by it.

Table 4-26 Analysis of sectors and stakeholder groups causing river flow alteration and degeneration of water quality, as well as those impacted by such

River basin	Key Problem		Stakeholder groups															
			Agriculture and Forestry					Mining		Industry		Energy Production		Fisheries		Urbanisation	Transport		
	Alteration of flow	Degradation of water quality	Small-scale farmers	Large-scale farmers	Pastoralists	Small-scale loggers	Industrial Loggers	Small-scale miners	Industrial mining	Light manufacturing industry	Agro-processing industries	Hydro-dam operators	Power station operators	Artisanal fishers	Industrial fishers	Town Planners	Ports	Roads	Coastal Communities
Tana	X	X	C, I	C	C, I					C		C		I					
Athi-Sabaki	X	X	I		C, I	C	C							I		C		C	I
Pangani	X	X	C, I	C	C							C		I		C			I
Rufiji		X	C											I	I				
Rovuma																			
Zambezi	X		C, I	C								C		I	I				I
Pungwe	X		C	C			C			C				I		C			
Limpopo	X		C, I	C, I	C				C	C	C			I		C			
Incomati	X		C, I	C, I			C		C	C		C	C	I	I	C, I			I
Maputo		X		C						C	C			I	I	C			
Thukela	X	X	C	C			C			C		C	C						
Betsiboka	X		C		C	C								I	I		I		I
Tsiribihina			C		C	C								I	I				
Mangoky			C		C	C								I					
Fiherenana	X		C		C	C		C						I			I		I

Key: Hot spot basin | C = Cause | I = Impact | Where both "C" and "I" are present indication is of cause and impact applicable in different parts of the basin

Table 4-27 Analysis of sectors and stakeholder groups causing sediment flux alteration from river basins as well as those impacted by such

River basin	Key Problem		Stakeholder groups																	
			Agriculture and Forestry					Mining		Industry		Energy Production		Fisheries		Urbanisation	Transport			
	Sediment Increase	Sediment decrease	Small-scale farmers	Large-scale farmers	Pastoralists	Small-scale loggers	Industrial Loggers	Small-scale miners	Industrial mining	Light manufacturing industry	Agro-processing industries	Hydro-dam operators	Power station operators	Artisanal fishers	Industrial fishers	Town Planners	Ports	Roads	Tourists	Coastal Communities
Tana		X	I	C								C		I						
Athi-Sabaki	X		C, I	C	C, I	C	C							I		C	I	C	I	I
Pangani	X		C	C	C	C		C	C			I		I	I			C		I
Rufiji	–	–																		
Rovuma	–	–																		
Zambezi		X	I	C								C		I	I					I
Pungwe	X		C	C			C			C				I		C				
Limpopo	–	–																		
Incomati	X		C	C						C	C	C		I	I				I	I
Maputo	–	–																		
Thukela		X	C	C			C			C		C	C							
Betsiboka	X		C		C	C								I	I		I		I	I
Tsiribihina	X		C		C	C								I	I					
Mangoky	X		C, I		C	C														
Fiherenana	X		C		C	C		C						I			I		I	I

Key: Hot spot basin; C = Cause; I = Impact. Where both "C" and "I" are present indication is of cause and impact applicable in different parts of the basin

Chapter 5 – Governance Analysis

Chapter 5 – Governance Analysis

5.1 Introduction and overview

5.1.1 Background

The focus in this chapter is on governance in the WIO region in so far as it relates to the management and protection of the marine environment from land-based sources of pollution and activities. More specifically, the issues dealt with in this regard are:

- International and regional governance frameworks and institution;
- National policy, legal and institutional frameworks;
- The role of civil society;
- Financial mechanisms; and
- Education and public awareness.

The bio-physical character of the region is described elsewhere in this report (Chapter 2). Here it is pertinent to simply note that politically the region comprises ten states, of which five are mainland states and five are island states, a factor which is relevant to governance in that marine and coastal area management is generally better developed on the islands.

The ten countries have, from an ecosystem, historical and economic perspective formed more or less a cohesive geopolitical area, since the mid-1990's becoming known as the Western Indian Ocean (WIO) region. In recognition of the uniqueness of the coastal and marine environment of the region, the threats it faces, and the necessity for remedial and/or pre-emptive action, the countries of the WIO region adopted the 1985 Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region and its two protocols on Protected Areas and Wild Fauna and Flora (SPAW Protocol) and the Protocol concerning Cooperation in Combating Marine Pollution in Cases of Emergency. The Nairobi Convention is one of a dozen or so *Regional Seas* initiatives promoted under UNEP's *Regional Seas* Programme and provides a useful point of departure to examine the governance regime in the region.

An important aspect of understanding threats and causes of coastal and marine environmental degradation is to identify key governance issues with a view to planning and recommending action for optimizing governance in the region. As such, this chapter straddles international, regional and national laws, policies and institutions with the overall purpose of generally understanding the role of governance in better managing and regulating use of the marine and coastal environment in the WIO region. A particular strength of the Nairobi Convention, with strong relevance to the WIO region, is that all ten countries referred to above are parties to it. The Nairobi Convention and its protocols are described in more detail in section 5.3.1. In that section, reference is also made to a third draft protocol which is currently being developed and which will deal specifically with issues related to the protection of the marine and coastal environment from land-based sources and activities.

The process leading up to compiling this governance analysis has been as follows:

- The foundation for governance analysis was laid by a team of national and regional experts under the overall guidance of the Regional Legal and Technical Review Task Force. This team undertook a regional assessment of policy, legal and institutional frameworks as well as the status of ratification of international conventions related to protection of the marine and coastal environment from land-based sources of pollution and activities. The Regional Synthesis Reports resulting from this exercise form the main basis for this governance analysis (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009b&c).
- Further analysis of the regional governance situation was undertaken during a special meeting of the Legal and Technical Review Task Force[1] when shortcomings and gaps related to national and regional policy were highlighted and the adequacy of legal and institutional frameworks for land-based marine pollution management assessed.
- Subsequently, the First Regional TDA/SAP Stakeholders Workshop[2] identified governance as a key crossing-cutting issue in each of the three problems areas discussed in Chapter 4. During the further course of the TDA development, the analyses presented in this chapter of the TDA were examined in more detail.

5.1.2 'Governance' and 'government' in the context of land-based marine pollution

The term 'governance', has a meaning very distinct to 'government'. Government denotes the formal legal institutions of the state, including, in particular, formal political authority and leadership structures. In terms of classical constitutional separation of powers, it means the executive arm of the state, that is, the political, socio-economic and administrative management of public affairs. As such it encompasses the mechanisms, processes and institutions through which citizens and groups articulate their various interests, mediate their differences and exercise their legal rights and obligations (UNDP, 2003).

In contrast, governance is much broader and includes, in meaning and scope, the exercise of political authority and control over society and how that affects the management of a country's economic and social resources for development (Landell-Mills and Serageldin, 1993; cited in UNDP, 2003). Governance usually broadly brings together all development and other players or stakeholders in society and emphasizes shared or collective responsibility in ensuring overall well-being of the society in question. Governance is defined as the process of informed decision making that enables trade-offs between competing users of a given resource so as to balance protection with beneficial use in such a way as to mitigate conflict, enhance equity, ensure sustainability and hold officials accountable (Turton *et al.*, 2007). Governance, thus entails the institutional capacity of public organizations (not limited to formal government) to furnish public and other goods and services to the citizens in an effective, transparent, impartial and accountable manner (subject to resource constraints), thus intertwining both political and economic governance (World Bank, 2000; UNDP, 2003). As such, governance provides an enabling environment for development and eradication of poverty and deprivation, and has qualities such as protection of property rights, equitable development and accountability (UNDP, 2003). Governance plays out at various levels and in respect of varying parties including both the formal government sphere and civil society. In this context, governance loosely comprises of a hybrid of international and national laws and policies as well as the institutions and actors both in government and in civil society

1 Held in Zanzibar: Jan/Feb 2007)
2 Held in Nairobi, 17-19 April, 2007)

which make them work, or not, in some cases. Thus, in the national government sphere, the point of departure for international governance are the various international conventions and related institutions outlined under Section 5.3 below, presenting a review of relevant international and regional governance frameworks and institutions.

5.2 Governance analysis of main problems and issues

A broad spectrum of governance approaches is evident among Eastern and Southern African coastal nations and island states. Like governance systems in sub-Saharan Africa as a whole, these vary or have varied in a historical perspective from authoritarian regimes on the one hand to successful democracies on the other. Some systems retain remnants from colonial governance processes, particularly with respect to legal systems, institutional frameworks and language. Thus, while much of eastern Africa is English-speaking, the official language of Mozambique is Portuguese while most of the island nations in the southwest Indian Ocean are French-speaking. However, a general feature is that current governance institutions reflect ties to former colonial powers to a greater or lesser extent.

This section identifies, analyses and describes the governance-related issues of the three main problem areas related to the degradation of the coastal and marine environment described in Chapter 4, namely:

- Problem area 1: Water and sediment quality degeneration due to pollution from land-based sources;
- Problem area 2: Physical alteration and destruction of habitats (PADH); and
- Problem area 3: Alteration of freshwater flow, quality and sediment loads.

5.2.1 Overview of governance issues related to the three TDA problem areas

A number of the governance issues related to each of the three key problem areas, are summarised in this section. It should be noted that not every issue identified is equally applicable in all countries of the region[3]. Furthermore, in many cases it is possible to fine-tune the governance intervention to a more focused level of management of individual sources and activities, which raises a plethora of additional governance issues, as explained in Box 5.1 Rather than going into such detail, this chapter seeks to identify the broader governance issues related to the three problem areas[4]. Within the same context, it should also be noted that the governance issues identified here may not be exhaustive due to the large variety of issues specific to the various levels in the governance framework for LBSA management.

An analysis of governance issues contributing to problem area 1 *(Water and sediment quality degeneration due to pollution from land-based sources)* is presented in Table 5-1. The main issues are grouped into legal, institutional and policy frameworks as they relate to the discharge of pollutants to the coastal and marine environment.

3 Where such is the case, the term 'partial' is used in the analysis presented in this section.

4 Which may serve, among others, as a basis for more detailed localized analysis within the context of the relevant national governance processes, e.g. National Programmes of Action on Land-based Activities, Integrated Coastal Zone Management Plans, National Environmental Management Plans.

Box 5.1 Example of detailed governance at the activity level

In the case of sources of marine pollution, a direct cause of coastal water quality degradation could be attributed to mining activities. From a governance perspective this would trigger analysis of any number of possible legal, policy and institutional intervention from local to international level, raising the following potential queries: At the local level, is there a water quality emission standard which is included in the mining license? At national level, is there a water law providing for the setting of standards, if so are the necessary institutional frameworks in place and is it working adequately and if not, why not? Is there the necessary human and resource capacity to enforce this standard and/or law? Does the mining law require coastal water quality considerations to be taken into account in granting an upstream mining authorization? At regional level, is there a legal obligation to set coastal water quality targets; similarly at international level? What does international law, for example the UN Convention on Law of the Sea, state in this regard and how is this implemented at national level? What is the role of international institutions through to local community organizations with regard to this one particular problem area?

Table 5-1 Governance issues related to the degeneration of water and sediment quality due to pollution from land-based sources.

Cat	Regional/international governance	National governance
Legal framework	• Absence of a regional agreement with regard to the management of land-based sources of pollution • Absence of a regional agreement for maintaining minimum coastal water quality targets • Absence of a regional agreement for transboundary EIA/SEA, including reporting procedures • Shortcomings in the adoption and ratification of key LBSA-related conventions, including the Nairobi Convention • Weak integration of regional inter-governmental agreements (including economic treaties)	• Partial absence of national effluent standards • Partial absence of national water quality objectives and target values • Fragmented (sectoral as opposed to integrated) legislation • National legislation not adequately aligned with international and regional obligations • Poor/lack of enforcement of legislation • Lack of adequate dispute resolution procedures
Institutional framework	• Absence of a regional 'champion' providing oversight on land-based sources of pollution management • Shortcomings in collaboration and coordination between regional institutions • Absence of adequate regional financial mechanisms • Inadequate data for sustainable management	• Restricted capacity of national institutions responsible for regulating and controlling discharges of land-based sources • Partial absence of national water quality monitoring programmes • Conflicting mandates and inadequate cooperation between national institutions charged with various aspects of LBSA management • Partial absence of a register of industries and wastewater treatment facilities • Insufficient public and private sector involvement • Lack of human resources and technical capacity for managing, monitoring and enforcement • Lack of adequate financial mechanisms and resources
Policy framework	• Absence of coherent regional policies and strategies for land-based sources of pollution management • Limited awareness and understanding with regard to the importance of management of land-based sources of pollution, especially in political sphere • Low priority afforded to LBSA-related issues at political level	• Absence of coherent national policies and strategies for land-based sources of pollution management • Low priority afforded to LBSA-related issues at political level

The governance issues raised in relation to Problem Area 2 (*Physical alteration and destruction of habitats)PADH*) relate largely to problems associated with marine artisanal fisheries mangrove forests, seagrass beds, coral reefs, coastal forest degradation and shoreline changes. The relevant governance issues identified in section 4.3 are summarized in Table 5-2.

Table 5-2 Governance issues related to physical alteration and destruction of habitats (PADH)

Cat.	Regional/international governance	National governance
Legal framework	• Non- or only partial implementation of Nairobi Convention and its Protocols • Shortcomings in the adoption and ratification of key LBSA-related conventions, including the Nairobi Convention • Weak integration of regional inter-governmental agreements (including economic treaties)	• Inappropriate and incomplete national legislation for dealing with PADH • Fragmented (sectoral as opposed to integrated) legislation • National legislation often not aligned with international and regional obligations • Poor/lack of enforcement of legislation • Lack of adequate dispute resolution procedures
Institutional framework	• Absence of a regional 'champion' providing oversight on critical habitat management • Shortcomings in collaboration and coordination between regional institutions • Absence of adequate regional financial mechanisms • Inadequate data for sustainable management • Inadequate capacity to assess ecosystem health	• Lack of human resources and technical capacity for natural resource management • Lack of human resources and technical capacity for managing, monitoring and enforcement • Inadequate cooperation and conflicting mandates of national institutions charged with various aspects of LBSA management • Limited involvement of stakeholders in resource use planning and management • Lack of adequate financial mechanisms and resources
Policy framework	• Absence of coherent regional policies and strategies for habitat management • Limited awareness and understanding with regard to the importance of management of critical coastal habitats, especially in political sphere • Low priority afforded to LBSA-related issues at political level	• Lack of understanding of the values of ecosystem services at policy-maker level • Absence of coherent national policies and strategies for habitat and biodiversity management • Low priority afforded to LBSA-related issues at political level

The governance issues raised in relation to Problem Area 3 (*Alteration of freshwater flow, quality and sediment loads)* focus primarily on problems associated with the interaction between river basins and the coastal and marine environment. Highlighted are alteration and/or modifications of freshwater flows, alteration and/or modifications of sediment loads and water quality/pollution. The governance issues identified in section 4.4 are summarized in Table 5-3.

Table 5-3 Governance issues related to alteration of river flows and sediment loads.

Cat	Regional/international governance	National governance
Legal framework	• Lack of harmonised legal frameworks (including inter-governmental agreements) for the management of transboundary water resources/rivers • Shortcomings in the implementation of inter-governmental agreement for river basin management	• Lack of a coherent legal framework for the governance of river basins • Lack of a legal framework for inter-state collaboration • National legislation often not aligned with international and regional obligations • Poor/lack of enforcement of legislation • Lack of adequate dispute resolution procedures
Institutional framework	• Limited financial and human resource capacity for effective implementation of agreements and comprehensive water resources management regimes • Lack of inter-sectoral water governance, i.e. involvement of different water use sectors in the management of the resource • Lack of information on and data of the nature, causes and impacts of water resources utilization, particularly on the marine and coastal environments	• Limited involvement of stakeholders in resource use planning and management • Lack of awareness of stakeholders of the impact of their activities on other stakeholders and the ecosystem as a whole in particular marine and coastal environments • Inadequate cooperation and conflicting mandates of national institutions charged with various aspects of water resources management • Lack of human resources and technical capacity for integrated river basin and coastal area management • Lack of adequate financial mechanisms and resources
Policy framework	• Lack of adequate integrated regional water resource management policies to address increased demands for limited water resources • Low priority afforded to LBSA-related issues at political level	• Limited awareness and understanding with regard to the importance of management of river basins • Absence of coherent national policies and strategies for river basin management • Low priority afforded to LBSA-related issues at political level

The above-presented analysis illustrates that that there are a number of common denominators regarding weaknesses in the existing governance structures related to the three problem areas. In all three problem areas there is a general shortcoming in the available legislative frameworks, with laws and regulations weak, incoherent or not existing. In other cases there is lack of implementation and/or enforcement (both at the national and regional level – in the form of inter-governmental agreements). This legislative weakness is accentuated by weaknesses in the institutional framework, which highlight issues of human resources and technical capacity as well as financial mechanisms. Weak coordination between various government institutions involved in LBSA management, as well as limited stakeholder involvement (including private sector) are other general issues of concern. Finally, at the policy level, the main issue pertains to a lack of coherence in policies, which are often sector-based rather than integrated. The general lack of awareness and recognition of the (economic) values of coastal and marine resources and services at the level of policy makers and the wider public, contributes to the low priority afforded to LBSA-related issues at political level. Table 5-4 presents a summary of such common weaknesses in LBSA governance.

Table 5-4 Common weaknesses in LBSA Governance.

Cat	Regional/international governance	National governance
Legal framework	• Absence and/or shortcomings in regional inter-governmental agreements. • Shortcomings in the ratification and implementation of inter-governmental agreements	• Absence and/or shortcoming in national legal and regulatory frameworks • Fragmented (sectoral as opposed to integrated) legislation • Poor/lack of enforcement of legislation
Institutional framework	• Absence of a regional 'champion' providing oversight on LBSA Governance • Shortcomings in collaboration and coordination between regional institutions • Lack of adequate regional financial mechanisms	• Restricted capacity of national institutions • Inadequate cooperation and conflicting mandates of national institutions • Insufficient stakeholder (including private sector) involvement • Lack of adequate financial mechanisms and resources
Policy framework	• Absence of coherent regional policies and strategies • Lack of awareness and recognition of the (economic) values of coastal and marine resources at the level of policy makers	• Absence of coherent national policies and strategies • Lack of awareness and recognition of the (economic) values of coastal and marine resources at the level of policy makers

The challenge is thus to identify and examine the root causes of such 'weak' governance in the WIO in the context of the legal and institutional frameworks relating to the three Problem Areas. Accordingly, a number of common governance-related root causes for poor performance can be identified (see Box 5.2), although these may differ from country to country.

Box 5.2 Summary of common governance-related problems

Policy and legislative inadequacies	• Inadequate updating, implementation, enforcement and monitoring of relevant legislation • Inadequate ratification and domestication of relevant international and regional instruments
Limited institutional capacity	• Lack of mechanisms for effective coordination and inter-sectoral governance • Inadequate human resources and technical capacity in institutions charged with the responsibility of addressing LBSA-related issues
Inadequate awareness	• Inadequate awareness, understanding and appreciation of the economic value of coastal/marine ecosystem goods and services among policy makers and legislators, the civil society and the private sector
Inadequate financial mechanisms	• Inadequate financial mechanisms and resources for dealing with LBSA-related issues
Poor knowledge management	• Lack of adequate scientific and socio-economic data and information to support policy making, monitoring and enforcement

Addressing the many issues related to the governance of LBSA management is severely complicated by the large number of players/stakeholders involved. This is especially relevant at the national level, which, coupled with the above-mentioned lack of adequate mechanisms for effective coordination and inter-sectoral governance, often results in incoherent and inefficient management approaches. Stakeholder involvement in LBSA Governance is therefore a key cross-cutting issue.

For this reason, a separate analysis of stakeholders involved in LBSA management, focusing on the national level, is presented in the following section.

5.2.2 Stakeholders involved in LBSA Governance

After considering both direct and root causes, the national and synthesis reports identified and described the respective constitutional structures, laws, policies and institutions in eight WIO countries. The reports further identified eight sectors as being central to addressing the degradation of the coastal and marine environment. These sectors, as well as their respective governing institutions, are presented in Table 5-5. Each of the sectors shown has a broad array of laws, institutions and policy aspects pertaining to it, either directly or indirectly. It follows that each sector also has an array of stakeholders, ranging from civil society to top levels of government.

At national level, the precise government structures (institutions responsible) for the various sectors may vary from country to country, although generally they are as indicated in the third column of Table 5-5. Whatever the exact names of the institutions involved, from a governance perspective these sectors are all central to preventing and combating coastal degradation. (Further perspectives on existing national policy, legal and institutional frameworks are presented in section 5.4)

At the regional level there exists an array of institutions and organization involved in issues related to the governance of LBSA, in addition to a range of international and regional agreements, conventions and programmes. (A further perspective on these regional and international governance frameworks is presented in section 5.3)

There are also community and civil society organizations, NGO's and related actors and stakeholders involved with various facets of governance, not only at institutional level but also in developing polices, sometimes at national level. Indeed, the concept of co-management, especially in fisheries has been successfully developed in several locations. Since 2000, the presence of at least some level of co-management in a selected suite of some 163 WIO fisheries has improved from 27% to 51%. (van der Elst et al., 2009) Some of these co-management arrangements have grown into so-called beach management units (BMUs) where a wider range of environmental and socio-economic issues are jointly managed (Wanyonyi, 2009). Such beach management units are in place in Kenya, Tanzania and Mozambique. The role of civil society in LBSA management is further described in section 5.5.


Appropriate LBSA management involves a wide range of stakeholders, at local, national, regional and international level (photo courtesy of Rudy v.d. Elst, ORI)

Clearly, the number and diversity of stakeholders potentially involved in LBSA management is extensive. Hence, achieving coordination and coherence in addressing LBSA-related issues is one of the main challenges of LBSA governance. Fortunately, this important weakness is increasingly acknowledged by policy makers and many countries have, or are embarking on, integrated governance processes such as ICZM, National Action Plans or the like. Also, the use of integrated management tools such as EIA and SEA are becoming progressively more embedded in national management frameworks. However, much still remains to be done in order to achieve adequate levels of stakeholder involvement and coordination to ensure efficient and effective LBSA governance.

Table 5-5 Table of key sectors, stakeholder groups and governing institutions involved in LBSA Management.

Sectors	Typical stakeholder groups	Governing department
Fisheries and aquaculture	Artisanal fishers Industrial fishers Recreational fishers Seaweed farmers Industrial prawn farmers Fish & shellfish farmers	Fisheries Environment Conservation
Agriculture and forestry	Charcoal makers Small-scale loggers Industrial loggers Small-scale farmers Large-scale farmers Forest users/herbalists Pastoralists Ranchers Poultry farmers Dairy farmers Beekeepers	Environment Agriculture Forestry Conservation, Natural Resource Management Wildlife Management Livestock
Tourism	Tourists Hotel owners & operators Small-scale traders Tour, boat & SCUBA operators	Tourism Infrastructure Wildlife Forestry
Mining	Coral/lime miners Sand miners Small-scale salt producers Industrial salt works Small-scale miners Industrial mining companies Fuel suppliers & stations Oil & gas production	Minerals Energy Infrastructure
Industry	Heavy manufacturing industry Light manufacturing industry Agro-processing industries Oil refining	Infrastructure
Transportation	Ports Dredging companies Clearing and forwarding Railway Roads Airports Airlines Shipping	Harbour Infrastructure Transport Water management
Energy production	Hydro-dam operators Power station operators Renewable energy producers	Infrastructure. Energy
Coastal development and urbanisation	Solid waste operators Sewage managers Property developers Property owners Town planners Coastal community	Local authorities Infrastructure Physical planning Environment

5.3 International and regional governance frameworks and institutions

International and regional conventions, inter-governmental frameworks, agreements and institutions are central to governance in the WIO region. Such instruments are present across a broad range of levels from regional economic integration units at the broadest level, to specific transboundary commissions such as the management of shared resources, river basin management authorities and civil society organizations at the local level. Seven distinct classes of relevant frameworks are described and assessed in the following sections.

5.3.1 International and regional conventions

A number of international and regional conventions, and the work of related institutions, are relevant to meeting the increasing challenge posed by land-based sources and activities that cause pollution and degradation of the marine environment in the WIO region. The two main international conventions are the United Nations Convention on the Law of the Sea and the Nairobi Convention (introduced in section 5.1.1). These are described below, with brief details of other relevant conventions. These must also be seen in the context of the broader array of relevant 'soft laws', which, together with the relevant institutions, provide an international and regional framework to help protect and conserve the marine and coastal environment in the WIO region.

UN Convention on the Law of the Sea (UNCLOS)

The first concerted effort to regulate marine pollution generally, and land-based marine pollution specifically at the international level, emerged with the adoption of the 1982 UN Convention on the Law of the Sea (UNCLOS). Part XII (Articles. 192 to 237) of UNCLOS is devoted to "Protection and Preservation of the Marine Environment". Of particular relevance are articles which impose an obligation on States to protect and preserve the marine environment (Article 192); a duty imposed on states to take measures that are necessary to prevent, reduce and control of the marine environment (Article 194) and specifically Article 207, headed "Pollution from Land-based Sources", which obliges states to:

(1) adopt laws and regulations to prevent reduce, and control pollution of the marine environment from land-based sources, including rivers, estuaries, pipelines, and outfall structures, taking into account internationally agreed rules, standards and recommended practices and procedures

The fifth Conference of Parties to the Nairobi Convention held in Johannesburg, South Africa, provided the basis for the final negotiation and adoption of a new regional Protocol on LBSA management

(2)…

(3) States shall endeavour to harmonise their policies in this connection at the appropriate regional level.

(4) States, acting especially through competent international organizations or diplomatic conference, shall endeavour to establish global and regional rules, standards and recommended practices and procedures to prevent, reduce, and control pollution of the marine environment from [?] land-based sources…

A further potentially relevant article is Article 198 entitled "Notification of imminent or actual damage" because of its potential linkage to the Nairobi Convention Emergency Protocols. It states:

> "When a State becomes aware of cases in which the marine environment is in imminent danger of being damaged or has been damaged by pollution, it shall immediately notify other States it deems likely to be affected by such damage, as well as the competent international organizations"

All ten countries that are parties to the Nairobi Convention are also parties to the 1982 UNCLOS. UNCLOS however only sets the framework to encourage governments to address the impacts on the marine environment from land-based sources and activities as its provisions are by their nature framed in broad terms. Thus, further initiatives have been taken at international level to deal with land-based sources specifically as now outlined.

UN Convention on the Law of the Non-Navigational Uses of International Watercourses 1997 (the 'International Watercourses Convention')

The International Watercourses Convention is particularly relevant to the five terrestrial WIO countries given the aridity of the region and the likelihood that the problems associated with drought, PADH and so on, are likely to be exacerbated by climate change. The Convention obliges watercourse states to protect, preserve, and manage international watercourses and their waters (Art. 1(1)), and specifically to protect and preserve watercourse ecosystems (Article 20). It defines 'watercourse' as "a system of surface waters and ground waters constituting by virtue of their physical relationship a unitary whole and normally flowing in a common terminus"; an 'international watercourse' is defined as "a watercourse, parts of which are situated in different states"(Articles 2(a) & (b)). Article 3 of the Convention encourages the adoption of watercourse agreements at a regional level and to this end a South African Development Community (SADC) Water Protocol, later a Revised Water Protocol, was adopted (as outlined in section 5.3.2). The convention goes on to oblige states to prevent, reduce and control pollution, in particular in harmonising their policies. The measures advocated include setting joint water quality objectives and criteria, establishing techniques and practises to address pollution from point and non-point sources, and establishing lists of substances whose introduction is to be prohibited, limited, investigated or monitored (Article 21).

It is evident that the Convention is especially relevant to the five mainland WIO states particularly with respect to combating marine pollution from land-based sources and PADH. More generally the boundaries of eleven of the SADC countries straddle fifteen major perennial and ephemeral river basins (Pallet, 1997) while fifteen major rivers are shared between the different SADC countries on the sub-continent.

Nairobi Convention

The central and key convention of regional significance is the 1985 Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region, (the 'Nairobi Convention'). Originally it included two protocols: the Protocol Concerning Protected Areas and Wild Fauna and Flora in the East African Region (the 'SPAW Protocol') which is particularly relevant to PADH in the region and which is elaborated on below, and secondly, the Protocol concerning Co-operation in Combating Marine Pollution in Cases of Emergency (the 'Emergency Protocol'). The Convention and its two Protocols were adopted in 1985 and has been in force since 30 May 1996 when the necessary number of ratifications signatories was obtained. South Africa was not an original signatory in 1985 but acceded to the Convention and associated Protocols on 16 May 2003. Thus a particular strength of the Convention is that is has achieved 100 % ratification by all signatories which is a rare achievement for a regional or international convention.

The Convention provides a framework for regional cooperation in the protection, management and development of the WIO region's marine and coastal environment, for sustainable socio-economic growth and prosperity. The Preamble recognises "the threat to the marine and coastal environment, its ecological equilibrium, resources and legitimate uses posed by pollution and by an insufficient integration of an environmental dimension into the development process…"; it goes on to acknowledge: "the need for co-operation amongst themselves and with competent regional and international organizations in order to ensure a coordinated and comprehensive development of the natural resources of the region…". Of specific relevance to this report is the fact that the Convention under the heading 'Pollution from Land-based Sources' states:

> The Contracting Parties shall endeavour to take all appropriate measures to prevent, reduce and combat pollution of the Convention area caused by coastal disposal or by discharges emanating from rivers, estuaries, coastal establishments, outfall structures or any other sources within their territories.

Article 4(1) of the Convention headed 'General Obligations' goes on to state:

> The Contracting Parties shall, individually or jointly, take all appropriate measures in conformity with international law and in accordance with this Convention and those of its protocols in force to which they are party, to prevent, reduce and combat pollution of the Convention area and to ensure sound environmental management of natural resources, using for this purpose the best practicable means at their disposal, and in accordance with their capabilities.

The remaining sub-articles of Article 4 go on to oblige contracting parties to cooperate in the formulation of protocols, to cooperate with the competent international, regional and sub-regional organizations, to harmonise policies in this regard and to assist each other in fulfilling their obligations under the Convention (Article 4(2) to (5)).

The SPAW Protocol's relevance to PADH stems from its recognition of "…the danger from increasing human activities which is threatening the environment of the Eastern African region", and "…that natural resources constitute a heritage of scientific, cultural, educational, recreational and economic value that needs to be effectively protected…" (Preamble to the Protocol). Article 2 elaborates by providing for a general undertaking that the parties "…shall take all appropriate measures to maintain essential ecological processes and life support systems, to protect genetic diversity, and to ensure the sustainable utilization of harvested natural resources…[and] shall endeavour to protect and preserve rare or fragile ecosystems as well as rare, depleted, threatened or endangered species of wild fauna and flora and their habitats in the Eastern African region. The

Convention then lists the 'Protected species of wild flora', 'Species of wild fauna requiring special protection', 'Harvestable species of wild fauna requiring protection' and 'Protected migratory species' in four separate annexes, and provides for appropriate protection for each category (Articles 3 to 6 respectively). It also provides for specific protection measures (Article 10), Publicity and Notification (Article 14), Public Information and Education (Article 15), Regional Co-operation (Article 16) and related provisions.

The sister to SPAW, the 'Emergency Protocol' is relevant to pollution of marine and coastal waters, primarily geared to combat oil pollution from ships. Though it specially defines 'oil', it is clearly not limited thereto as it also defines 'harmful substances'. (The equivalent protocol in the western African Abidjan Convention is limited to oil). Moreover, various articles refer to 'marine pollution incident' which is defined as '…a discharge or spillage of oil or other harmful substance into the marine environment, or a significant threat of such a discharge or spillage…of a magnitude that requires emergency action…". This would clearly cover a land-based disaster or a threat thereof, such as a chemical outflow from an industrial plant, a serious spill of chemicals at a coastal mining site, or from inappropriate or accidental drilling chemical or waste disposal at sea. The Protocol obliges parties to cooperate (Article 3), exchange information (Article 4), and provide mutual assistance (Article 6). As such, it seems clear that the necessary regional law is in place, providing for disasters but the governance question remain whether national frameworks are in place to practically deal with such disasters.

A third (draft) Protocol on LBSA to the Nairobi Convention was presented by the Nairobi Convention secretariat to the fifth conference of parties (COP5) in November 2007 in Johannesburg, South Africa. The development of this Protocol is a tacit acknowledgement of an existing legal gap to confront the increasing challenge and severity of land-based sources and activities causing pollution and degradation of the marine environment in the WIO region. More specifically, it is currently being developed as a result of calls by the Conference of Parties (COPs) of the Nairobi Convention made in 1999 in Nairobi, and subsequently by COP 3 (Maputo, 2001), COP 4 (Antananarivo, 2004) and COP5 (Johannesburg, 2008). These called upon the Executive Director of UNEP to expedite the process of revision of the Nairobi Convention and its protocols as well as the development of the LBSA Protocol in the context of a more general initiative calling for the review of the Convention and its protocols. This would bring them up to date as modern and dynamic legal instruments better suited for the protection and conservation of the marine and coastal environment in the WIO region. The new LBSA Protocol is expected to be officially adopted by the Governments of the region during a meeting of plenipotentiaries to be held during the 6th COP to the Nairobi Convention in March 2010.

The management of the Nairobi Conventions is broad-based, and besides the core secretariat staff based in Nairobi, the Convention is guided by the governments of the region through a network of national focal points and thematic experts groups. The premier decision-making organ of the Nairobi Convention is the Conference of Parties (COP) - a biennial meeting that brings together the Ministers of Environment and technical experts from all the countries that are party to the Convention. The Ministers of Environment are represented in the technical meetings of the Convention by senior government officers in a forum referred to as the Forum of Focal Points. The Forum provides over-arching policy direction and coordination to the programmes implemented by the Convention secretariat.

On the institutional side, the Convention has two offices: the secretariat is based at the UNEP headquarters in Nairobi, Kenya, and a Regional Coordinating Unit (RCU) is based in the Seychelles. The UNEP-based secretariat works closely with the Seychelles unit, and is responsible for providing overall technical coordination, planning and developing the work programme of the Convention and monitoring the progress in its implementation. Meanwhile, the RCU based in the Seychelles is responsible for activities geared towards enhancing political visibility for the Nairobi Convention, and resource mobilization. The responsibilities of the Convention are therefore split into: (a) programme coordination based in Nairobi and (b) inter-governmental political coordination based in the Seychelles. Task forces and Working Groups under the Nairobi Convention provide a means for collaboration and cooperation between partners in addressing urgent technical issues within the scope of the Convention. The Legal and Technical Review Task Force; the Coral Reef Task Force, the Group of Experts for Marine Protected Areas in Eastern Africa (GEMPA-EA); the Physical Alteration and Destruction of Habitats (PADH) Task Force, The Municipal Wastewater (MWW) Task Force, the EIA Task Force and the Working Group on Water, Sediment and Biota Quality provide technical inputs to all organs of the Nairobi Convention.

Other international conventions

Having provided a brief overview of the main international and regional conventions which shape governance of sources of marine pollution in the WIO region the main international and regional inter-governmental frameworks and institutions are now turned to. Those related to, and those directly relevant to land-based sources in the region include:

- Convention on the Non-Navigational Uses of International Watercourses based on the articles drafted by the International Law Commission, adopted by the UN General Assembly 1997 ("Watercourse")
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 ("London")
- Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972), 1996
- International Convention for the Prevention of Pollution from Ships (1973/78). ("MARPOL")
- Convention on Biological Diversity, 1992 ("CBD")
- Convention on Persistent Organic Pollutants, 2001 ("Stockholm")
- Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade, 1998 ("Rotterdam")
- African Convention on Conservation of Nature and Natural Resources, 1968 ("African Nature")

Status of ratification of international conventions

The nine international conventions described above embrace a broad range of issues and responsibilities that would appear to ensure sustainable utilization of the marine and aquatic resources and environment of the WIO region. However, assent to the terms and responsibilities of and thus signatory to the conventions is not uniform throughout the region, though in general there is widespread inclusion (see Table 5-6).

Table 5-6 Key conventions relevant to LBSAs and ratification status in each WIO country

CONVENTION	Comoros	France (La Réunion)	Kenya	Madagascar	Mauritius	Mozambique	Seychelles	Somalia	South Africa	Tanzania
UNCLOS 1982	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Watercourses 97	No	n/a	No	No	No	Yes	No	No	Yes	No
London 1972	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
MARPOL 73/78	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
CBD 1992	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Stockholm 2001	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Rotterdam 1998	No	Yes	Yes	Yes	-	No	Yes	No	Yes	No
Nairobi 1985	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
African Nature 1968/2003	Yes	Yes	Signed	Yes	Yes	Signed	Yes	Signed	Yes	Signed

Notwithstanding the few shortcomings in ratification of regional and international conventions, the main challenge to countries in the region remains the actual implementation of such conventions in terms of national policy, legal and institutional frameworks. Based on a region-wide assessment of the status of ratification and implementation of relevant convention (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009c), the key challenges faced by countries from the region in this regard may be summarized as follows:

(i) Inadequate Technical Capacities.

(ii) Inadequate Financial Capacities.

(iii) Overlapping/Uncoordinated Institutional Mandates.

(iv) Multiplicity of Sectors affecting LBSA Issues.

(v) Lack of or inadequate Political Goodwill.

(vi) Language and Legal System Constraints.

(vii) Multiplicity of Regional Affiliations.

(viii) Political Instability.

An overview of each of these challenges is presented below.

(i) Inadequate Technical Capacities

Across the WIO region lack of, or access to, adequate technical capacities is seen as a factor that constrains ratification and/or implementation of LBSA relevant conventions. With regard to technical capacities, most of the countries would benefit from strengthening their human capacity and associated resources in the process of evaluating and selecting which conventions to negotiate or ratify. Often, state legal services are overstretched in dealing with a plethora of national domestic issues. Consequently, many LBSA relevant conventions are not ratified by the countries, and even where they are ratified they are not adequately implemented. This means that the countries will need support for enhancement of human technical capacities through *inter-alia,* training courses and programmes, as well as attendance and participation at relevant technical meetings concerning LBSA related conventions. Other technical requirements which are lacking or inadequate include basic equipment such as computers (including software), telecommunication facilities and new information technologies generally. These constrain the effective or timely delivery of services to the relevant departments even in the cases where the human resource is available.

(ii) Inadequate financial capacities.

Membership and implementation of many of the LBSA-related conventions and protocols requires a financial commitment. Although the funds required vary for different conventions and is not excessive, many countries do not prioritise such funds so that they do not meet their subscription requirements under the various conventions. Several of the countries run into years of arrears on their financial contributions to the conventions. This also affects the countries' participation in negotiations, preparatory work, public education, advocacy, awareness and other work required for timely ratification and effective implementation of the conventions. Responsible ministries and departments such as state law offices, national environmental agencies, local or municipal authorities are therefore unable to effectively deal with their mandates concerning ratification and implementation of the conventions and protocols.

(iii) Overlapping/uncoordinated institutional mandates.

In those countries with greater devolution in their political systems, such as the Comoros and South Africa, there is a tendency to have some institutions falling under different layers of Government (i.e. national, provincial or local) or under different government ministries and departments. Inadequate coordination also affects the other countries such as Kenya, Tanzania and Mauritius. In the latter case, the Ministry of Foreign Affairs is responsible for the negotiation, ratification and adoption of international conventions while the environmental mandate *per se* belongs to the Ministry of Environment. On the other hand the Ministry of Agro Industry and Fisheries, and Local Authorities are directly responsible for LBSA related issues. Others include the Wastewater Management Authority. All these ministries and departments do not seem to have a coordinating mechanism, thus leading to lack of clarity as to their respective mandates in ratification and implementation of LBSA-related conventions and protocols.

In Kenya, the situation is similar, with ministries responsible for water, environment and natural resources, local authorities, transport and agriculture each having a role in LBSA, but without a coordinating mechanism. Apart from the National Environment Management Authority (NEMA), which is the premier environmental agency, there are other institutions such as the Coast Development Authority, water services boards, local authorities, regional development authorities, and research institutions, which all have certain LBSA-related mandates.

While South Africa has a large and sophisticated governance structure, coordination problems also occur, mostly attributable to poor administration of issues relating to LBSA-related conventions and protocols. The Department of Foreign Affairs (DFA), carries overall responsibility for negotiations and adoption of international conventions. Significantly, it includes a Marine and Coastal Environment Directorate. The Department of Environmental Affairs and Tourism (DEAT) is also involved in negotiation meetings and in ensuring that the relevant international conventions are implemented. Similarly, the Department of Water and Forestry (DWAF) is responsible for water quality and water-related international legal instruments. Other national government departments with LBSA-related mandates include the Department of Trade and Industry, the Department of Transport and the Department of Agriculture.

Thus, at the horizontal level, various national government departments lack co-ordination and appear to have overlapping mandates. At the provincial and local government level there is yet more overlapping and lack of co-ordination. There are four coastal provinces in South Africa, which have a direct bearing on LBSA issues: Northern Cape, Western Cape, Eastern Cape and KwaZulu-Natal. While some national departments have provincial equivalents, others do not have. Moreover, while provincial and local governments do not have direct responsibility concerning negotiation and ratification of international conventions and protocols, they have responsibilities concerning implementation at the local level. At the level of implementation, further difficulties arise due to the multiplicity of laws and institutions, as well as the mandates of the provincial and local government.

Mozambique has potentially one of the best coordinating structures in its Ministry for the Coordination of Environmental Affairs (MICOA). This ministry is delegated to provide inter-ministerial coordination of environmental matters and report directly to the Council of Ministers. In practice this has not yet proven successful and there is unclear division of tasks of each of the key institutions involved in LBSA-related conventions which is a constraint to ratification and implementation. Weak intra and inter-institutional capacity accentuates these problems.

(iv) Multiplicity of sectors affecting LBSA issues.

Coastal zone management is complex and necessarily involves is multiplicity of sectors and players, especially concerning LBSA issues. These range from physical planning, local government/ authorities, agriculture, tourism, mining and other natural resources extraction, forestry, fisheries, regional development and transportation (including road infrastructure, air and water ports). While all these sectors interact in practice, effective coordination is complicated. Yet, without adequately involving all these stakeholder sectors from different ministerial and departmental affiliations, successful management of LBSA can not be achieved.

(v) Lack of or inadequate Political Will

Another common constraint is the absence of political to tackle LBSA issues. There is a tendency to regard coastal and marine issues at the lower-end of national priorities, reflected in poor financial allocations and technical resources. This is also reflected in lack of comprehensive national policies to elaborate the Government's approach to LBSA instruments. Only a few countries (South Africa, Tanzania and Mozambique-and to some extent-Kenya) have sought to develop integrated coastal zone management (ICZM) policies. Thus, in many respects an over-arching policy framework concerning the negotiation, ratification and implementation of LBSA-related conventions and protocols is lacking in most of the countries in the WIO Region. The lack of, or inadequacy, political will is also reflected in the low level of public education and awareness concerning LBSA-related conventions and protocols and issues generally. Consequently, public participation in LBSA-related conventions and protocols is generally weak.

(vi) Language and legal system constraints.

Differences in language can also handicap negotiation, ratification and implementation of LBSA related conventions and protocols. Countries of the WIO are more or les evenly divided between French and English, with the mainland states being largely Anglophone with the island states mostly Francophone. Seychelles and Mauritius are essentially bilingual. This language disparity impedes the region's capacity to collectively negotiate or agree to ratify and implement LBSA relevant conventions. This is further complicated by the different legal systems existing in the various countries. This is particularly so for Mozambique which is Portuguese speaking, while most of the conventions and protocols are in English and/or French. This includes the Nairobi Convention and its protocols, including its newly drafted LBSA Protocol.

The civil law system common to Francophone and Lusophone countries, such as in Madagascar, Comoros and Mozambique, creates long and complex procedures for the ratification and implementation of conventions. There are detailed constitutional and legal processes to be adhered to before ratification and implementation can take place.

Moreover, for countries with a dualist approach to international law, there is the necessity of domestication of international law instruments through consequential national legislation. This means that where the national parliament has not enacted a law to domesticate an international convention or protocol even if the latter were ratified, the same would not be implemented in the country. This usually causes delay or impediment to implementation of international legal obligations.

(vii) Multiplicity of regional affiliations.

Countries of the WIO have formed a series of different regional economic blocks and arrangements, especially concerning differences between small island developing states (SIDS) and mainland Africa. Examples include the Indian Ocean Commission (IOC) (all the island states); East Africa Community (EAC) (Kenya and Tanzania); Southern Africa Development Community (SADC) (South Africa, Mozambique, Mauritius, Madagascar, Seychelles and Tanzania); and Common Market for Eastern and Southern Africa (COMESA) (Comoros, Madagascar, Mauritius, Seychelles, Kenya, Tanzania, and Mozambique). This multiplicity of regional arrangements has implication for the WIO as it may impede a common regional approach towards LBSA in that there will be varying levels of commitments; priorities and standards regarding LBSA. However, the draft LBSA Protocol to the Nairobi Convention is reflective of a growing collective regional consensus and approach to tackling LBSA issues generally.

(viii) Political instability.

Several countries which have in the past suffered political instability, including Mozambique and South Africa during the years of apartheid rule. Somalia, though not within the review of the present study has suffered devastating internal revolution and political instability for close to two decades. Political instability, especially where armed conflict exists, leads to a general breakdown of legal and institutional systems as well as direct destruction and degradation of the environment in many (but not all) cases. Periodic political instability in some countries has also affected their participation in negotiations, ratification and implementation of LBSA–related conventions and protocols. For example, the Comoros experienced several years of political and institutional instability, with frequent Government changes which caused confusion in government programmes including environmental activities and programmes. In the process, Comoros lost time and opportunities in terms of participation in negotiation, and ratification and implementation of LBSA relevant instruments. Similar issues have arisen in Madagascar, which impeded its full participation at several forums to advance LBSA initiatives.

5.3.2 Soft laws and related developments

There are five important 'soft' laws that have been established over the last twenty years that are relevant to the WIO region. These are presented below in chronological order.

Montreal Guidelines

After UNCLOS was adopted, the Montreal Guidelines for the Protection of the Marine Environment against Pollution from Land-based Sources were prepared by an expert group under the auspices of UNEP and were adopted by its Governing Council in 1984. These Guidelines represented the first attempt to address the problem of land-based pollution at a global level.

Agenda 21

One of the documents adopted at the 1992 Rio Summit was Agenda 21. Chapter 17 on the marine environment includes some key elements that focus on sustainable development and an integrated approach to the protection and preservation of the marine environment. Although Agenda 21 is a 'soft' law instrument and not a 'hard' convention, many of its provisions have laid the foundation for subsequent incorporation in 'hard' law as evidenced by a number of multilateral environmental agreements (MEAs) entered into over the last fifteen years.

Washington Declaration and Global Programme of Action on Protection of the Marine Environment from Land-Based Activities (GPA)

In 1995, the above developments were followed up with an inter-governmental conference in Washington, USA, dealing specifically with land-based marine pollution. Two key documents were adopted: firstly the Washington Declaration on the Protection of the Marine Environment from Land-based Activities, secondly the Global Programme of Action (GPA) (www.gpa.unep.org). The GPA is a 'soft' law agreement reflecting the resolve of states to address the impacts of LBSA and physical degradation of the coastal and marine environments. As such it is an action-oriented programme with the over-arching goal to address the negative effects of land-based activities on the coastal and marine environment. It has a coordination office based in the Netherlands but is not an international institution. Rather, it is an inter-governmental programme that addresses the inter-linkages between freshwater and the coastal environment and has a close working relationship with the UNEP Regional Seas Programme (RSP). Chapter 2 of the GPA (paras. 29 to 35) sets out its objectives which include the strengthening of regional cooperation agreements, such as the Nairobi Convention, and where necessary, to create new ones to support effective action, strategies and programmes (www.gpa.unep.org).

The GPA has identified at least nine pollutant or source nodes across most of the UNEP's Regional Seas Programmes (RSPs). Many of these source nodes are also manifested in the WIO region and are described in the respective problem areas in section 5.2. Briefly, these include: municipal wastewater, heavy metals, litter, nutrients, oil, physical alterations and destruction of habitats (PADH), sediment mobilization and persistent organic pollutants (POPs).

The GPA assists states in taking concrete actions that produce tangible results within their respective policies, priorities and resources available. The implementation of the GPA is primarily the task of governments, in close partnership with all stakeholders, including local communities, public organizations, non-governmental organizations and the private sector. It also has initiated the drafting of LBSA protocols for at least six of the world's Regional Seas Programme treaties. As such, the GPA plays a central role in the WIO region mainly because it is active through the Nairobi Convention to help mainstream LBSA in the region. In particular, the WIOLaB is a demonstration project for the GPA, executed by the Nairobi Secretariat. The GPA is also involved in capacity building.

World Summit on Sustainable Development and Johannesburg Plan of Implementation

A further significant development was the 2002 World Summit on Sustainable Development (WSSD) held in Johannesburg. This adopted a Plan of Implementation (JPOI) which included provisions dealing with oceans, coasts and islands (Recommendations 30-36). It also endorsed the provisions of Agenda 21 (referred to above) and reiterated the importance of sustainable use and management of the marine environment in reducing poverty and achieving the goals of sustainable development (www.un.org/esa/sustdev/documents). Furthermore, the JPOI specifically endorsed the GPA referred to above (adopted through the Washington Declaration of 1995) (Recommendation 33).

The JPOI also makes specific reference to the GPA in that it encourages its implementation and that of the Montreal Declaration on the Protection of the Marine Environment from Land-based Activities, with particular emphasis in the period 2002-2006 on municipal waste water, the physical alteration and destruction of habitats, and nutrient pollution (paragraphs 32 and 52(e)). The JPOI also formulated a framework of actions at different levels to advance GPA implementation, in particular to:

- facilitate partnerships, scientific research and diffusion of technical knowledge; mobilise domestic, regional and international resources; and promote human and institutional capacity-building, paying particular attention to the needs of developing countries;
- strengthen the capacity of developing countries to develop their national and regional programmes and mechanisms to mainstream the objectives of the GPA and to manage the risks and impacts of ocean pollution;
- elaborate regional programmes of action and improve the links with strategic plans for the sustainable development of coastal and marine resources, noting in particular areas which are subject to accelerated environmental change and development pressures;
- make every effort to achieve substantial progress by the next GPA Conference in 2006 to protect the marine environment from land-based activities.

Finally, the Plan of Implementation calls to "effectively reduce, prevent and control waste and pollution and their health-related impacts by undertaking by 2004 initiatives aimed at implementing the GPA in small island developing states". This would include Mauritius, Seychelles and Comoros in the present case (UNEP/GPA, 2006).

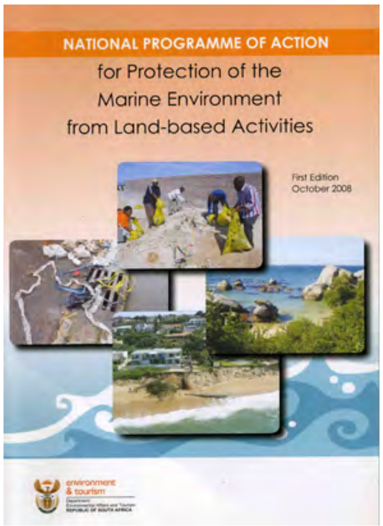
UNEPs Regional Seas Programme

Invoking of the Nairobi Convention by the GPA must be seen in the context of UNEPs Regional Seas Programme in terms of which more than a dozen regional conventions on marine and coastal waters have been adopted in various parts of the world. The first was the 1976 Barcelona Convention for the Protection of the Mediterranean Sea against Pollution. Of central relevance to the WIO is the Nairobi Convention referred to in section 5.1 and elsewhere in this report, and to a lesser extent its counterpart, the Abidjan Convention, which is applicable to the west coast of Africa.

These Regional Seas conventions lay down a broadly uniform pattern of principles. While these have been adopted by many coastal states, only a few have included specific protocols on preventing and combating land-based sources of marine pollution. Accordingly, the process of developing new LBSA protocols is under way, as in the 1999 Caspian Sea Convention, the 1985 Nairobi Convention and the 1983 Abidjan Convention.

5.3.3 Regional Economic Integration Agreements

This section outlines the four main regional economic integration units relevant to the WIO region and especially in the context of combating marine pollution from land-based sources. All four (SADC, COMESA, the EAC and the IOC) must be seen against the backdrop of the Nairobi



Many countries, including South Africa, have confirmed their engagement in the GPA on LBSA Management by developing specific National Action Plans

Convention which is the regional springboard for implementing LBSA implementation mechanisms at national levels. Table 5-7 accordingly lists the Nairobi Convention parties and depicts which other regional economic integration units each of the Nairobi Convention parties belongs to.

It is evident from Table 5-7 that there is no ideal regional economic integration unit that would be a logical vehicle to launch land-based sources of marine pollution implementation mechanisms or related instruments. Four of the WIO countries are not members of SADC including Comoros and Kenya; similarly four are not members of COMESA including South Africa and Tanzania; by its nature only three coastal countries are members of the EAC; and only the island states are members of the IOC. However, each can play a role in one way or another of at least generating political momentum behind efforts to combat land-based marine pollution. Thus for example, if the SADC, (as described in the next paragraph), had an environmental assessment protocol, it would provide the momentum for the adoption of such laws in other countries in the region. Such a framework is discussed further in the conclusion of this section.

Southern African Development Community (SADC)

SADC is a regional economic cooperation agreement constituted under the 1992 Treaty of the Southern African Development Community (SADC). It origins go back further in particular to the predecessor of SADC, the Southern African Development Coordination Committee which was not underpinned by a formal treaty but was nevertheless an effective mechanism. The objective of the treaty is to "achieve development and economic growth, alleviate poverty, enhance the standard and quality of life of the peoples of southern Africa and support the socially disadvantaged through regional integration" (Article 5(1)(a)). According to the preamble, member states are committed to "coordinate, harmonise, and rationalise their policies and strategies for sustainable development in all areas of human endeavour…" and "agree to co-operate in the areas of natural resources and the environment" (Article 21(3)(e).

On the regional scale, the SADC Protocol is the key instrument for transboundary water management. It is a framework agreement containing the generic rules for the management of shared rivers within the SADC region. Article 5, establishes the institutional set-up for the management of shared watercourses, consisting of the SADC Water Sector Organs and Shared Watercourse Institutions (SWCIs).

There are currently fifteen members of the Treaty, although this number varies from time to time as some countries have been known to interrupt their membership or new ones join the Treaty. From the 15 members, six are also members of the Nairobi Convention as shown in Table 5.7. The Table also illustrates membership and overlaps with other relevant conventions, namely COMESA, the EAC and IOC.

Table 5-7 Membership of Nairobi and other relevant regional integration agreements.

Country	Nairobi (9)	SADC (15)	COMESA (19)	EAC (5)	IOC (5)
Angola		X			
Botswana		X			
Burundi			X	X	
Comoros	X		X		X
Djibouti			X		
DRC		X	X		
Egypt			X		
Eritrea			X		
Ethiopia			X		
Kenya	X		X	X	
Lesotho		X			
Libya			X		
Madagascar	X	X	X		X
Malawi		X	X		
Mauritius	X	X	X		X
Mozambique	X	X			
Namibia		X			
France (Réunion)	X				X
Rwanda			X	X	
Seychelles	X	X	X		X
South Africa	X	X			
Sudan			X		
Swaziland		X	X		
Tanzania	X	X		X	
Uganda			X	X	
Zambia		X	X		
Zimbabwe		X	X		

The SADC Treaty is headquartered in Gaberone, Botswana and administered by sectoral sub-committees including an Environment and Land Management sector and a Fisheries sector. There is no sector dedicated specifically to the marine environment but the Fisheries Protocol and the Shared Water Courses Protocol (Table 5-8) are relevant to the coastal and marine environment but not to land-based marine pollution directly. Similarly, there is no environmental assessment protocol governing potential transboundary pollution and impacts. The adoption of a dedicated protocol on environmental assessment in SADC along the lines of the Espoo Convention in the EU would however go a long way to adopting and harmonising environmental assessments at national level. The challenge therefore is to include at least land-based marine pollution concerns and 'thinking' in developing and implementing protocols whether they are to SADC or to the Nairobi Convention.

The Revised Protocol on Shared Water Courses follows from the International Water Courses Convention referred to in section 5.2 and encourages the establishment of institutions for all river basins in the region, to be known as Permanent River Basin Water Commissions or Operating Authorities to manage shared water resources in a sustainable way.

Table 5-8 SADC Protocols relevant to pollution of marine and coastal waters

Year	SADC Protocol
2004	Declaration on Agriculture and Food Security
2003	Revised Protocol on Shared Watercourses in the SADC Region
2001	Protocol on Fisheries
1999	Protocol on Wildlife Conservation and Law Enforcement
1997	Protocol on Mining
1996	Protocol on Energy
1995	Protocol on Shared Watercourse Systems in the SADC

Specific agreements have been entered into regarding a number of basins, while other instruments of co-operation for specific basins also exist, such as: the Permanent Joint Technical Commission between Angola and Namibia on the Kunene River Basin; the Limpopo Basin Permanent Technical Committee between Botswana, Mozambique, Zimbabwe and South Africa; the Incomati Tripartite Committee, and others. In addition, a number of multi- and bi-lateral treaties have been entered into in the SADC (including WIO countries). These are addressed in more detail in section 5.3.6.

Common Market for Eastern and Southern Africa (COMESA)

COMESA is a regional inter-governmental framework which extends from *Libya* to *Zimbabwe*. Since its inception in 1994 its objective has been to further economic integration by the removal of trade and economic barriers between member states. In that year it replaced a previous preferential trading area agreement which had existed since 1981. The focus of its vision has accordingly shifted from pure 'economic' integration to 'development integration' by 'the attainment of a fully integrated economic community through a combination of trade development and investment promotion and co-ordination' (*www.comesa.int/about/vision).*

There are currently nineteen member states within COMESA (see Table 5.7) but only Seychelles, Mauritius, Madagascar, Kenya and the Comoros are party to the Nairobi Convention, with Tanzania recently leaving the group. Consequently, COMESA is unlikely to play a central role in governance in the WIO region.

East African Community (EAC)

The East African Community is a regional inter-governmental organization now comprising five member countries: Kenya, Uganda and Tanzania, and more recently Rwanda and Burundi. It is headquartered in Arusha, northern Tanzania. Originally it was a customs union but its remit was widened under the 1999 Treaty for the Establishment of the East African Community, so that it is now a regional economic integration organization. Environmental considerations are not a priority for the EAC and with only three (continental) members of the WIO region, it has little relevance to regional marine pollution.

Indian Ocean Commission (IOC)

The Indian Ocean Commission is a regional organization comprising five island states: Comoros, Madagascar, Mauritius and Seychelles and France (by virtue of its sovereignty over Reunion and Mayotte). It was established in 1984 under the General Victoria Agreement and its objectives include diplomatic cooperation, economic and commercial cooperation, cooperation in marine fisheries, agriculture, scientific, technical and cultural fields as well as the conservation of resources and ecosystems. A common area of focus of the five IOC countries is marine fisheries, to which much effort and development is targeted. Central to fisheries are a number of Fisheries Partnership Agreements (FPAs) (elaborated on in section 5.3.4). Increasingly, the IOC is also focussing on integrated coastal zone management and providing a coordinating role in a number of regional programmes that have the potential to contribute towards ameliorating LBSA. Examples include the Regional Programme for the Sustainable Management of the Coastal Zones of the Indian Ocean Countries (ReCoMaP / ProGeCo) and the Maritime Highway Project that includes LBSA elements as it relates to the transport of oil and hazardous products to and from the maritime sector to land-based facilities.

Conclusion

The above analysis reveals that the focus of these four regional economic integration units is primarily economic integration with environmental considerations mostly of secondary concern. However, trans-boundary resource management and environmental issues are indeed well accommodated in the SADC protocols, especially the Shared Waters Protocol. In light of this, it is recommended that a concerted effort be made to promote the development of a SADC environmental assessment Protocol which would include land-based marine pollution considerations. Given that it is unlikely that such a Protocol will be developed for SADC in the near future, an interim measure would be to incorporate a land-based marine pollution clause in the anticipated Nairobi Convention Protocol on Land-based Sources of Marine Pollution.

SADC environmental assessment Protocol, if and when it emerges, could be along the lines of the Convention on Environmental Impact Assessment in a Transboundary Context, 1991 ("Espoo") which applies to trans-boundary impact in the European context. A general obligation under Espoo is that states agree to: "take all appropriate and effective measures to prevent, reduce and control significant adverse transboundary environmental impact from proposed activities" . It provides useful definitions of the terms "transboundary impact" and "environmental impact" in addition to setting out the required contents and other relevant provisions of environmental impact assessment documentation. It should be noted that a number of international agencies have well developed directives and guidelines on environmental assessment. These include the World Bank, the African Development Bank, UNEP, IUCN, and the International Association for Impact Assessment (IAIA), an international NGO active in developing environmental assessment procedures and techniques. However, it should also be noted that Article 13 of the Nairobi Convention entitled 'Environmental Impact Assessment' provides for environmental assessment in the following terms:

1. As part of their environmental management policies, the Contracting Parties shall, in cooperation with competent regional and international organizations if necessary, develop technical and other guidelines to assist the planning of their major development projects in such a way as to prevent or minimize harmful impacts on the Convention area.

2. Each Contracting Party shall assess, within its capabilities, the potential environmental effects of major projects which it has reasonable grounds to expect may cause substantial pollution of, or significant and harmful changes to, the Convention area.

3. With respect to the assessments referred to in paragraph 2, the Contracting Parties shall, if appropriate in consultation with the Organization, develop procedures for the dissemination of information and, if necessary, for consultations among the Contracting Parties concerned.

It is accordingly clear that the Convention already binds parties to undertake environmental assessments where there may be transboundary impacts or where there may be a significant impact on the Convention area.

A final matter which needs to be considered under this review of regional agreements is the possibility of linking both the Nairobi and Abidjan conventions to SADC, the IOC, and/or other relevant regional integration units in some way such as by an inter-governmental agreement. This could be achieved by both the Nairobi and Abidjan conventions adopting a land-based marine pollution protocol and linking this to the LME programmes described below, thereby taking into account ecological considerations.

5.3.4 International and Regional Institutions

There are six principal international institutions involved in economic development and the marine environment of the WIO. As the following descriptions reveal, their focus within the region are varied and approaches to implementation diverse.

United Nations Environment Programme (UNEP)
UNEP is a specialized UN agency constituted under a Governing Council of 59 members elected by the General Assembly and is based in Kenya. Although it an international institution, its physical location in Nairobi makes it a central player at the regional African and WIO level. It, among many other things initiated the international Regional Seas Programme (RSP) referred to in section 5.3.1 including the central convention to this report: the 'Nairobi Convention' and its three protocols, described in the previous section. UNEP also initiated two further RSP conventions relevant to the African region namely the Convention for the Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, 1981 "Abidjan" which applies to the West Coast of Africa and the 1976/1995 Barcelona Convention which applies to the Mediterranean including North Africa.

The secretariat to the Nairobi Convention is in fact a joint secretariat with the Abidjan Convention, thus providing a platform for regional African cooperation. This agency is thus central in driving the initiative to regulate, control and coordinate land-based activities at the regional level including the development of the LBSA Protocol referred to in the introductory section 5.1.

UN Development Programme (UNDP)
The UNDP is involved by virtue of being the principle channel of multilateral, technical and investment assistance to developing countries, and includes various environmental programmes, such as the GEF (Global Environmental Facility) which not only makes funds available to developing countries but has also initiated capacity-building programmes.

African Ministerial Conference on the Environment (AMCEN)
The African Ministerial Conference on the Environment (AMCEN) was established in December 1985, following a conference of African ministers of environment held in Cairo, Egypt. It meets every two years and is mandated to provide advocacy for environmental protection in Africa; to ensure that basic human needs are met adequately and in a sustainable manner; to ensure that

social and economic development is realized at all levels; and to ensure that agricultural activities and practices meet the food security needs of the region.

AMCEN led the process for the development of the action plan for the Environment Initiative for the New Partnership for Africa 's Development (or NEPAD - described below). It endorsed a specific NEPAD Environment Action Plan which commenced in 2002, early on in the NEPAD initiative. This was endorsed by the African Union in the same year. The Environment Action Plan is underpinned by the notion of sustainable development in that it takes consideration of economic growth, income distribution, poverty eradication, social equity and better governance. It is organised in programme clusters and project activities to be implemented over a period of ten years. AMCEN has provided guidance in the process for the implementation of the action plan for the environment initiative of NEPAD, including its work programme for the biennium 2005-2006.

AMCEN has also prompted and encouraged the preparation of the comprehensive regional report on the state of Africa's environment, *Africa Environment Outlook (AEO)*, by the United Nations Environment Programme (UNEP). The AEO is an instrument for monitoring and reporting on the environment. Additionally, AMCEN successfully facilitated the revision of the 1968 African Convention on the Conservation of Nature and Natural Resources (Algiers Convention). Current measures are being taken to strengthen the linkages between AMCEN and the region's two marine and coastal conventions, namely, the Nairobi Convention and the Abidjan Convention. The UNEP Regional Office for Africa has served as the secretariat to AMCEN since its inception.

New Partnership for Africa's Development (NEPAD)

NEPAD is a vision and programme of action for the collective development of the African continent, formulated by African leaders through the African Union and adopted in October 2001. It is a comprehensive integrated development plan that addresses key social, economic and political priorities for the sustainable growth of Africa. The goals of NEPAD are broad and include: to promote accelerated growth and sustainable development, eradicate widespread and severe poverty and halt the marginalization of Africa in the globalization process.

Relevant to land-based impacts on the ocean is the fact that NEPAD has developed an environmental Action Plan to address priority environmental issues. A framework for the action plan was endorsed by the African Ministerial Conference on the Environment (AMCEN) in 2002 and by the African Union later in the same year. The framework proposes four strategic directions: (1) capacity building for environmental management; (2) securing political will to address environmental issues; (3) mobilizing and harmonizing international, regional and national resources, conventions and protocols; and (4) supporting best practice and pilot programs. The Action Plan is organized in programme clusters and project activities to be implemented over an initial period of ten years. The environmental initiative identifies programme areas that cover, among others, the following priority sectors and cross-cutting issues: combating land degradation, drought and desertification, wetlands, invasive species, marine and coastal resources, cross-border conservation of natural resources and climate change. The Action Plan builds on the related coastal problems of pollution, forests, freshwater, capacity-building and technology transfer.

The African Process for the Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa (the 'African Process') and the Pan African Conference on Sustainable Integrated Coastal Management (PACSICOM)

PACSICOM and the African Process are not really inter-governmental frameworks or institutions. Instead, they are processes, the results of which are incorporated into framework plans. For example, the results of the African Process are integrated into the NEPAD Action Plan. The African Process is a Global Environment Facility (GEF) supported initiative which emerged out of priorities highlighted at two conferences held in 1998: PACSICOM in Mozambique, and the Cape Town Conference on Cooperation Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. These events stimulated a unified political awareness amongst African governments for the need to develop an integrated approach towards sustainable development of coasts and the oceans fringing Africa.

The underlying motivation for the African Process is the recognition of the need for regional cooperation to maximize capacity in order to address the many social, economic and environmental problems that are either transboundary in nature, or common to most countries. The initiative drew scientific expertise from within individual countries and regional bodies, such as the Western Indian Ocean Marine Science Association (WIOMSA) (see section 5.5.1), so as to identify priority areas for action. This has led to the incorporation of a coastal and marine sub-component of the environment section of the NEPAD Action Plan, known as the NEPAD Coastal and Marine Secretariat (COSMAR) with its secretariat based in Nairobi, Kenya.

African Ministerial Conference on Water (AMCOW)

The African Ministerial Council on Water (AMCOW) was formally launched in Abuja, Nigeria on April 2002 by African Ministers responsible for water with a specific focus on water and sanitation issues. This was done in the same year as the establishment of the African Union and the launch of NEPAD. Essentially, AMCOW is a regional inter-governmental response to encourage new approaches to Africa's sustainable development challenges, and to meet the challenges posed by the Millennium Declaration and the Millennium Development Goals (MDGs).

The Mission of AMCOW is to provide political leadership, policy direction and advocacy in the provision, use and management of water resources for sustainable social and economic development and maintenance of African ecosystems, and strengthen inter-governmental cooperation to address the water and sanitation issues in Africa. Its functions include: to facilitate regional and international cooperation through the coordination of policies and actions amongst African countries regarding water resource issues; to review and mobilize additional financing for the water sector in Africa; and to provide a mechanism for monitoring the progress of implementation of major regional and global water resources and water supply and sanitation initiatives.

AMCOW aims to develop mechanisms that will promote "best practice" for water policy reforms, integrated water resources management, food security, water supply and sanitation. It will also enhance and solidify inter-governmental and regional cooperation in the management of shared waters, including surface and groundwater. AMCOW engages in dialogue and consultations with UN agencies, regional economic groupings and with regional and global financial institutions on financing and other issues relevant to the water and sanitation sector in Africa. Issues addressed include greater participation in regional studies regarding climate change, the development of observation networks, facilitating information exchange the development of policies and strategies for addressing water issues. The AMCOW institutional set-up consists of a full Council of Ministers (the minister responsible for water from each member country), an Executive Committee supported by a Technical Advisory Committee and a President as chair. The main AMCOW Secretariat is in Abuja, Nigeria and is headed by an Interim Executive Secretary and support staff.

5.3.5 Inter-governmental Frameworks and Agreements

There are a number of Africa-wide, sub-Saharan and WIO region inter-governmental arrangements, agreements and frameworks which are relevant to this TDA. Their focus is generally on shared natural resource management, more particularly around marine fisheries, marine ecosystem management and freshwater management, as outlined below.

Financial support provided through the Global Environment Facility has enabled the development of a comprehensive suite of projects in the WIO region, all contributing towards an ecosystem-based management approach for the region

Marine fisheries management

Marine fisheries agreements have in recent years enjoyed some prominence, in part attributable to the fishery demands imposed by the fleets from distant fishing nations of the EU and Asia, operating in the WIO. Regional structures that may have eventual management implications have been developed by a number of international institutions including the GEF (World Bank) which implements the South West Indian Ocean Fisheries Project (SWIOFP) as well as the West Indian Ocean Fisheries database (WIOFish/ www.wiofish.org) The SADC Fisheries Protocol discussed earlier, is also a relevant agreement.

Effective management agreements are still in their infancy, although their value is increasingly recognised. The FAO administered South West Indian Ocean Fisheries Commission (SWIOFC) is one of the WIO's Regional Fisheries Management Organisations (RFMOs) While the SWIOFC is increasingly active, it remains a voluntary and non-binding body that in time will hopefully increase its mandate and authority over fisheries management in the WIO. The second RFMO that is relevant is the Indian Ocean Tuna Commission (IOTC), based in Seychelles. While it has been operational for some years, it too operates largely on a voluntary basis, unlike its counterpart on the Atlantic (ICCAT) that more formally allocates and monitors quotas for individual countries.

There are also European Union Fisheries Partnership Agreements (FPAs) that have been developed in the context of the more general ACP-EU Economic Partnership Agreements initiative. The previous Contonou Partnership Agreement between the EU and African, Caribbean, Pacific (ACP) States has been replaced by a comprehensive partnership agreement between the EU and ACP regional groupings, including the WIO region. There are currently 79 members of the African, Caribbean and Pacific (ACP) group of states including the WIO countries (www.acpsec.org/en/acp_states.htm*)*. At ACP level, there is considerable scope for improving the contribution of fisheries to poverty reduction strategies. An aspect to be noted is the central role that ACP artisanal fisheries sector activities play in food security, job creation and, increasingly, in generating foreign exchange earnings. Through FPAs, the EU has signalled a change in its approach to bilateral fisheries access agreements, particularly those signed with ACP countries, in order to contribute to responsible fishing in the mutual interest of the parties concerned. However, bilateral fisheries agreements are often still concluded in isolation and not in the context of an overall regional management approach

While the RFMOs traditionally focus on the sustainability of harvesting, increased recognition of the ecosystem approach to fisheries is evident so that RFMOs now also play a greater role in wider fishery activities including socio-economic and environmental issues, including operational impacts such as those from polluting fish processing plants and fishing port activities.

Large Marine Ecosystems (LME) Programmes

Large Marine Ecosystem programmes (LMEs) are a multinational and ecosystem-wide approach to the assessment and management of coastal and marine resources. The underlying rationale of the LMEs is that they will evolve into inter-governmental management agreements in support of Chapter 17 of Agenda 21 (UNCED 1992). More than 29 LME programmes have been implemented or concluded worldwide. LME programmes focus on ecosystems rather than national domains and are designed to improve global ocean and coastal health, reduce pollution and restore depleted biomass yields (Sherman, 2003) They are supported by the GEF and its implementing partners: UNDP,, UNEP and the World Bank. Projects are based on a five-module assessment and management methodology, targeting productivity, fisheries, pollution, ecosystem health, socio-economics and governance.

An example of a successful LME programme is the Benguela Current LME (BCLME) where an ecosystem-based approach in partnership with the governments of Angola, Namibia and South Africa promotes integrated management, sustainable development and environmental protection of the south-east Atlantic region. Significantly, the BCLME has now spawned the three-nation BCLME Commission to strengthen regional cooperation and to coordinate management of shared resources in the Benguela ecosystem. Until recently, the WIO had not benefited from an LME approach, but now a similar process to the BCLME is underway here, namely the Agulhas Somali Current Large Marine Ecosystem Project (ASCLME). The ASCLME broadly includes three large ecosystems, namely the Agulhas Current the Somali Current and the Mascarene Plateau Marine Ecosystems. The study region thus extends from the Horn of Africa to Cape Agulhas, including the island states. The UNDP supported ASCLME has a strong focus on unravelling the major oceanographic driving forces that influence changes in biomass, impact on the assimilative capacity of waste and other dynamic processes. within the broader region on spatial and temporal scales (UNDP, 2006). Support from the GEF has been conditional on integrating the three projects: ASCLME, SWIOFP and WIO-LaB, so that a common Transboundary Diagnostic Analysis (TDA) and subsequent Strategic Action Plan (SAP) can be developed for the region.

Transmap

The objective of this multi-institutional and European Union funded project has been to develop the scientific basis underpinning the creation of transboundary networks of marine protected areas in the East African region. As such it is directly related to the PADH chapter of this report. More particularly, the project focuses on the definition of the type, size and location of single reserves, which together, and irrespective of political borders, can maintain ecological functions, sustainable resource-uses and expected future socio-economic development. This involves the identification and indexing of data relating to the various research thrusts of the project, which are biophysical, genetic connectivity, socio-economic, governance, existing protected areas and framework, as well as geo-analytical support in the form of aerial and satellite imagery, spatial information and related matters. Transmap was implemented at the northen and southern borders of Mozambique.

These two distinct ecoregions, one subtropical and one tropical, together encompass a significant proportion of the biogeographical range of the East African coastal and marine environment. Options for MPA zonation that regulate activities and resource use in these zones have been developed with the broad aim to maintain ecological functions, resource-uses and future socio-economic developments in these selected coastal areas.(http://www.transmap.fc.ul.pt/).

5.3.6 River-basin Governance frameworks

A leading authority states that the management of international watercourses through regional cooperation provides the most comprehensive basis for environmental protection and pollution control (Birnie and Boyle, 2002). Numerous examples of Shared Water or Joint Water Commissions exist in the region. Probably the best known is the 1987 Botswana-Mozambique-Tanzania-Zambia-Zimbabwe Agreement on an Action Plan for the Environmentally Sound Management of the Common Zambezi River System (Zambezi River System Agreement) which now also includes the Democratic Republic of Congo and is administered by the Zambezi River Basin Commission (ZAMCOM). Such shared water agreements are flexible in nature but provide broadly for two categories of shared watercourse institutions:

- Shared Water Commissions that are essentially advisory bodies providing a forum for: notification, consultation and negotiation; coordinating responses to emergencies; collecting data and other environmental matters such as the setting of water quality targets and standards; and
- River Basin Authorities that can implement in that they have specific powers granted to them by parties to the shared waters agreement concerned.

Both the International Water Course Treaty and the SADC Protocol on Shared Watercourses (SADC, 2000) envisage the formation of both these kinds of arrangements. In the case of the SADC Protocol, Article 5(3) provides two relevant paragraphs:

(a) Watercourse States undertake to establish appropriate institutions such as watercourse commissions, water authorities or boards as may be determined.

(b) The responsibilities of such institutions shall be determined by the nature of their objectives which must be in conformity with the principles set out in (the) this Protocol.

Within the SADC region there is a rich history of international agreements dealing with freshwater management and allocation as well collaboration between associated institutions at the basin level. Some of these agreements were concluded between the then colonial powers (and are still valid), others between the countries of the region post-independence. In South Africa alone, there are at least 60 of these agreements, of a bilateral as well as a multi-lateral nature (see Ashton et al., 2006). Although Malzbender and Earle (2007) identify over twenty shared water institutions in the SADC region, only two are relevant to the east coast of Africa and can be considered as falling into the category of river basin authorities referred to above. These are the Zambezi River Authority, between Zimbabwe and Zambia, established to manage and develop the shared hydro-electric infrastructure between the two states on the Zambezi River; and the Komati Basin Water Authority (KOBWA) between the Kingdom of Swaziland and the Republic of South Africa. The latter is a bi-national company formed in 1993 to manage a large dam project between these two countries under the Treaty on the Development and Utilization of the Water Resources of the Komati River Basin which is part of the wider Incomati water basin, shared by these two countries as well as Mozambique. For other examples see Table 5-9.

A general feature identified by Birnie and Boyle (2002) and Malzbender and Earle (2007) is for member countries to forego some of their sovereign rights by granting powers to a river basin authority. Such management authorities, or river basin organizations, have specific executive powers and secretariats. Apart from the Zambezi system, others are in the process of being established or converted from commissions to authorities, e.g. Limpopo Basin Commission with member Botswana, Mozambique, South Africa and Zimbabwe. In addition, these arrangements are now beginning to be dove-tailed with the environmental requirements of the SADC Protocol as exemplified by the Incomaputo-Agreement (described in more detail below).

Table 5-9 Bilateral and multi-lateral water agreements

Participating countries	Nature of Cooperation	Objectives
Mozambique, South Africa, Swaziland	Joint Incomati Basin water resources management	Provide valuable information necessary for producing a basin plan.
Mozambique, South Africa, Swaziland	Pongola and Maputo rivers development and planning	Study present conditions and future plans for the two rivers to ensure proper water flow quantities and water quality.
Mozambique, Zimbabwe	Joint water commission for the Save, Buzi and Pungwe rivers	Produce basin management plans to assess sustainability of water transfers for the Pungwe and Save rivers, including EIAs.
Zambia, Zimbabwe	Management of Kariba Dam and related infrastructure through the Zambezi River Authority	Operate, monitor and maintain the Kariba Dam, investigate new dam projects, collect and process hydrological and environmental data, liaise with utilities of the water plus various administrative functions.

Despite these positive initiatives, the region is still faced with a number of problems in collective water basin management , including lack of sufficient capacity to address transboundary issues, poor coordination among different initiatives, overlapping responsibilities, weak promotion of sectoral approaches to include coastal and marine environment issues, and lack of sustained political and financial commitment to the protection of the coastal and marine environment, partly as a result of lack of awareness.

Three of the four continental WIO states (Mozambique, South Africa and Tanzania) are SADC Member States and bound by the SADC Protocol (see section 5.3.3). In addition, most other SADC Member States that contribute run-off to rivers terminating in the WIO are also bound by the SADC Protocol (see Table 5-10).

At the regional scale, the SADC Protocol, complemented at policy level by the SADC Regional Water Policy and SADC Regional Water Strategy, establishes the institutional set-up for the management of shared watercourses, consisting of the SADC Water Sector Organs and Shared Watercourse Institutions (SWCIs) (see-SADC Shared Water Courses Protocol Article 5).

With respect to the International Watercourses Convention and the SADC Protocol referred to in section 5.3.3, the nature and scope of the obligation to protect the "aquatic environment", enshrined in Article 4(2)(d) are not well defined. By contrast, the respective provision of the UN Convention, Article 23, obliges states to take all necessary measures to protect and preserve the "marine environment," including estuaries. The relevant SADC Protocol, being otherwise identical with the UN Convention, uses the term "aquatic environment" instead of "marine environment". While there is no universally accepted definition for aquatic ecosystems, these are considered to include riverine systems, estuarine systems, coastal marine systems, wetland systems, floodplains, lakes and groundwater systems (Masundire and Mackay, 2002). Following this definition the SADC Protocol obligation would extend only to coastal marine systems but not include impacts that occur in the open sea, i.e. beyond coastal areas, as discussed by Malzbender and Earle (2007).

Table 5-10 Overview of applicable laws in the WIO countries and SADC states contributing to rivers terminating in the WIO region.

Country	WIO state without shared rivers	WIO state with shared rivers	Non-WIO state contributing to shared rivers terminating into the WIO	SADC Member state	Country bound by SADC Protocol on Shared Watercourses	National Water Legislation
Angola			X	X	X	Water Law (2006)
Botswana			X	X	X	Water Act (34 of 1968)
Comoros	X					
Kenya		X				Water Act (No. 8 of 2002)
Madagascar	X			X	(ratification pending)	Water Law (No 98-029 of 1999)
Malawi			X	X	X	Water Resources Act 1969
Mauritius	X			X	X	
Mozambique		X		X	X	Water Law (Law 16/91, of 1991)
Namibia			X	X	X	Water Act No 54 of 1956; Water Resources Management Act (24 of 2004) pending commencement
Seychelles	X					Water Resources Management Act (No. 99/ 2005)
South Africa		X		X	X	National Water Act 36 of 1998
Swaziland			X	X	X	Water Act (No 7 of 2003)
Tanzania		X		X	X	Water Utilisation (Control and Regulation) Act (42 of 1974)
Zambia			X	X	X	Water Act 1948
Zimbabwe			X	X	(signatory state but ratification pending)	Zimbabwe Water Act (31 of 1998)

The difference between the two provisions might in practice be less significant since many impacts that affect the marine environment in the open sea would also affect the estuary and coastal areas, in which case the protection obligation applies in any case. Where this does not happen, the protection obligations set forth in the SADC Protocol is arguably less rigorous, with potential implications for marine water quality in the WIO region.

As a framework agreement, the SADC Protocol does not contain basin-specific rules; rather it provides that watercourse states may enter into watercourse specific agreements that apply the provisions of the Protocol to that watercourse or part thereof (see Article 6(3)). In line with this article of the SADC Protocol, the Incomaputo-Agreement[5] is one of the first comprehensive basin-wide agreements that has been drafted for the WIO Region?). Although other basins in the regions still lack such governance, it can be expected that in the long-run similar agreements will be drafted, thereby harmonising the management of shared watercourses within the framework set by the SADC Protocol (as explained by Malzbender and Earle, 2007). The SADC Protocol is also notable in that it preserves the validity of existing agreements that member states have entered into prior to the entry into force of the SADC Protocol.

Institutional framework

In practice, the institutions operating within SADC are currently mandated primarily with monitoring functions concerning the application of the SADC Protocol, as well as with facilitating the harmonisation of water laws and policies between SADC member states. These water management institutions are not mandated with the implementation and enforcement of basin-wide agreements. Instead, where such activities are undertaken, they are done by Shared Watercourse Institutions (SWCIs) as well as relevant domestic institutions in each country. Through the above-mentioned basin-specific agreements, a range of organisations have been formed to advise basin states on river management issues (such as basin commissions), cooperate over technical aspects (technical committees) and implement projects (development authorities) (Malzbender and Earle, 2007). An overview of the various organisations in the SADC is provided in Table 5-11.

The SADC Protocol is non-prescriptive on the types of shared water course institutions (or SWCIs) which may be formed, leaving their scope of powers and mandate to member states to determine with their own mechanisms considered most appropriate to their situations. For WIO rivers, only four organizations: Tana and Athi Rivers Development Authority (TARDA), Pangani Basin Water Office (PBWO), Zambezi River Authority (ZRA) and Komati Basin Water Authority (KOBWA) have an executive mandate (see Table 5-11), meaning that they have the authority to develop, implement and maintain joint projects and to make management decisions about those projects. They are formed to specifically address a joint project, such as dam construction or operation, hydropower generation or irrigation. They do not engage in inter-state negotiations or policy formation – only operating within their clearly defined mandate as agreed by the states concerned (Malzbender and Earle, 2007).

The two transboundary river basin organizations (RBOs) with an executive mandate are the Zambezi River Authority, formed between Zambia and Zimbabwe to manage and further develop the shared hydro-electric infrastructure on the Zambezi River, and the Komati Basin Water Authority, formed between South Africa and Swaziland to implement Phase 1 of the Komati River Basin Development Project. These two organisations cover transboundary rivers yet do not include all the basin states,. Nevertheless, these SWCIs are important as they represent a tangible example of cooperation between states, developing and managing water-related infrastructure in an effort to promote the socio-economic development which the region requires (as explained by Malzbender and Earle, 2007).

5 Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and The Kingdom of Swaziland for Co-operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses.

Table 5-11 River basin organisations (RBOs) in the WIO region (note: no such organisations exist in Madagascar).

Basins	States	RBO'S with executive authority	Commissions with basin-wide mandate	Technical committees
Tana	Kenya	Tana and Athi Rivers Development Authority (TARDA)		
Athi-Sabaki	Kenya	TARDA		
Pangani	Kenya Tanzania	Pangani Basin Water Office (PBWO)		
Rufiji	Tanzania	Rufiji Basin Development Authority; Rufiji Basin Development Office		
Rovuma	Mozambique Tanzania		Rovuma Joint Comm. (being formed)	
Zambezi	Angola Botswana Malawi Mozambique Namibia Tanzania Zimbabwe Zambia	Zambezi River Authority (ZRA)	Zambezi River Basin Commission (ZAMCOM) (pending ratification)	Joint Permanent Committee
Pungue	Mozambique Zimbabwe		Pungwe River Basin Commission	
Limpopo	Botswana Mozambique South Africa Zimbabwe		Limpopo River Commission	
Incomati	Mozambique South Africa Swaziland	Komati Basin Water Authority (KOBWA)		Tripartite Technical Committee
Maputo	Mozambique South Africa Swaziland			Tripartite Technical Committee

In addition to SWCIs with an executive mandate, several basin-wide commissions have also been formed between states, operating as advisory bodies to their national states – thus not limiting their sovereignty (Malzbender and Earle, 2007). These commissions mostly work through subcommittee systems in which the members are technical experts or advisors nominated by each delegation. It is at this level that studies are carried out to provide the information to enable the committees to reach consensus around river and water management issues. Several of these commissions have now formed secretariats to assist them in conducting their duties (Malzbender and Earle, 2007).

Various other bilateral, or non-basin-wide, technical committees and commissions exist in the region. These will most likely continue to be the mechanisms for the implementation of joint projects, although some of them are increasingly coming under the remit of basin-wide commissions.

5.4 National governance frameworks

5.4.1 Legal and policy frameworks

From a constitutional perspective, it is noted that the systems of government vary between the different national jurisdictions of the WIO. Thus, some of the countries have a unitary form of government (particularly the island states) where administration is centralized, with the notable exception of Comoros where government is decentralized, each of the three islands having their own ministries and departments. Governments of the mainland states range from being centralized to a form of (quasi) federal system of government where administration in some sectors is decentralized.. South Africa has a quasi-federal state where nine provinces, including the four coastal provinces, exercise significant powers and where functions are divided between national, provincial and local authorities in line with the constitutional imperative of cooperative governance. The position in Tanzania, officially the United Republic of Tanzania, is somewhat complicated. In 1964 it became a unitary state comprising of the island of the former Peoples' Republic on Zanzibar and the former Republic of Tanganyika. The constitution distinguishes between Union and non-Union matters. Thus 'environment' is a non-Union matter resulting in separate laws and administrative authorities for Zanzibar (which also includes the sister island of Pemba) and the mainland. The same applies for marine fisheries where the island and mainland have separate laws and authorities but where an additional act, the Deep Sea Fishing Act is common to both and is a Union matter.

A growing trend in countries of the region is that of decentralization, especially in the context of managing the coastal zone. Mauritius, and Madagascar are moving towards devolving powers to the provinces (No 21 of The Courier (ACP-EU) Nov 2003). Tanzania is also in this process by granting greater powers to district councils, while in Mozambique the coastal provinces have considerable power, especially in issues relating to coastal zone management and artisanal fisheries.

Analysis of the legal and policy frameworks as found in individual country reports reveals more or less the following eight key sectoral areas from which laws, institutions and policies can be examined: fisheries and aquaculture, agriculture and forestry, tourism, mining, (mainly terrestrial but to some extent off-shore oil and gas activities), industry, transportation, energy production, coastal development and urbanisation. The Synthesis Report (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009b) identified these sectors and analysed their national legal and policy frameworks from a constitutional, regulatory framework, adoption of international conventions, policy and institutional perspective. From a governance perspective, the key legal issues concern the existence of environmental provisions in the constitution, the existence of a framework environmental act, including environmental assessment provisions, and at least a policy promoting the notion of integrated coastal area management. These are now examined in turn.

Constitutional frameworks

The constitutional legal frameworks of the WIO-LAB countries have been broadly shaped by their respective colonial past. Thus the constitutional governance structures of former British colonies such as Kenya and Tanzania have their roots in the British Westminster system of parliamentary democracy. Conversely, those countries which fell under European colonial masters such as Mozambique or Seychelles have constitutional structures which are continental European in nature; yet others for example Mauritius, have a blend of both British and continental systems.

With the advent of independence in African countries including those of the WIO-LAB region, most WIO countries adopted more modern forms of constitutional frameworks. These have to some extent been influenced by the United States model of incorporating a Bill of Rights. However, the United States' Bill of Rights includes only civil and political rights, meaning that the state must guarantee certain fundamental rights and freedoms such the right to vote, freedom of assembly, expression etc, and not to interfere with such rights. Modern day constitutions tend to also include socio-economic rights such as the right to health care or a right to a decent environment. The latter imposes a positive duty on the state rather than merely requiring it to desist from interfering with fundamental rights and freedoms. Clearly this is more socialist in nature.

The African Charter on Human and Peoples' Rights, which is a regional treaty encouraging the adoption of human rights principles by states in the African region includes socio-economic rights among its articles as well as a right to a healthy environment in article 16. At the national level South Africa was a pace-setter in the African context as regards environmental rights with its new constitutional dispensation in 1994 that included an environmental right in its Bill of Rights. Two other countries in the WIO region have also adopted such environmental rights in their constitution, as depicted in see Table 5-12. This is significant when seen in the context of the fact that no other developing nations have such rights in their constitution, though some medium developed countries do, as for India and Brazil. It is difficult to assess the practical impact is of these relatively young rights but it is safe to say that at the very least they given greater prominence to environmental issues in the national context, including those described in this report. As such the inclusion of an environmental right sets in place the overall environmental governance framework for individual countries.

Table 5-12 Inclusion of an environmental right or related provisions in the Constitutions of the ten WIO countries and their nature.

Country	Environmental Right	Brief description
Comoros	No	n/a
Kenya	No	n/a
Madagascar	No	n/a
Mauritius	No	n/a
Mozambique	Yes	Everyone has a right to live in a balanced environment; duty to protect environment imposed on the people and Government.
Réunion	Yes	Contains a special 'Charter for the Environment' (2004)
Seychelles	Yes	Citizens have the right to clean and safe environment; State to ensure a safe and clean environment.
South Africa	Yes	Everyone has an environmental right; state to enact laws in this regard
Somalia	Not known	Not known
Tanzania	No	n/a

Framework environmental act and/or environmental assessment legislation

A related and also relatively recent trend is for countries to adopt framework environmental legislation. Such an Act can include basic environmental management principles such as the 'polluter pays' and precautionary principles. In addition, the Act could include specific and all-important environmental assessment provisions. Such umbrella legislation would also invariably establish governmental environmental institutions and set out their powers and objectives. Environmental concerns are by their nature cross-cutting, overlapping with the activities of most government departments, so that it is imperative for countries to have in place legislation and instruments to ensure that environmental considerations are taken into account in all aspects of governance. The environmental assessment procedure is a key instrument in this regard. Most WIO countries have enacted framework environmental legislation and/or environmental impact assessment legislation. In particular, Somalia has a weak and fragmented environmental legislative framework, attributable to the civil war and to the relative autonomy of the Somaliland and Puntland regions. Each of these coastal regions developed a basic coastal and marine policy framework in 2000 that includes environmental assessment and related issues van der Elst, *pers com*). Reunion too has well developed environmental assessment legislation, especially relating to LBSA in the coastal zone

Water Quality and pollution-related laws and/or policies

Many of the WIO countries have in place effluent discharge standards incorporated in legislation or accompanying regulations to combat freshwater pollution. In some countries, as is the case in South Africa, these are set in the context of Receiving Water Quality Objectives (RWQOs) (RSA DWAF, 2004). South Africa has gone further by developing environmental quality objectives and targets (EQO/Ts) for the coastal marine environment. These are provided for four types of uses of coastal marine waters, namely protection of aquatic ecosystems (e.g. conservation), recreational use, marine aquaculture and industrial use (e.g. seawater intake for hydro-cooling).

A diverse range of water quality and use legislation exists with numerous institutions responsible for ensuring water quality and thus implicitly coastal water quality (see Table 5-13).

Table 5-13 Water (Quality) Act and potential key national land-based marine pollution government institutions.

Country	Water (quality) Act	Coastal water quality institution
Comoros	Loi No. 94-018 du 2 Juin 1994	Direction Nationale de L'Environment (DNE)
Kenya	Water Act 2002	Water Services Regulatory Board Water Services Boards
Madagascar	Loi No. 90-033) Relative a la Charte de L'Environnement Malagasy of December 21 1990	L'Organe de Lutte contre l'Evènement de Pollution Marine par les Hydrocarbures Comité Interministériel de l'Environnement Conseil National de l'Environnement
Mauritius	Environmental Protection Act 2002 amended by Act 6 of 2008 Central Water Act 1971 Canal and Rivers Act 1868 Wastewater Management Act 2001	National Environment Commission Director of Environment National Environmental Laboratory
Mozambique	Law 495/73 6 Oct, Pollution of Waters, Beaches and Margins Law no. 16/91, of 3 of August, Water Law	National Council of Water Regional Water Authorities
Seychelles	Environment Protection Act (EPA) 1994 Public Utilities Corporation Act, 1985	Ministry of Environment and Natural Resources; Public Utilities Corporation
Somalia	n/a	n/a
South Africa	National Water Act 1998	Department of Water Affairs (DWAF)
Tanzania	Environment Management Act 2004	Department of Water Resources (Ministry of Water and Irrigation) National Environment Management Council

Integrated Coastal Zone Management (ICZM) laws and/or policies

In examining legal and policy frameworks, a particular priority area which emerges from this governance review is the notion of Integrated Coastal Zone Management (ICZM). Worldwide the trend is for coastal states, including islands, to promote the concept of integrated coastal area management. At the time of writing, ICZM has been adopted in some WIO countries (see Table 5-14).

Table 5-14 Adoption of Integrated Coastal Zone Management policies laws and/or institutions in the WIO.

Country	Coastal policy	Coastal area legislation	Coastal management institution
Kenya	Policy prepared	Yes	National Environment Management Authority (NEMA) Coast Development Authority (CDA)
Tanzania	Yes	Yes	National Environment Management Council (NEMC)
Mozambique	Yes	Yes	Ministry for the Coordination of Environmental Affairs (MICOA)
South Africa	Yes	Yes	Department of Environmental Affairs and Tourism (DEAT) – Marine and Coastal Management (MCM)
Comoros	Yes	Yes	Direction Nationale de l'Environnement (DNE)
Madagascar	Yes	Yes	Comite National des Zones Marins et Cotieres
Mauritius	Yes	Yes	Ministry of Environment and National Development Unit (MOE) - ICZM Department
Seychelles	Yes	Yes	Department of Environment (DOE)
Somalia	Basic policy developed in some regions	No	n/a

It evident from the above that most countries, in particular South Africa, Kenya and Tanzania, have formally moved towards developing policies, laws and institutions promoting Integrated Coastal Zone Management (ICZM). On the other hand, environmental management policies laws and institutions in the small island states are by their nature all concerned with coastal and marine issues to a greater or lesser degree. Be that as it may, there have been a number of developments and regional initiatives, and organizations formed, to further ICZM. These include:

- The Arusha Resolution (April 1993) on Integrated Coastal Zone Management in Eastern Africa including the island states. This is a soft law declaration which focuses on the promotion and monitoring of long-term regional impacts caused by climate change; adaptation to, and planning for, the effects of sea-level rise in the coastal areas; formulating an inventory of potential hotspots in the region (shoreline changes, coastal erosion, land-based and marine sources of pollution, coral reefs and associated ecosystems); and the establishment and strengthening of regional measures of forecasting and early warning capabilities to deal with natural disasters.

- The Pan African Conference on Sustainable Integrated Coastal Management (PACSICOM, Maputo, July 1998) was a conference which further drove this particular process and ICZM more generally in the region (see also section 5.3.4);

- The African Process on Protection, Management and Development of the Marine and Coastal Environment, adopted the portfolio of actions arising from PACSICOM; and
- The Cape Town Conference (December 1998).
- Regional Programme for the Sustainable Management of the Coastal Zones of the Indian Ocean Countries – RECOMAP. This EU funded programme is implemented under the auspices of the Indian Ocean Commission (IOC) and focuses on improving the integrated management of the coastal zone, its biodiversity and resources, primarily motivated by the need to improve the living conditions of coastal people. RECOMAP includes seven countries (Mauritius, Madagascar, Seychelles, Comoros, Kenya, Tanzania and Somalia. There are seven explicit outputs, all aimed at strengthening coastal zone management frameworks in the region (www.recomap-io.org)

An important institution in this regard is NEPAD-COSMAR referred to in section 5.3.3 above.

5.4.2 National institutional frameworks

A particular feature and potential strength is that all the countries which are subject to this study have one or more national government institution for the environment and or natural resource management. Their area of jurisdiction can be broad, such as environmental management, natural resource management or conserving biodiversity (resources and PADH), or more specific, such as regulating (water) pollution and waste management. But invariably a number of institutions are involved. Thus, for example in South Africa, there is a national Department of Environmental Affairs and Tourism, a separate department of Water Affairs and Forestry, provincial departments of nature conservation in the (nine) provinces and parastatal bodies such as the South African National Biodiversity Institute (SANBI) charged with the study and conservation of biodiversity. Another example is the Seychelles, where the Ministry of Environment and Natural Resources is the parent ministry to a number of sub-agencies including the Marine Park Authority, the Solid Waste and Cleaning Agency, the Seychelles Fishing Authority, and pollution control. In Tanzania the National Environmental Management Council (NEMC) established under the Environmental Management Act of 2004 plays a regulatory and enforcement role on similar matters, while the Department of Environment is responsible for the review of strategic environmental assessments and hazardous waste management. In Mauritius, there is a National Environment Commission which is chaired by the Prime Minister and has the power to set national objectives and goals and determine policies and priorities, as well as reviews progress made by public departments, local authorities and other government organizations.

A strength revealed in the Regional Synthesis Report on Policy, Legal and Institutional Frameworks (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009b) is that all the countries, with the possible exception of Somalia (but excluding the Somaliland region), have a national government institution championing the environmental impact assessment process. Thus for example in Kenya the National Environmental Management Authority (NEMA) is charged with implementing the EIA process and reviewing the completed EIA reports. However, when it comes to land-based marine pollution and degradation, the position is more complex. For example in Kenya, the Coast Development Authority (CDA), established under the CDA Act (Chapter 449) focuses primarily on coastal regional development and hosts the ICZM Secretariat. Its mandate is to coordinate coastal development programmes in Kenya but the country has no land-based marine pollution legislation or regulations in place. In Tanzania, the National Environmental Standards Committee of the Tanzania Bureau of Standards sets water quality standards which in the case of LBSA are gazetted by the Minister responsible for the Environment. The nine national river basin authorities in Tanzania are charged with implementing them in the respective basins. This illustrates the fact that in many countries there are a number of national agencies which are (potentially) involved with land-based marine pollution and that attention needs to be paid to the development of effluent and/or marine environmental quality standards.

The survey reveals that in general there tends not to be a lead agency championing the notion of integrated coastal area management, including taking the lead in designing and implementing regulations on land-based sources of marine pollution. The priority then is for each country to identify which government institution should be charged with leading regulation on marine pollution activities. In the longer term, the ideal is for each country to have a dedicated coastal agency or a coastal and marine desk/department within an existing institution such as the environmental affairs department.

Conversely, a particular weakness in virtually all the countries is that there is no dedicated government agency charged with the marine environment and marine resources along the lines of the National Oceanographic and Atmospheric Authority (NOAA) in the USA. This often results in the fragmentation of matters pertaining to marine and coastal waters. Thus for example in South Africa, the Department of Environmental Affairs (DEAT) is charged with marine fisheries (Division: Marine and Coastal Management), the Department of Water Affairs and Forestry (DWAF) is charged with estuarine management and land-based sources of marine pollution, the Department of Transport (with the parastatal South African Maritime Safety Authority (SAMSA)), is charged with shipping and prevention and combating oil and hazardous waste spills.

5.5 The role of civil society

The role and influence of Civil Society Organisations (CSOs) in environmental governance generally, and the coastal and marine environment in particular, whether at international, regional or local levels, has been steadily growing over the years. Today CSOs are important stakeholders and partners in the efforts to protect the environment of the WIO region. Nevertheless, there are also weaknesses and limitations and constraints, as well as opportunities for further engagement. The general roles of CSOs working on the coastal and marine environment in the WIO Region include the following:

- Advocacy: Advocacy and campaigns for the improvement of the coastal and marine environment, including the reduction, mitigation, or elimination of adverse impacts from land-based marine activities, especially at the grassroots and community levels. This includes the establishment of formal and informal networks and collaborative arrangements.
- Education, Training and Capacity Programmes: The development of enhanced capacity and impact through education, training and research programmes is a key feature of the roles of CSOs in the region. This includes the empowerment of communities and individuals to participate better in the governance of coastal and marine resources.
- Research and Information: CSOs also have a role in research and information gathering relevant to land-based marine activities in the region. Some of the organizations specialise in process aspects, others in specific resources.
- Alternative Voice of Government: In their areas of mandate, CSOs in the region play the role of alternative voices, which keeps government and public institutions in check and more accountable to the public. In this role, CSOs assist governments in the provision of basic goods and services, especially for poorer communities.

Some of the strengths of the CSOs as facilitators of governance include the following:

- International Financial Support: These are considered to be viable alternative vehicles to government as agents of development and environmental conservation, being at times more flexible, more efficient and generally subjected to tighter fiscal controls. Because of these features, CSOs are often recipients of financial support from international development partners (see further discussion in section 5.6). Such support is usually directed towards funding the human and institutional capacity development of the CSOs. Owing to this support, more CSOs have either emerged or become strengthened and attracted some of the best intellectuals and scientists in the region.

- Technical Capacity: Many of the CSOs in the region are run by highly trained and skilled intellectuals, scientists and managers. Because they are generally project or activity-based, there is usually a concentration of specific skills and competencies. This is the case with regard to those which deal with coastal and marine environment of the WIO region, including those involved in land-based activity issues.

- Operational Flexibility: Compared to government institutions or public authorities, CSOs are generally more flexible operationally. Their financial and administrative operations, including decision making, is more flexible than the more rigid structures of government.

- Participatory and Advocatory: CSOs are generally strong on participatory and advocacy mechanisms, especially at the grassroots and community levels.

- Legitimacy: CSOs generally own the initiative and it is not imposed on them.

However, despite these well-recognised strengths, there are also areas of weaknesses and limitations to the involvement of CSOs in governance of WIO marine and coastal resources, including aspects of land-based marine pollution. These include:

- Poor Governance: Many CSOs, especially the smaller national ones, lack accountability and proper governance structures, thus making it difficult to hold them responsible where they fail to deliver on stated environmental goods and services.

- Weak Capacities: Many of the national CSOs lack financial and technical capacities to contribute effectively to management of impacts from land-based activities. They are often small or medium sized organisations whose impact is barely discernible.

- Lack of Coordinated Structure and Approach: In most of the countries, there appears to be an absence of a specific coordination structure and approach to the work and intervention of the CSOs working on land-based issues. This leads to duplication, rivalries, competition for projects or exposure and consequently ineffective interventions. This applies even to the work of larger, international or regional CSOs. However, in some countries a modicum of coordination structure between NGOs does exist. For example, the Kenya Marine Forum (KMF) is active in that country, while in Comoros there is the Association de Institutes pour Developement et l'Environnement (AIDE). Unfortunately, however, where they exist they are invariably weak. As regards international NGOs, the WIO-C (dealt with below) is expected particularly to play a key coordinating role.

- Restricted or Limited Mandates: Unlike government and public institutions generally, CSOs have restricted mandates, usually defined by their own constitutive instruments, their owners, trustees or management, and the laws or framework under which they are registered or operate. Thus they deal with specific issues or aspects of problems, often as a funded activity or project. This leads to lack of institutional memory and limited impact. Some larger, international CSOs also develop programmes primarily to sustain their economic viability, high expenses, management fees and individual salaries.

5.5.1 International and regional Non Government Organisations - NGOs

Various international and regional, as well as national non-governmental (civil) society organizations, have been active in the WIO region over time, with emphasis on various aspects of the marine and coastal environment and resources as outlined below. Many international (NGOs) have regional and/or national presence. For convenience, international and regional NGOs are described in the remainder of this section while national NGOs are the focus of section 5.5.2. .

The World Conservation Union (IUCN)

The IUCN was established in 1948 and brings together 83 States, 110 government agencies, over 800 non-governmental organizations (NGOs), and some 10,000 scientists and experts from 181 countries in a unique worldwide partnership (www.iucn.org). Its 1,100 staff are located in 40 countries, creating the world's most important and largest multicultural, multilingual conservation network. Its mission is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. Its headquarters and secretariat is in Switzerland. While IUCN's undisputed strength lies in the scientific basis of its activities, it also has an Environmental Law Centre based in Germany.

The IUCN has played an important role in developing treaties to protect wildlife, and for the conservation of natural resources. It has also undertaken numerous studies and produced many publications. These include the 1992 Convention on Biodiversity, the World Conservation Strategy which was first published in 1980, and an on-going series of Red Data Books listing endangered species of plants and animals.

The IUCN's work schedule consists of four-year Global Programmes. The priority of recent programmes has seen recognition of the many ways in which human lives and livelihoods, especially of the poor, depend on the sustainable management of natural resources. The Union promotes ecosystem management as a tool to conserve biodiversity and build sustainable livelihoods. Consequently, it is actively engaged in managing and restoring ecosystems and improving people's lives, economies and societies, including land-based issues of concern.

The IUCN East African Regional Office (EARO) was established in 1985, becoming IUCN's first regional office worldwide. Through its ability to galvanise funds from international donors, and to coordinate and manage implementation of programmes and activities, usually through sub-contracting consultants, the EARO has contributed to several important interventions in the WIO region. These included advocacy for rare, threatened and endangered species and habitats, as well as education and awareness programmes. Examples are numerous and include the facilitation of the Tanga Coastal Zone Conservation and Development Programme in Tanzania; the Eastern Africa Marine and Coastal Ecosystems Programme; its partnership with other organizations to implement the Jakarta Mandate for the implementation of the 1992 Biodiversity Convention; its support of the Kisite Marine Park in Kenya; its assessment of Somali biodiversity including coastal and marine development, and its support Tanzania's newly established Mnazi Bay-Ruvuma Estuary Marine Park and Moheli Marine Park in the Comoros. In addition, the organization has been assisting the region in the development of marine protected areas (MPAs), and particularly with the production of a 'Toolkit' to help MPA managers find the resource information they need; as well as also working in collaboration with the IUCN World Commission on Protected Areas to introduce the concept of 'assessment of management effectiveness'. All these initiatives have a direct bearing on land-based marine pollution.

Elsewhere, the IUCN supports projects on Kenya's coast such as the Diani Project which demonstrates how marine/coastal conflicts may be reduced. Also, special attention is given to biodiversity conservation in Small Island Developing States (SIDS), such as the Seychelles, where IUCN has been managing a fund established to support a series of practical biodiversity conservation projects. In the Comoros, IUCN assists with the implementation of a GEF funded biodiversity conservation project. IUCN-EARO provides support for the implementation of the Nairobi Convention through assistance to countries on national marine and coastal projects and through its regional work, funded by NORAD, WWF, UNEP/ICRAN and the Coastal Zone Management Centre of the Netherlands.

Western Indian Ocean Marine Science Association (WIOMSA)

WIOMSA is a non-governmental and non-profit regional organization for promoting the educational, scientific and technological development of all aspects of marine sciences throughout the WIO region. It promotes the educational, scientific and technological development of all aspects of marine sciences in the region with a view to sustaining the use and conservation of its marine resources (www.wiomsa.org). The association gathers and disseminates marine science information, coordinates meetings to foster marine science development and information exchange, and enhances communication among the marine scientists and other professionals involved in the advancement of marine science research and development in the WIO region. Among the flagship programmes of WIOMSA are the Marine Science for Management Fund (MASMA); regular marine scientific symposia and joint efforts and initiatives (with other partners) in support of the Jakarta Mandate for implementation of the 1992 Biodiversity Convention.

World Wide Fund for Nature (WWF)

WWF was established in 1961 and operates in more than 100 countries. Its stated mission statement is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity; ensuring that the use of renewable natural resources is sustainable; and promoting the reduction of pollution and wasteful consumption. WWF has secured funds for and is currently implementing around 2,000 conservation projects, employing almost 4,000 people worldwide. Apart from several other interventions both in the terrestrial and aquatic environment and natural resource base, the WWF has a global marine and coastal component with several initiatives. These include a dedicated marine programme, MPAs, sustainable fishing, sustainable resource use and climate change interventions (www.panda.org).

WWF has been involved in active conservation work in eastern Africa since 1962, beginning with the purchase of land in Nakuru (Kenya) to allow for the establishment of an enlarged park to help support the conservation of the flamingos of Lake Nakuru. The WWF Eastern Africa Regional Programme Office (WWF-EARPO) was established in Nairobi in 1986 within the WWF Africa and Madagascar Programme (WWF-AMP). WWF-EARPO acts as the principal focus within the eastern Africa region by providing project support and evaluation at the local and regional level. In the marine and coastal environment, the main interventions have included the WWF's East African Marine Ecoregion (EAME) project. Based in Tanzania this programme has developed a basic ecosystem template for sensitive areas along the East African coast, worthy of protection. Other specific interventions include coastal forests in Kenya and Tanzania, threatened marine turtles and climate change. It is expected that an East African Coastal Forest Programme is to be established to develop a more cohesive and region-wide mandate over coastal forests. The WWF works in close partnership with the Nairobi Convention and other stakeholders to promote the marine and coastal environment of the WIO region.

Consortium for Conservation of Coastal and Marine Ecosystems in Western Indian Ocean, (WIO-C)

A particularly relevant development, given the clear need to coordinate matters to do with land-based marine pollution in the WIO region, has been the relatively recent launch of the Consortium for Conservation of Coastal and Marine Ecosystems in the Western Indian Ocean, (WIO-C) at UNEP in Nairobi, in September 2006. Over the years, the governments of the WIO have voiced concern over the continued degradation of the marine and coastal environment as a result of which several regional organizations have developed strong coastal and marine conservation programmes. These programmes include the EAME (see above), plus related projects implemented by CORDIO, WIOMSA, WCS, UNEP and United Nations Educational, Scientific and Cultural Organization (UNESCO). Due to the multiplicity of projects and programmes, a number of key stakeholders came together to discuss and agree on how their initiatives could be more effective in influencing decision-making and changing the face of natural resource management in the WIO region. WIO-C was formed to rationalize these contributions and particularly to develop synergistic partnerships that will advance the interests of marine research, conservation and management in the region.

The nine founding members: IUCN, WWF, WIOMSA, CORDIO, WCS, UNEP-Nairobi Convention, Indian Ocean Commission (IOC), New Partnerships for African Development (NEPAD), and Inter-Governmental Oceanographic Commission (IOC-UNESCO), are committed to anchor the Consortium in the Nairobi Convention. The Consortium is expected to provide a credible network of organizations, which will be able to provide decision support, share information and management experiences, mobilize resources and develop collaborative programmes. These activities will particularly relate to regional and transboundary issues. While the nine-member leadership group will steer the Consortium, the day-to-day secretariat functions are to be a revolving responsibility – initially undertaken by the WWF-EAME office in Dar es Salaam, Tanzania. A formal launch took place during the COP 5 meeting for the Nairobi Convention in November 2007.

Other international and regional NGOs active in the WIO region include Conservation International (CI); Eastern African Wildlife Society (EAWS), the Oceanographic Research Institute (ORI) and World Conservation Society (WCS).

5.5.2 National civil society organisations

Besides the national branches of international or regional organizations described above, other homegrown NGOs, particularly at the community level, are also active. Many examples exist, such as ANAII (Associação dos Naturais e Amigos da Ilha da Inhaca) in Mozambique, KESCOM (Kenya Sea Turtle Conservation Committee), OTP (Ocean Training and Promotion) in Somalia and CoastWatch in South Africa. In reality, this category of LBSA stakeholders is important and indispensable in the governance of the coastal and marine environment. In their respective areas of mandate, they perform critical functions related to education and awareness, advocacy, research and information, and they also act as alternative voice to government.

5.6 Financial mechanisms

5.6.1 International and regional context

Financial mechanisms encompass not only the availability of finance but also include financial instruments such as incentive schemes and commercial arrangements such as partnerships, all of which together contribute to providing a secure financial basis to facilitate optimum environmental management in the marine and coastal sector. The topic traverses international, regional and national considerations partly because international stakeholders play an active role in national coastal sectors. These range from resource extraction, recreation and tourism development, to trade, transport, and communication. In this regard, the prevention of deterioration of the quality of environmental and natural resources such as fisheries, and the maintenance of recreational amenities, coastal infrastructure such as ports and harbours are ultimately all in the interest of both the international and regional community.

In general, the demand for environmental financing arises as a result of political commitment to the environment through budget transfers, users' willingness to pay for services and the use of environmental resources. The polluter's willingness, enforced or otherwise, to clean up and prevent environmental degradation may also contribute. National aspects such as coastal policies, institutions and legislative processes, dealt with in the next section, should therefore facilitate and promote international and regional funding and investments to combat land-based sources of marine pollution (UNEP, 2006). Accordingly, a fundamental cross-cutting issue is the availability of financial resources in the WIO region. This is critically important for the success of land-based activity interventions for all the problem areas outlined in Chapter 4. It is suggested that the scarcity of financial resources, linked to weak institutional capacity and the governance issue described above, remain the main limiting factors against optimal land-based activity interventions. Such interventions include planning, the setting of standards and designs, evaluation and implementation of concrete actions.

In the context of Large Marine Ecosystems (LMEs), Olsen *et al.* (2006) point out that 'there are literally hundreds of mechanisms for sustainable financing of LME programs'. Nevertheless, these authors identify four basic methods of financing government programmes whatever area they might target, namely: (i) taxes, (ii) user charges, (iii) borrowing (bonds and loans) and (iv) grants.

The use of general tax revenues is not preferred in the current context, as firstly, use of such taxes competes with other public funding priorities such as health care, education, infrastructure and defence, and secondly, there is no direct relationship between the amount of taxes paid by individual taxpayers and the amount of goods and services they have used or benefits received. The tendency in the context of financing marine and coastal related projects accordingly is to move away from broad-based taxation to the second category referred to above, namely user charges (also knows as fees or selective taxes paid for ecosystem services). This form of revenue-raising balances what individuals pay with the benefits they receive.

Olsen *et al.* (2006) describe user charges as the fees that individuals pay to their government based on the benefits received or the amounts used of the goods or services provided by their government, and distinguish four types of user charges:

a) User fees. These include royalties on the use of natural resources (e.g. a tax on fish landings), bridge and highway tolls, lease and rental payments, and charges for recurring sales of resources (e.g. water). For example, in the new South African ICZM Bill, the minister is authorised to implement: "fees, costs and rents for the use of coastal public property" (www.deat.gov.za)

b) Regulatory Fees. These include charges for inspecting and testing services, permit and license fees associated with regulatory programs, payment for providing electricity, water,

6 The Magnussen Act in the US channels this finance to marine conservation.

and waste water treatment services, solid waste disposal, construction of environmental facilities, permit services, etc.

c) **Beneficiary based taxes (or ear-marked taxes).** These are correlated with but not tied to, the use of a government-provided goods or services. For example, a government tax or levy on fuel may be dedicated to financing highway construction. Notice that in some countries great sums of money are generated by tax on fuel as road tax, even if the fuel is used to power boats at sea[6].

d) **Liability-based taxes.** These are charges for purpose of abating hazards, and fall into the legal category of the 'polluter pays' principle. The best known example of this is the international law scheme built around liability for oil spills and pollution.

As regards grants, the fourth category mentioned above, an important financing mechanism for environmental protection generally in the WIO region, is derived from domestic or international development partners such as the GEF and donors. These are amenable to contribute funding in the form of grants, loans, or other forms of financing without cost (UNEP, 2006). For lower income countries, donors tend to be the main source of environmental financing together with International Financial Institutions (IFIs). Bilateral and multilateral funding has been applied in the WIO region to assist countries in the formulation and implementation of ICZM/ICARM policies, resource management, capacity building, sectoral and regional programmes, and projects and research. Some of the external funding is channelled through regional organizations such as the Indian Ocean Commission (IOC), the UNEP/Nairobi Convention Secretariat (and related Nairobi Convention Regional Coordination Unit (RCU) in Seychelles), the WIOMSA and the now defunct Secretariat for Eastern African Coastal Area Management (SEACAM). Major external funding for activities, including international waters, has come from the Swedish International Development Agency/Department for Research Cooperation (Sida/SAREC); European Union (EU); World Bank (WB); Norwegian Development Agency (NORAD); Ireland Aid; the governments of the Netherlands, Finland and Denmark, the United States Agency for International Development (USAID); and the Global Environmental Facility (GEF) (SEACAM, 2001). The links with these to national institutions are elaborated further in section 5.6.2 below

NGOs, through their international donors, also contribute finance to implement projects, which largely by-pass the formal hurdles of national governments. For example, established international NGOs such as the WWF and IUCN, create a measure of sustainability and stability for interventions addressing land-based sources and related environmental issues. It would be worthwhile for the countries of the region to facilitate, promote and enhance the participation of such NGOs in order to ensure long term financial sustainability of land-based activity interventions. From a WIO perspective, the first priority is to secure and maintain a long-term sustainable financing mechanism to support the Nairobi Convention secretariat and its programme of work related to land-based activities. As important is the need to strengthen in-country capacity to address land-based activities which a regional institution is ideally placed to facilitate.

5.6.2 National context

The financing of activities related to land-based pollution and coastal disturbance issues is closely linked to the funding of integrated national coastal management policies and initiatives. National needs typically include funding for the development of infrastructure such as water and sewerage services, and/or appropriate alternative technologies, access roads, markets, fish landing sites, capacity building and human resource development. Related areas include financial resources and mechanisms for implementing the National Programmes of Action (NPAs), and the Strategic Action Programme (SAP) - expected to follow upon completion of this TDA. In practice, limited availability of long-term financing is one of the main obstacles to increasing environmental protection generally and reducing pollution from land-based sources in particular. This arises due to a variety of reasons including low public sector allocations, limited participation by private sector and users of environmental services and lack of awareness of the services and their value provided by ecosystems.

Sources of funding

Conventional sources of funding at national level include government allocations, through direct budgetary allocations, or through market-based instruments such as taxes, rebates and the polluter-pays principle. Also important are donor funding and private sector financing, support for civil society, as well as interventions and contributions from external development partners amongst others.

Government allocations have traditionally been, and remain, the main source of finance for environmental protection generally and coastal and marine issues in particular, including land-based activity interventions. For example, the government of South Africa, having received substantial British government support in 1999/2000 for their national environmental programme, directed most of the funds to coastal management for environmental action (SEACAM, 2001). However, government allocations to the coast are relatively more evident in the island states where there is a comparatively higher dependence upon coastal resources than compared to the Africa mainland states. The identification of domestic sources of funding (bonds, soft loans, taxes, etc.) remains a key to securing long-term support. For example, grants from the British Department for International Development (DfID) can assist in building a sustainable funding strategy but the core must be found within domestic resources.

Apart from government allocation, a further important source of domestic resources for land-based activity intervention is the private sector and civil society. As a category their contribution is smaller than public sector allocations and even perhaps external resources. Civil society groups do, however, play a small but increasingly important financing role, especially in working directly with local communities in awareness raising and empowerment programmes, financed mainly from external sources. However, the private sector is being increasingly involved in various development activities in the WIO region especially in Mauritius, Reunion, and Seychelles (SEACAM, 2001). In Mauritius, for example, an environment fund was established through which private sector invests in tourism and coastal zone planning projects. In the Seychelles, the Environment Trust Fund attracts about USD 100,000 per annum from the private sector. Nevertheless, voluntary contributions from the private sector remain isolated situations, mainly because investments for pollution abatement, such as waste water treatment, are costly (SEACAM, 2001). The main expenditure related to interventions on abating negative environmental impacts are usually in infrastructure, which have historically mainly been public sector funded.

Apart from conventional financing mechanisms, innovative arrangements such as public- private partnerships (PPPs) and decentralization may present appropriate financing options for coastal area management (UNEP, 2006). By having the private sector invest in, and operate facilities for, public services such as water supply and sewage services, the public utility may benefit from lower costs as a result of the more efficient management practices that are characteristic of the private sector. The PPP mechanism is being used in different places around the world with mixed outcomes (UNEP, 2006). Apart from PPP, pure self interest of the private sector, which is seen to have an interest in maintaining environmental quality in the coastal zone, can be a powerful motivating factor in providing financial means for maintaining a healthy coastal environment. Thus, for example, on the Kenyan coast, a group of hotels has formed a syndicate to manage sewerage outflows from their respective resorts to maintain the environmental integrity and water quality of the coastal area to ensure the sustainability of the tourist sector. Government-led incentive-based approaches can also be invoked to promote environmental quality of coastal areas. A vivid example of this is the 'Blue Flag' Programme which has been invoked in South Africa over the last decade, following the example of the EU. Twenty one beaches in South Africa have since been designated as such, meaning that they guarantee a certain marine waters quality, provide minimum human health and safety standards, and provide environmental information and management. However, the challenge is not only to initiate such projects but also to ensure their sustainability. Not all Blue Flag beaches have retained their status, largely through failed sewage treatment systems and apathy at government level.

Donor funding, addressed briefly in section 5.6.1, is attractive as supplementary to local resources, mindful of its limitations. These include lack of sustainability, as they are usually intended for specific activities or sectors and are time-bound. Consequently they are often short-term with little chance of durable impact on target groups (SEACAM, 2001; UNEP, 2006). This often obliges the recipient country to tailor or modify its funding request and proposal to meet donor criteria which may be discordant with the priorities in the recipient countries. It has been pointed out that it is of vital importance for donors to focus on projects which are initiated and designed by recipient countries, according to their priorities (SEACAM, 2001). Moreover, there is also the risk of donor dependence, especially where governments fail to take a firm position on national policies, priorities and practices. Apart from this, where external donors are not properly coordinated, this may lead to strategic confusion, financial wastage and ultimately an unsustainable result (SEACAM, 2001). Further disadvantages of donor funding include the lengthy process for obtaining grants, especially from multilateral organizations; significant lags between commitments and disbursements and the possibility of undermining local efforts at self-sufficiency and reduction in the potential for leveraging user-financing (UNEP, 2006). In recent year, donor 'fatigue' has been noted, reflected in diminishing inflows. It also remains doubtful whether donor support has in any event adequately addressed national and regional priorities of coastal and marine issues.

In conclusion, the urgent priority for the future remains the rather elusive sustainable financing mechanism for integrated coastal area management. It is essential for long-term action programmes to have financial plans based on realistic expectations of grant transfers or external resources as well as long-term sustainable domestic resources (UNEP, 2006). With respect to the latter, it is proposed that carefully negotiated public-private partnerships may provide the basis for needed sustainable investments in services such as sewage and solid waste disposal and other sources of land-based pollution and degradation in the WIO region (SEACAM, 2001). A much needed strategy to break this cycle of dependence lies in strengthening institutional capacities for planning and budgeting, including mainstreaming environmental finance into national budgets.

Moreover, it is feasible to use existing or new legal and institutional instruments, such as environmental taxes and environmental penalties, to improve the effectiveness of interventions. Environmental taxes, which may include penalties for environmental crimes, levies on production processes considered to be environmentally un-friendly, environmental licenses and/or permits or fees, or similar, are possible lines of revenue on the domestic front which could augment formal budgetary allocations in the countries. In South Africa, Part 4 of the new ICZM Act states that no person may claim an exclusive right to use or exploit any specific coastal resource in any part of, or that is derived from, coastal public properly unless authorised to do so. This authorization includes leasing such rights for a period of up to 20 years, for which a rent has to be paid. Similarly other use of the coast can generate revenue in terms of the Act, including permits to discharge waste under specified conditions. These, and other systems generating revenue for ICZM.

5.7 Education and public awareness

Education and public awareness programmes sensitize and empower the people, particularly coastal communities, concerning issues of sustainable management of the coastal and marine environment and for more effective interventions against LBSA. But education and public awareness programmes should target entire national populations and should not be limited to coastal communities and public officials and others directly involved in coastal zone governance. This is because LBSA issues are intimately connected with upstream activities and communities from a wider geographic zone. Through such programmes, national and local authorities can more easily initiate interventions addressing LBSA, including more effective management and regulatory measures. Education and public awareness also enlightens the public about development opportunities in the coastal zone as well as sensitive ecosystems. Lack of education and awareness, on the other hand, leads to ignorance, poor public participation and consequently increased pollution and degradation of the coastal and marine environment. Ultimately, successful co-management and devolution of authority to local levels is dependent on an informed society.

Education initiatives

A variety of public awareness, educational and training programmes has been implemented in the WIO region countries in recent years but largely in an *ad hoc* and un-coordinated manner. They have been disseminated mainly through the public media, workshops, conferences and specific public events, and they have had the effect of increasing awareness generally and particularly of ICZM issues (SEACAM, 2001; Uku and Francis, 2007).

More recently, a WIO LaB-supported "Educational Needs Assessment" for the WIO region (Uku and Francis, 2007) produced interesting results concerning education and awareness programmes relevant to LBSA. The findings of the educational survey indicated that educational programmes in most countries cover only limited aspects of marine and coastal environmental management. However, some countries in the WIO region have in place more advanced education programmes in this regard, which may prove to be useful in sharing of experiences between countries. From this survey, countries with advanced and coordinated educational and outreach programmes included Seychelles and South Africa.

These initiatives have largely been within the framework of more general ICZM pilot projects launched in the countries in recent years which have included public awareness and educational programmes such as for example in Kenya, Mauritius, Seychelles, Tanzania, and South Africa, among others. Television, radio programmes, posters and bill-boards, and the Internet, have all contributed to the raising of awareness and disseminating educational material, in spite of limited access especially to TV and the Internet across the region. Best practices from Mauritius and Seychelles include specific environmental media and education units which ensure the development and implementation of specific media and awareness programmes throughout the year. In Mauritius, the Information, Education and Research Division of the Ministry of Environment is fully involved in such activities (SEACAM, 2001). The challenge is to replicate such programmes in the other countries of the WIO region, and also to adequately emphasize LBSA issues.

These initiatives have had a measure of success in spite of various constraints including limited national budget allocations, limited private sector participation, and intermittent and unsustainable project-based donor support. It is suggested that these interventions can be improved by developing appropriate legislative, policy and institutional frameworks to institutionalize public awareness and education programmes. In addition, priority areas for attention could be identified and be incorporated as action points in the Strategic Action Plan (SAP) for the WIO region.

Education and awareness raising are crucial elements of a successful LBSA management strategy (photo: celebrations of World Ocean Day 2009 in Mombassa, Kenya)

Other critical challenges include the significant disparities in educational and socio-economic opportunities faced by historically disadvantaged people (particularly in South Africa); the practical challenges of establishing or mounting awareness and educational programmes among coastal zone stakeholders in rural and remote coastal areas; and the need to focus more specifically on target groups such as key decision makers, women and youth (SEACAM, 2001). As regards socio-economic and educational disparities, it would be necessary to devise methodologies to disseminate technically sophisticated information, *inter-alia,* by translating the same into "plain language" and in some cases go further to accommodate illiterate coastal communities and other stakeholders *(Ibid).* A corresponding challenge is to ensure that educational and public awareness programmes are available at all levels, and incorporate indigenous knowledge and local expertise, for wider and greater acceptability and sustainability.

Some of the national institutions responsible for educational and public awareness programmes in the WIO region include national environmental authorities such NEMA (Kenya), NEMC (Tanzania), DEAT (South Africa), MICOA (Mozambique), DNE (Comoros), ONE (Madagascar), MENR (Seychelles) and the Department of Environment (Mauritius). Others include educational institutions such as universities, which offer, among others, short courses and capacity-building for the development of public education materials. Elsewhere, there is a significant contribution to educational and awareness programmes by NGOs as highlighted the discussion of their roles under section 5.5.

Educational priorities

Among the main outstanding priorities for further action include the raising of adequate and sustainable financing for LBSA interventions, especially from national budgeting allocations, private public partnerships and longer term development partner support, as discussed in section 5.6. Another priority focus area is the development of capacity among institutions and human resources engaged in educational and public awareness issues on LBSA. In this respect, the countries ought to take concrete steps towards establishing effective legal policy and institutional frameworks to support the development of needed capacities. One practical approach would be to create appropriate frameworks to encourage and support private sector participation in educational and public awareness programmes. This could be part of their commercial advertisements for their goods and services, corporate and social responsibilities, and could entail financial contributions, the use of their commercial outlets and networks, and their profiles and standing. Such programmes could be integrated in private sector activities in key production and commercial activities such as tourism, fishing, mining, urban developments, aquaculture and agriculture.

Some of the possibilities suggested by Uku and Francis (2007) include the use of beach clean-up campaigns to raise awareness in schools, as one area in which the WIO-LaB project could contribute, particularly in countries like Tanzania (notably Zanzibar) and Comoros, modelled along the International Coastal Clean-up campaigns that are held in South Africa and Kenya annually. Moreover, the Coastal Environment Award Scheme conducted in Tanzania was successful in raising awareness of environmental issues as well as securing the support of communities during the development of the National Integrated Coastal Management Strategy. This programme promotes public participation in management of natural resources in the coastal region of Tanzania and encourages the use of environment-friendly technologies and practices and demonstrates government commitment to ICZM. CEAS could be used to motivate the communities to establish beach management units (BMUs), like those now established in Kenya and around parts of Lake Victoria, make them operational (Uku and Francis, 2007). Besides, South Africa, other countries in the region such as Kenya, the Seychelles and Mauritius, with substantial tourists visiting their coastal areas could benefit, and be assisted to initiate Blue Flag Programme for their beaches (Uku and Francis, 2007).

Finally, to address both technical capacities for the longer term and to increase the national impact of educational and public awareness campaigns, efforts should be made by countries of the WIO region to introduce and integrate coastal and marine environment, including LBSA issues in the formal curricula of schools and appropriate tertiary education institutions. At present, environmental studies in the formal school curriculum is rather sparse and even more insignificant with regard to coastal and marine or LBSA issues. This is in spite of the finding by Uku and Francis (2007) that some of the countries do have well-established educational programmes at the higher level. A notable exception is South Africa, where the Marine and Coastal Educator's Network (MCEN) is a countrywide initiative that reaches more than 400 000 learners every year, often through the conduit of a specialist facility such as SeaWorld-Durban. Simultaneously, curriculum support is provided by MCEN, so that coastal and marine conservation issues, including LBSA are promoted at school. Ultimately, enhanced public awareness and education on LBSA issues will lead to greater and inclusive public ownership and participation in appropriate interventions, and sustainable development and utilization, financing, and management of the enormous coastal and marine environment and resources of the WIO region.

5.8 Conclusions

Despite a plethora of policies and legal instruments, the degradation of coastal and marine habitats has continued. No doubt the complex and integrated nature of the coastal zone adds to the challenges of management, but overall the governance arrangements appear largely to have failed. This analysis has identified the many stakeholders directly involved or implicated in governance of the coastal zone. Traditionally, governance of these sectors was based on a sectoral approach; each managed separately through dedicated legal/regulatory, institutional and policy frameworks. This fact, in addition to the often overlapping mandates and responsibilities of such stakeholders, makes LBSA management a complex undertaking. Clearly there is a great need for an integrated approach, as is being developed by most of the WIO countries. In 2009, South Africa promulgated its Integrated Coastal Zone Act, which can be considered a positive contribution to improving regional governance through a more integrated approach.

There are a number of common causes that are at the root of these weaknesses with respect to inappropriate and incoherent legislation or lack of adequate institutional framework for dealing with LBSA issues. These are often inter-related and a summary of such 'root causes of governance' is presented in Box 5.3.

Box 5.3 Summary of common governance related problem areas.

Policy and legislative inadequacies	• Inadequate updating, implementation, enforcement and monitoring of relevant legislation • Inadequate ratification and domestication of relevant international and regional instruments
Limited institutional capacity	• Lack of mechanisms for effective coordination and inter-sectoral governance • Inadequate human resources and technical capacity in institutions charged with the responsibility of addressing LBSA-related issues
Inadequate awareness	• Inadequate awareness, understanding and appreciation of the economic value of coastal/marine ecosystem goods and services among policy makers and legislators, the civil society and the private sector
Inadequate financial mechanisms	• Inadequate financial mechanisms and resources for dealing with LBSA-related issues
Poor knowledge management	• Lack of adequate scientific and socio-economic data and information to support policy making, monitoring and enforcement

The main recommendations emanating from this chapter are further outlined in Chapter 6.

CHAPTER 6 – FINAL ANALYSIS AND CONCLUSIONS

6 Final analysis and conclusions

6.1 Introduction

This final Chapter of the TDA is a synthesis and overall assessment of the transboundary problem analyses presented in the previous chapters. It also provides an overview of various possible areas of intervention to address these problems as a bais for the long-term Strategic Action Programme on LBSA for the WIO region.

6.2 Overall synthesis of transboundary problems

Three main categories of transboundary environmental problems related to LBSA have been described in Chapter 4:

1. Water and sediment quality degeneration due to pollution from land-based sources;
2. Physical alteration and destruction of habitats; and
3. Alteration in freshwater flows and sediment loads from rivers.

An overview of the main elements, root causes and sectors involved in each of the three problem categories is shown (Table 6-1). This succinct analysis reveals some general conclusions, grouped under three themes:

A. Transboundary elements

- All three problem categories have elements of a transboundary nature that are shared by many of the counties in the WIO. Moreover, the impact of these problem areas has the potential to extend beyond national borders with effects on shared coastal habitats, stocks of migratory and straddling species as well as on the deterioration of water quality for human well-being.
- There are two types of transboundary effects. One is direct where certain types of persistent pollutants and litter result in direct transboundary impacts. The second is less direct where pollutants, physical alteration and destruction of habitats, river-coast interactions and other activities may influence overall ecosystem integrity through impacting on important neighbouring coastal habitats of WIO countries.

B. Root causes

- Common root causes are attributable to population pressure, poverty, inequality, knowledge and awareness gaps, inadequate financial resources and inappropriate governance, all of which are relevant to the transboundary problems identified.
- In addition, climate change, a diversity of natural processes and economic drivers, are at the core of physical alteration of habitats and impact on river basins. This includes the non-sustainable use, and extraction, of mineral and living resources.

C. Sectors

- Most economic sectors are cross-cutting in that they affect all three categories of transboundary problems (although not all to the same extent), but two are more specific:

    a. Industry is relevant to water quality degradation.

    b. Fisheries impacts are mostly confined to physical alteration of coastal habitats and estuaries.

A synthesizing analysis of each of the three problem areas is presented in the sections that follow. Furthermore, section 6.4 provides an overall analysis of the governance aspects related to the three transboundary problem areas, based on the findings of Chapter 5.

Table 6-1 Synthesis Matrix of transboundary problems (see Box 6-1 for description of codes).

Major Transboundary Problem	Transboundary elements	Major root causes							Main sectors implicated							
		Population pressure	Poverty and inequality	Inadequate governance	Inadequate financial resources	Inadequate knowledge and awareness	Climate change and natural processes	Economic drivers	Fisheries and aquaculture	Agriculture and forestry	Tourism	Mining	Industry	Transportation	Energy production	Urbanization and coastal development
WATER AND SEDIMENT QUALITY DEGENERATION DUE TO POLLUTION FROM LAND-BASED SOURCES	• Common in all countries • Affects spawning, nursery & foraging areas of straddling & migratory marine organisms • Potential for transboundary dispersion of persistent pollutants and litter	■	■	■	■	■				■	■	■	■	■	■	■
PHYSICAL ALTERATION AND DESTRUCTION OF HABITATS	• Common in all countries • Affects spawning, nursery & foraging areas of straddling & migratory marine organisms	■	■	■	■	■	■	■	■	■	■	■		■	■	■
ALTERATION IN FRESHWATER FLOWS AND SEDIMENT LOADS FROM RIVERS	• Common in many countries • Affects spawning & nursery areas of straddling & migratory marine organisms	■	■	■	■	■	■	■	■	■	■	■		■	■	■
	Category codes	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8

Box 6-1 Index to category codes of root causes and sectors in Table 6-1.

	Generic Root Causes
A	**Population pressure** Rapid population growth and associated urbanization in the WIO region has increased the generation of waste and concentration of waste streams. Also, population growth has led to increased demand for ecosystem goods and services.
B	**Poverty and inequality** The WIO region is characterized by high poverty levels, which result in increased reliance on the exploitation of natural resources. The consequent lack of financial resources has led to problems such as inadequate sanitation infrastructure, and institutions and regulatory bodies lacking capacity.
C	**Inadequate governance** In the countries of the WIO region there exists a weakness in policy, legal and institutional structures and building blocks for effective management of the coastal and marine environment.
D	**Inadequate financial resources** Most countries in the WIO region do not have adequate financial resources, whether in absolute terms or through inadequate priority setting, for effective management of the coastal and marine environment.
E	**Inadequate knowledge and awareness** Gaps in the knowledge base and inadequate awareness of the value of ecosystem goods and services provided by a healthy coastal and marine environment are a major cause of management inefficiencies by coastal communities and policy makers in the WIO region.
F	**Climate change and natural variability** Climate change and variability in the WIO region is already influencing rainfall patterns, evidenced by the frequency and intensity of extreme weather events, changing the flow patterns of rivers (causing floods and impacting on floodplains, deltas and coastal ecosystems) and other events such as the bleaching of corals.
G	**Economic drivers** The demand for ecosystem goods and services, including from export markets, is exceeding the availability and regeneration capacity of elements of the ecosystems in the WIO region.

	Generic sectors
1	**Fisheries and aquaculture** • Artisanal fisheries • Industrial fisheries • Seaweed farmers • Industrial prawn farmers • Fish & shellfish farmers
2	**Agriculture and forestry** • Charcoal makers • Small-scale loggers • Industrial loggers • Small-scale farmers • Large-scale farmers • Pastoralists • Ranchers • Poultry farmers • Dairy farmers • Beekeepers
3	**Tourism** • Tourists • Hotel owners & operators • Small-scale traders • Tourist boat & SCUBA operators
4	**Mining** • Coral/lime miners • Sand miners • Small-scale salt producers • Industrial salt works • Small-scale miners • Industrial mining companies • Fuel suppliers & stations • Oil & gas production
5	**Industry** • Heavy manufacturing industry • Light manufacturing industry • Agro-processing industries • Oil refining
6	**Transportation** • Ports • Dredging companies • Clearing and forwarding • Railway • Roads • Airports • Airlines • Shipping
7	**Energy production** • Hydro-dam operators • Power station operators • Renewable energy producers
8	**Urbanization and Coastal Development** • Coastal communities • Solid waste operators • Sewage system managers • Property developers • Town planners

6.3 Summary of transboundary problems

6.3.1 Water and sediment quality degeneration from land-based sources

Pollution of coastal waters originates largely from land-based sources and activities. Municipal and industrial discharges, contaminated surface and sub-surface run-off, polluted rivers and atmospheric emissions are all sources that contribute to pollution of the sea. While a dynamic ocean environment may have considerable assimilative capacity, pollutants from such land-based activities are typically received in the fragile coastal zone where they affect some of the most productive areas of the marine environment, such as estuaries, coral reefs and seagrass meadows. Moreover, such contaminants pose risks not only to natural resources but also to human health by being transported long distances by watercourses, ocean currents and atmospheric processes.

Chapter 4 identified five distinguishable pollution categories, a brief summary of which is presented in Table 6-2. The various categories of pollution are not equally dispersed through the region and in many cases their impacts are confined to specific hot spots, often related to urban centres and/or river outlets. Some 35 hotspot sites of pollution were identified and the specific transboundary problems associated with each are presented in Table 6-3.

Table 6-2 Overview of the five pollution categories identified in the TDA.

Microbial contamination	Microbial contamination is characterized by the presence in water of pathogenic organisms (protozoa, bacteria and/or viruses) of either human or animal origin that can pose health risks to humans. In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater, contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing and industrial effluents (mainly from food-processing industries).
High suspended solids	High suspended solid loads from land-based sources enter WIO coastal waters mainly through municipal and industrial wastewater discharges, river discharges and surface runoff, particularly during rainy seasons. Dredging activities (usually associated with ports and harbours) can also significantly contribute to this problem.
Chemical pollution	Chemical pollution in the WIO region is characterized by the adverse effects of chemical contaminants (heavy metals, hydrocarbons and persistent organic compounds) released to the coastal environment from land-based human activities. Chemical pollutants in the WIO region are typically linked to agrochemical discharges (accidental or intentional), industrial discharges, dredging activities in ports and harbour (re-suspending sediment-bound heavy metals and hydrocarbons), and leachate from solid waste dump sites.
Marine litter/solid waste	Most of the major cities and towns found in the WIO region generate significant amounts of solid wastes, some of which reach the sea to contribute to marine litter problem. Important land-based sources of solid waste are found in major urban centres (ports, industrial and commercial areas and informal settlements) and discharges through rivers (transporting solid waste/debris from urban areas located in their watersheds).
Eutrophication (harmful/ nuisance algal blooms)	Eutrophication refers to artificially enhanced primary productivity (algal and phytoplankton growth) and organic matter loading in coastal waters as a result of the increased availability or supply of nutrients, usually as a result of inappropriate disposal of municipal wastewater or nutrient-enriched agricultural return flows.

From the analysis presented in section 4.2 it was shown that the highest pollutant loads entering the WIO originate from the mainland states and Madagascar. South Africa and Tanzania contribute the greatest overall loading of nutrients and organic matter, material originating mainly from the discharge of wastewater from the larger coastal municipalities such as Durban and Richards Bay.

However, these systems use deepwater outfalls that are regularly monitored and have a greater assimilative capacity.

Table 6-3 Overview of pollution hotspots in the WIO region and associated (perceived) pollution problems.

COUNTRY	HOT SPOT	CATEGORY[a]	TRANSBOUNDARY PROBLEM				
			Microbial contamination	Eutrophication (harmful algal blooms)	Marine litter (solid waste)	Suspended solids	Chemical Pollution
Comoros	Mitsamihouli beach	2	■	■	■		■
	Chindini Beach	4	■		■		
	Chomoni Beach	4			■		
	Moroni Port	1	■	■	■		■
	Anjouan Port	1	■	■	■		■
	Fomboni Port	4	■	■	■		■
Kenya	Mombassa	1	■	■	■	■	■
	Lamu inshore waters	1	■	■	■	■	■
	Malindi Bay and Sabaki Estuary	1	■	■	■	■	■
	Diani	2	■	■	■	■	■
Madagascar	Port de Mahajanga	1	■	■			■
	Port de Nosy-Be	1	■	■			■
	Toliara	1	■	■		■	
	Port de Tamatave	2					■
	Bay de Diego	1		■			■
	Baie de Fort-Dauphin	2	■				■
Mauritius	Pointe Aux Sables to Bay du Tombeau (through Port Louis)	1	■	■	■	■	
	Belle Mare/Palmar	1	■	■			
	Flic and Flac	4	■	■		■	■
	Grand Baie	3	■	■		■	
	Rodrigues[b]	?				■	
Mozambique	Maputo Bay	1	■	■	■	■	■
	Beira	4	■	■	■		
	Nacala Bay	4	■	■	■		
	Pemba Bay	4	■				
	Incomati Estuary	4		■			
Seychelles	Port Victoria	2	■	■			■
	La Digue	3	■				
	Anse Volbert	4	■				
	Beau Vallon Bay	2	■	■			
	East coast Mahe	3	■	■			■
South Africa	Richards Bay	3				■	■
	Durban	1	■				
	East London	4	■	■			
	Port Elizabeth	4	■				■
	Eastern Cape and Kwazulu-Natal estuaries and adjacent coastal areas	4	■	■			
Tanzania	Dar es Salaam	1	■	■			■
	Tanga	1	■	■			
	Zanzibar	1	■	■			

a. Hot spots ranked in order of decreasing severety from 1 to 3; Category 4 refers to emerging hot spots.
b Rodrigues did not form part of the WIO-LaB regional monitoring programme and is consequently not ranked.

One main conclusion that can be drawn from the above overview of pollution hotspots in the WIO region, shown in Table 6-3, is that the most common transboundary problem related to pollution is microbial contamination. With the evidence presented in section 4.2 it may further be concluded that microbial contamination, largely originating from the discharge of untreated wastewater in nearshore waters, is one of the most significant common failures of governance in the region. This form of pollution also has the highest level of impact as a health risk to coastal populations, either through direct contact with seawater and via the consumption of seafood products.

A second important failing is the inadequate or inappropriate management of solid waste which leads to marine litter, a now common feature on all the coasts, especially Comoros, Mozambique, Kenya and Tanzania. Issues related to high levels of suspended solids, furthermore, are largely confined to areas around the main river outlets, while chemical pollution is mostly associated with major ports or rivers that have riparian industries

Although elevated nutrient levels have been recorded at many hot spots, the levels are generally below thresholds for causing eutrophication. Some examples do exist, such as in Seychelles, Mauritius and South Africa where, for example high oxygen demand from pulp mill effluents is a cause for concern. Harmful algal blooms may not be common, but have periodically been reported from the WIO region. Indications are furthermore that climate change, ocean acidification and coral bleaching may accentuate algal blooms (Quod, *et al*, 2001).

6.3.2 Physical alteration and destruction of habitats (PADH)

Transformation and loss of habitat is yet another priority transboundary problem for the WIO. This involves both physical and biological processes. Physical processes include dredging of waterways, deforestation, diversion of freshwater flows, heavy metal mining in dunes, sand winning, construction of ports and jetties, tourist resorts housing developments, coastal erosion and a range of other activities and processes. Biological transformation involves over-exploitation and associated destruction of coastal forests, mangroves, seagrass meadows and coral reefs. Land reclamation for agriculture and development, as well as extensive upland deforestation, also cause acute upstream habitat transformation in major catchments such as the Tana, Sabaki, Rufiji and Zambezi. In addition, global climate change, which is a cross-cutting concern at least partly attributed to human activities, accentuates these transformations through abnormal rainfall patterns, droughts, floods, and sea level change.

The cumulative impacts of these transformations and losses have lead to significant physical and ecological changes in the region and an overall decline in many ecosystem services. These impacts are grouped under five categories of PADH and presented in Table 6-4. In all, some 25 hotspot sites of PADH in the WIO region have been highlighted in this TDA, and the specific transboundary problems associated with each are presented in Table 6-5. It is noted this list is not exhaustive and reflects only those 'known' hot spots identified during the TDA process; other hotspots are known to occur throughout the region. It is obvious that the categories or types of PADH are not the same throughout the region, although all countries face problems related to shoreline changes, albeit to varying extents. The other categories of PADH are largely dependent on the extent to which certain resources are available, such as mangroves, which are found mainly in Tanzania, Kenya, Mozambique and Madagascar, and coral reefs which are mainly limited to the island states, Kenya and Tanzania.

Table 6-4 Overview of the five categories of PADH identified in the TDA.

Degradation of mangrove forests	As a dynamic zone between land and the sea, mangrove wetlands are controlled by several interacting factors such as tides, periodicity of freshwater and sediment fluxes, topography, soil and water salinity, temperature and sedimentation patterns. These factors are closely related to land- and water-use practices in the areas adjacent to and upstream of mangrove forests. Human-induced stresses range from diversion of freshwater flow, poor land use in and around mangrove forests to over-exploitation of mangrove resources. These stresses disrupt the natural equilibrium, ultimately leading to the degradation of the mangrove wetlands, which in turn not only depletes the resources within their boundaries, but also affects the productivity of adjacent coastal and marine ecosystems.
Degradation of seagrass beds	Seagrass degradation in the WIO region is generally evidenced by continued destruction and/or reduction of seagrass habitats in shallow inter-tidal and sub-tidal areas. This degradation is usually as a result of physical action (e.g. dragging of nets, or clearing), pollution or by climate change through increased discharge of sediment-laden low-salinity water derived from flooded river systems. Seagrass degradation has negative impacts on the system's productivity, biodiversity and hence food security, ultimately leading to loss of livelihood and increased poverty among coastal populations.
Degradation of coral reefs	Coral reef ecosystems face various types and levels of impact across the WIO region. In addition to anthropogenic threats such as destructive fishing activities, there is climate change, which led to severe coral bleaching during the 1997-98 El Niño/Southern Oscillation phenomenon, damaging reefs throughout the region. Continuous degradation of coral reef biodiversity lowers fisheries productivity and leaves shorelines unprotected, impacting on livelihood and incomes of local communities, thereby increasing poverty levels.
Degradation of coastal forests	Degradation of coastal forests occurs mainly in the form of land transformation through intense clearing for agriculture, mining, human settlement and coastal development, including tourism. There is also destruction associated with an increased demand for forest products such as timber and firewood. Transformation of coastal forests has a significant impact on the coastal environment through reduction of plant and faunal diversity, loss of fertile soils, increased soil erosion, and a reduction in the recharge of groundwater aquifers. Ultimately, these impacts change the dynamics of both sediment and water exchange in the coastal zone.
Shoreline changes	Erosion and accretion of coastlines can result in significant shoreline change. Episodic storm events, in part driven by climate change, have an impact on critical habitats, coastal infrastructure, agricultural land and human settlements. As many WIO shores are dominated by rapidly eroding sediments and low-lying wetlands, the impact of storms and hence shoreline changes are accentuated. Changes in accretion of the coast originate from two main sources: changes in sediment loads from rivers and the re-suspension of benthic sediments by rough seas. In addition, increased water turbidity, due to re-suspended sediments, can result in smothering of corals, seagrasses and mangroves, hence further contributing to shoreline change. Sea level rise is an additional problem for low-lying coastal areas, such as central Mozambique, the west coast of Madagascar, and the Tana and Rufiji Deltas in Kenya and Tanzania respectively.

Table 6-5 Overview of main PADH hotspots in the WIO region.

COUNTRY	HOT SPOT	TRANSBOUNDARY PROBLEM				
		Degradation of mangrove forests	Degradation of seagrass beds	Degradation of coral reefs	Degradation of coastal forests	Shoreline changes
Comoros	Moheli			■	■	■
	Grand Comoros			■	■	■
	Anjuan			■	■	
Kenya	Malindi Ungwana Bay		■	■		■
	Vanga-Msambweni Complex	■				■
	Tana Delta	■			■	■
	Mida Creek	■				
Madagascar	Toliare	■		■	■	
	Mahanjanga Bay					■
	Nosy Be					■
	Hahavavy	■				
Mauritius	Rodrigues			■	■	
	Grand Bay		■			■
	Flic en Flac		■			■
Mozambique	Maputo Bay	■	■		■	■
	Nacala-Mossuril seascape	■			■	■
	Zambezi delta	■				■
Seychelles	La Digue					■
	East Coast, Mahé			■		■
	Anse Volbert, Praslin					■
South Africa	Richards Bay				■	■
Tanzania	Dar es Salaam	■				■
	Tanga Coastal Area	■			■	■
	Zanzibar			■		■
	Bagamoyo					■

6.3.3 Alteration in fresh water flows and sediment loads from rivers

The interaction between river basins and the coastal and marine environment is also a key factor relating to the environmental health of the WIO. Throughout much of the region, many of the coastal issues identified are linked to human activities and climatic variability far removed from the coastline. This is especially so for continental states where such distant impacts have altered the nature of the river systems' drainage, impeding the flow of freshwater, terrigenous sediment and organic matter. These changes have also affected the quality of the water, mainly through the addition of nutrients and pollutants from domestic sewage, industrial and agro-chemical discharges. An overview of the two main categories of river-coast interaction is presented in Table 6-6.

Table 6-6 Overview of the two categories of river-coast interaction identified in the TDA.

Alteration of river flows and water quality	The alteration of the natural river flow (whether through a drop in quality, quantity or timing of flow) is found to some degree in many of the major river basins in the WIO region. The four most frequent reasons for flow alterations are: (i) overall reduced flow due to consumptive uses of water, (ii) increase of river surface area along sections of the river due to impoundment/damming, (iii) changed seasonal flow patterns (e.g. releases for hydropower-generation during the dry season), (iv) increased floods due to wetland losses (loss of water retention capacity). These are coupled with the large-scale realities and uncertainties brought about as a consequence of climatic change, as a consequence of which some basins are predicted to receive more rainfall than the historic mean and others less.
Alteration of sediment loads	A number of factors, such as changing climate, land-use practices and dam construction, have led to changes in the sediment load transported by some of the rivers in the WIO region. The alteration of sediment loads in the WIO region rivers broadly manifests itself in three ways: • Increased sediment loads – this has a negative impact on the coastal and marine environment, through for example the degradation (smothering) of mangroves, coral reefs and seagrass beds, as in the case of Athi-Sabaki and Mwache river in Kenya, and the Betsiboka river in Mozambique. • Decreased sediment loads – Has a negative impact on the marine environment through increased erosion of the delta mouth, and through increased salt-water intrusion, leading to a reduction of downstream habitats for mangroves and other species, as in the case of the Tana River in Kenya, and the Zambezi and Incomati rivers in Mozambique. • Variable sediment loads in different parts of the basin - in some rivers, there is both increased sediment loads from erosion in upstream areas, and reduced sediment transport downstream of dams due to trapping of the sediments behind the dam wall.

An overview of the type of river-coast interaction problems for the 15 main river basins in the WIO region is presented in Table 6-7. Despite limitations in the level of assessment (the TDA did not focus specifically on each of the individual basins), it is clear from Table 6-7 that in terms of severity of these problems, the alteration of river flow is common . In addition, there are cases where changes in sediment loading and water quality have severely impacted on coastal habitats. According to the analysis, the most affected river basins are:

- Pangani (Kenya and Tanzania);
- Athi-Sabaki (Kenya);
- Incomati (South Africa, Swaziland and Mozambique);

- Zambezi (Angola, Botswana, Democratic Republic of Congo (DRC), Malawi, Namibia, Tanzania, Zambia, Zimbabwe and Mozambique); and
- Betsiboka (Madagascar).

Table 6-7 Overview of river-coast interaction problems for main rivers in the WIO region.

COUNTRY*	HOT SPOT	TRANSBOUNDARY PROBLEM			
		Alteration in river flow	Degradation of water quality	Increase in sediment load	Decrease in sediment load
Kenya	Tana	■	■		■
	Athi-Sabaki	■	■	■	
Madagascar	Betsiboka	■		■	
	Tsiribihina	■		■	
	Mangoky	■		■	
	Fiherenana	■		■	
Mozambique	Zambezi	■			■
	Pungue	■			■
	Limpopo	■			
	Incomati	■			■
	Maputo		■		
South Africa	Thukela	■			■
Tanzania	Pangani	■	■	■	
	Rufiji		■		
	Ruvuma				

* Refers to country of river outflow

■ Issues of 'critical' concern

6.4 Overview of governance problems related to LBSA management

Management of issues relating to land-based sources and activities is a complex undertaking. While most countries in the WIO Region have put in place policy, legal, regulatory and institutions frameworks that are relevant to the protection and management of the coastal and marine environment, most countries have not (yet) succeeded in reversing the trend of degradation of the coastal and marine ecosystems. A primary root cause of the transboundary problems as identified in the TDA is the fact that governance structures are in many cases inappropriate, ineffective and/or inadequate. An overview of the main weaknesses in LBSA governance, as identified in Chapter 5, is presented in Table 5-17.

Table 5-17 Common weaknesses in LBSA governance in the WIO region.

Policy and legislative inadequacies	• Inadequate updating, implementation, enforcement and monitoring of relevant legislation • Inadequate ratification and domestication of relevant international and regional instruments
Limited institutional capacity	• Lack of mechanisms for effective coordination and inter-sectoral governance • Inadequate human resources and technical capacity in institutions charged with the responsibility of addressing LBSA-related issues
Inadequate awareness	• Inadequate awareness, understanding and appreciation of the economic value of coastal/marine ecosystem goods and services among policy makers and legislators, the civil society and the private sector
Inadequate financial mechanisms	• Inadequate financial mechanisms and resources for dealing with LBSA-related issues
Poor knowledge management	• Lack of adequate scientific and socio-economic data and information to support policy making, monitoring and enforcement

Coastal zone users are diverse in nature, involving a variety of economic sectors such as fishing and aquaculture, agriculture, forestry, tourism, mining, manufacturing industry, transport, energy, as well as related coastal development and urbanisation activities. Traditionally, governance of these sectors was based on a sectoral approach; each managed separately through dedicated legal/regulatory, institutional and policy frameworks. It is therefore not surprising that a primary root cause of governance ineffectiveness is related to a lack of coordination of administrative decisions affecting the development and or exploitation of the coastal and marine environment and associated natural resources.

A key conclusion derived from the governance analysis undertaken as part of the TDA process is therefore that crosscutting governance instruments need to be promoted and developed to meet the unique challenges in the coastal zone. Such instruments and initiatives include Integrated Coastal Zone Management (ICZM), Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), and Marine Protected Areas (MPA). A positive development is recognised whereby virtually all WIO countries have to a greater or lesser degree commenced, or at least considered the application of such instruments in their jurisdictions.

Furthermore, since many of the impacts related to land-based sources and activities cut cross borders, efforts should be focused on harmonizing and adopting legislative frameworks at the regional level. In this regard, the development of regional-level strategies for the management of land-based sources and activities and establishing mechanisms for coordination between institutions as well as financial mechanisms as envisaged in this document is crucial. A variety of conventions (international and regional) and inter-governmental agreements, that in one way or the other informs governance in the WIO region, are already in place, although not all have been ratified by all countries. In addition, a number of key institutions have been established to support the implementation of such instruments. The central challenge now is to provide effective coordination mechanisms between such governing bodies.

Finally, few policy makers are fully aware of the economic importance of natural environments, and in particular coastal and marine ecosystems. For this reason, destructive activities often escape their attention and in certain instances are allowed to proceed without clear guidelines and regulation, causing damage to critical habitats. The potentially devastating socio-economic consequences of this are not effectively communicated to politicians and the public, resulting in the low priority given to these issues in the national processes for environmental policy formulation and budget allocations.

6.5 Prioritization of transboundary problems and related causes

Initial prioritization of transboundary problems was undertaken by a working group of regional experts and stakeholders[1]. The primary method applied for this exercise was a multi-criteria analysis undertaken by over 40 experts from various disciplines and representing all the project countries, based on a set of six criteria, which can be divided into two general categories:

(a) the *scope* of the problem:

- Transboundary nature of the problem (i.e. geographical scope)
- Scale of benefits of resolving problem
- Feasibility of finding solutions to the problem

(b) the *severity* of the problem:

- Environmental impact of the problem
- Socio-economic impact of the problem
- Macro-economic consequences of the problem

Following detailed analysis of the transboundary problems, the prioritization of problems was further refined by the Scientific and Technical Review Workshop of the TDA[2], which analysed the various problems and causes through a step-wise prioritization exercise. A detailed overview and description of the method and criteria used for prioritization, as well a detailed report on its results is presented in Annex 3 and 4 respectively. The results of the prioritization exercise identify the key issues that should be on top of the list of policy makers when defining actions and strategies.

6.6 The way ahead: a framework for a Strategic Action Programme

This TDA identifies the key transboundary problems related to the impacts of land-based activities on the marine and coastal environment of the WIO. Throughout the different steps of the TDA and in particular during consultations with stakeholders, a number of priority areas of intervention to address such problems were identified. It is recommended that these areas of intervention will form the basis for development of the SAP. An overview of these priority areas of intervention derived from the TDA process is presented in Annex 5.

Annex 5 identifies specific actions for each of the three main problem areas, as well as a number of cross-cutting areas of intervention. Four main categories of actions are defined:

1. Monitoring and Assessment - actions geared at filling gaps in data and information in order to generate the necessary knowledge for better, more sustainable management.
2. Management Tools - actions geared towards the preparation of management tools such as guidelines and investment plans, as well as actions geared towards demonstrating appropriate approaches.

---

1 At a UNEP-hosted workshop in Nairobi, April 2007.
2 held in Mombassa in August 2008

3. **Governance -** actions geared towards the development and implementation of governance frameworks, including policies, laws, regulations and standards, as well in stimulating and supporting governments in mainstreaming marine and coastal management in existing policies and budgets.

4. **Information management, capacity building and awareness raising -** actions geared at capacity building and education, as well as providing platforms for information exchange and interaction with stakeholders.

It is suggested that during the various steps of the SAP development, the areas of intervention will be further defined, detailed and prioritized.

Annex 5 furthermore identifies potential partners that could be involved in the design and implementation of specific actions. It is recommended that consultations with such stakeholders be held to define specific, targeted interventions, including investment plans and required policy, legal and institutional changes.

At the national level, attention will furthermore be paid to the mainstreaming of SAP activities into national policy and legal frameworks, development plans and budgets. At the regional level, supporting activities will be defined, including activities directed at capacity building, strengthening of the regional legal framework and financial mechanisms.

BIBLIOGRAPHY

A

Abdallah, F.A., Bacari, A., Sinane, H.M., Ibrahim, Y. and Mouridi, A.A. 2006. Rapport national sommaire sur les activités terrestres, les sources de pollution et les niveaux des polluants dans l'eau et les sédiments : Comores. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 43 pp.

Abrantes, K. G. S. and Pereira, M. A. M. 2003. Boas Vindas 2000/2001: A Survey on Tourists and Tourism in Southern Mozambique. 21 pp. Maputo, BICO/FNP.

Aboubacar O.Z. 1991. Etude sectorielle des pèches maritimes de la Republique Federale Islamique des Comores. In: Ardill J.D and Sanders M.J. (eds.) 1991. Priorities for fisheries management and development in the Southwest Indian Ocean. FAO Fisheries Report 457: 29-42.

Abuodha, P.A.W. and Kairo, J.G. 2001. Human-induced stresses on mangrove swamps along the Kenyan coast. *Hydrobiologia* 458: 255-265.

Abuodha, P.A.W. 2003. Coastal erosion in Kenya: The Bamburi-Shanzu case study. A report prepared for UNEP/GPA, UNEP and WIOMSA.

AFRISCO, 1994. Lake Chala Water Resources Development Project (Phase One). Project Evaluation Report to Coast Development Authority, Kenya. Afrisco Ltd., Israel.

Ahamada, S., Bijoux, J., Bigot, L., Cauvin, B., Kooonjul, M., Jean Maharavo, J., Meunier, S., Moine-Picard, M., Quod, J-P. and Pierre-Louis, R. 2004. Status of the coral reefs of the South West Indian Ocean Island States. In: Wilkinson, C. (eds.) Status of Coral Reefs of the World: Vol. 1. AIMS, Townsville: 189-211.

Akitanda, P. 2002. South Kilimanjaro catchment forestry management strategies – perspectives and constraints for integrated water resources management in the Pangani River Basin. Paper presented at the International Conference on Integrated River Basin management, Pangani River Basin. 13-14 June 2001, Moshi, Tanzania.

Aldegheri, M. 1967. Fleuves et Rivières de Madagascar. ORSTOM, Antananarivo.

Alemaw, B.F.and Chaoko, T.R. 2006. The 1950-1988 warm ENSO events and regional implications to river flow variability in Southern Africa. Water SA 32(4): 459-464.

Alusa, A.L. and OGALLO, L.J. 1992. Implications of expected climate change in the East African coastal region: an overview. UNEP Regional Seas Reports and Studies No. 149. UNEP, Nairobi.

American Meteorological Society 2000. American Meteorological Society glossary of meteorology. http://amsglossary.allenpress.com/glossary/search?id=somali-current1

Amir, O.A., Berggren, P. and Jiddawi, N.S. 2002. The incidental catch of dolphins in gillnet fisheries in Zanzibar, Tanzania. *W. Indian Ocean J. Mar Sci.* 1(2): 155–162.

Amir, O.A., Jiddawi, N.S. and Berggren, P. 2005. The occurrence and distribution of dolphins in Zanzibar, Tanzania, with comments on the differences between two species of Tursiops. Tanzania. *W. Indian Ocean J. Mar. Sci.* 4 (1): 85-94.

Anon. 1968. Somalia. In: Marine science activities of the nations of Africa. National council on marine resources and engineering development. April 1968: 52-54

Anon. 2001. Transboundary water management as an international public good. Development Finance 2000. Report prepared for the Ministry for Foreign Affairs, Sweden. Stockholm, Sweden.

Anon. 2006. Prawn fishery performance for the year 2006. Ministry of Natural Resources and Tourism, Fisheries Division, Dar es Salaam.

Anon, Mauritius 2009. National summary report on land-based activities, sources of pollution and pollutant levels in water and sediment: Mauritius. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 103 pp.

Anon. Mozambique 2007. Draft national status report on land-based activities, sources of pollution and pollutant levels in water and sediment: Mozambique. Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya, 24 pp.

Antoine, H., Carolus, I., Naya, N., Radegonde, V. and Sabury, E. 2008. The status of coastal and marine pollution in Seychelles. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 149 pp.

Arthurton, R., Korateng, K., Forbes, A., Snoussi, M., Kitheka, J., Robinson, J., Shah, N., Taljaard, S. and Monteiro, P. 2006. Chapter 5: Coastal and marine environments, 155-195. In: UNEP (2006) Africa Environment Outlook 2-Our Environment, Our Wealth. ISBN: 92-807-26691-9, Nairobi, Kenya: 542 pp.

Arthurton, R. 1992. Beach erosion: Case studies on the East African coast. In: proceedings of Bordeaux, 1992, International Convention on Rational Use of the Coastal Zone. IOC, Bordeaux: 91-95.

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

Ashton, P.J., Earle, D., Malzbender, A., Molo, MBH, Patricki, M.J. and Turton A.R. 2006. A compilation of all the international freshwater agreements entered into by South Africa with other states report to the water research commission. WRC Report No. 1515/1/06.

Ashton, P.J., Love, D., Mahachi, H. and Dirks, P.H.G.M. 2001. An overview of the impact of mining and mineral processing operations on water resources and water quality in the Zambezi, Limpopo and Olifants catchments in southern Africa. Contract report to the mining, minerals and sustainable development (southern Africa) project, by CSIR-Environmentek, Pretoria, South Africa and Geology Department, Uni. of Zimbabwe, Harare, Zimbabwe. Report No. ENV-P-C 2001-042I xvi + 336 pp.

Autrand, M. 1997. Etude du schéma d'aménagement de l'aquaculture de crevettes à Madagascar : Phase I : Cas des zones 2, 3, 5. Les élevages de crevettes de mer : Contexte général et grand choix préliminaires. Rapport provisoire. Consortium OSIPD-FTM-PHD.

Azemia, R. and Robinson, J. 2004. Seychelles Artisanal Fishery Statistics for 2003. Seychelles Fishing Authority Technical Report (SFA/RandD/059), 2004: 82 pp.

Azemia, R.T. and Assan, C.N. 2006. Seychelles artisanal fisheries statistics for 2005. Seychelles Fishing Technical Report. SFA/R&d/063: 79 pp.

B

Bailey, C.L. and Scholes, R.J. 1999. Progress report on the global change research project. CSIR, Pretoria.

Baird W.F. and Associates Coastal Engineering Ltd. 2003. Study on the coastal erosion of Mauritius. Vol. 1 Final technical Report. Ontario (Canada): 462 pp.

Baker, A.C., Starger, C.J., McClanahan, T.R., and Glynn, P.W. 2004. Corals' adaptive response to climate change. *Nature* 430: 741.

Bakun, A., Roy, C. and Lluch-Cota, S. 1998. Coastal upwelling and other processes regulating ecosystem productivity and fish production in the Western Indian Ocean. In: Sherman, K., Okemwa, E.N. and Ntiba, M.J. (eds.) Large marine ecosystems of the Indian Ocean: Assessment. Sustainability, and management. Blackwell Science, London: 103-142.

Baloi AP, de Premegi N, van der Elst R and Govender, A. 1998. Towards sustainable development- the artisanal fisheries of southern Nampula Province. IIP unpublished report: Maputo: 82 pp.

Balidy, J. 2003. Variação de cobertura das comunidades de ervas marinhas, causas desta variação e seu valor ecológico-económico na Baía de Maputo. Tese de Licenciatura, Universidade Eduardo Mondlane, Maputo. 90 pp.

Bandeira, S.O. 1995. Marine botanical communities in southern Mozambique: Seagrass and seaweed diversity and conservation. *Ambio* 24: 506-509.

Bandeira, S.O. 1998. The seaweed resources of Mozambique. In: Critchley, A. and Ohno, M. (eds.) Seaweed Resources of the World. Japan International Cooperation Agency: 385-388.

Bandeira S.O. 2000. Diversity and ecology of seagrasses in Mozambique: emphasis on *Thalassodendron ciliatum* structure, dynamics, nutrients and genetic variability. PhD Thesis. Göteborg University, Sweden.

Bandeira, S.O. 2002. Diversity and distribution of seagrasses around Inhaca Island, Southern Mozambique. South Afr. J Bot. 68: 191-198.

Bandeira, S.O. and António, C.M. 1996. The intertidal distribution of seagrasses and seaweeds at Mecúfi Bay, northern Mozambique. In: Kuo, J., Phillips R. C., Walker D.I. and Kirjman, H. (eds.) Seagrass Biology: Proceedings of an International Workshop. University of Western Australia, Netherlands: 15-20.

Bandeira S.O. and Bjork, M. 2001. Seagrass research in eastern Africa region: emphasis to diversity, ecology and ecophysiology. South Afr. J Bot. 67: 420-425.

Bandeira S.O. and Gell, F. 2003. The Seagrasses of Mozambique and Southeastern Africa. In F. Short and E. Green. Seagrass Atlas of the World. World Conservation Monitoring Centre. University of California press: 93-100 pp.

Bandeira S., Kairo J. and Rönnbäck P. 2006. Ecological economics of mangrove associated fisheries –food security and sustainability. Marine Science for Management (MASMA) final Research Report. 50 pp.

Bandeira S.O., Paula e Silva, R., Paula, J., Macia, A., Hernroth, L.,Guissamulo, A.T. and Gove, D.Z. 2002. Marine Biological Research in Mozambique: past, present and future. *Ambio* 31: 606-609.

Bandeira S, Barbosa, F., Bila, N., Azevedo J. F., Nacamo E., Massinga, A., Mafambissa, M. and Rafael, J. 2007. Vegetation assessment of the Quirimbas National Park. Technical report to WWF: 128 pp.

Barbosa, F.M.A., Cuambe, C.C and Bandeira, S.O. 2001. Mini review: status and distribution of mangroves in Mozambique. *South Afr. J Bot.* 67(3): 393-398.

Barnabas, A.D. 1991. *Thalassodendron ciliatum* (Forsk.) den Hartog: Root structure and histochemistry in relation to apoplastic transport. *Aquatic Botany* 40: 129-143.

Barnes, D.K.A. and Fraser, K.P.P. 2003 Rafting by five phyla on man-made flotsam in the. Southern Ocean. *Mar. Ecol. Progr. Ser.* 262: 289-291.

Barnett, R., 1997: The shark trade in mainland Tanzania and Zanzibar. p 39-67. In: Marshall, N.T. and R. Barnett, (eds.)The trade in sharks and shark products in the Western Indian and Southeast Atlantic Oceans. TRAFFIC East/ Southern Africa: 132 pp.

Beckley, L.E. 1998. The Agulhas current ecosystem with particular reference to dispersal of fish larvae. In: Sherman, K., Okemwa, E.N. and Ntiba, M.J. (eds.) Large marine ecosystems of the Indian Ocean: Assessment. Sustainability, and management. Blackwell Science, London: 255-276.

Beentje, H. and Bandeira S.O. 2007. Field Guide to the Mangrove Trees of Africa and Madagascar. Royal Botanic Gardens, Kew: 91 pp.

Beilfuss, R. 1999. Can this river be saved? Rethinking Cahorra-Bassa could make a difference for dam-battered Zambezi. *World Rivers Review* 14 (1): 8-11.

Benbow, B 1976. Dangerous marine animals of East Africa. East African Literature Bureau: 24 pp.

Benno B., Verheij E., Stapley J., Rumisha C.,. Ngatunga B., Abdallah A. and Kalombo H. 2006. Coelacanth discoveries and conservation in Tanzania. *S. Afr. J. Sci.* 102: 486–490.

Berggren, P. 2009. Whales and dolphins, a field guide to marine mammals of East Africa. WIOMSA. East Publishing, UK: 128 pp.

Berggren, P. 2000. Dolphin tourism as a conservation tool for critical habitats for dolphins in East Africa. European Cetacean Society Conference, Cork, Ireland, 3–5 April 2000.

Berggren P, Amir, OA, Guissamulo, A. Jiddawi, N.S. Ngazy, Z., Stensland, E. , Särnblad, A. and Cockroft, V.G. 2007. Sustainable dolphin tourism in East Africa. WIOMSA Book series No 7: 72 pp.

Berkelmans R., De'ath G., Kininmonth S. and Skirving W. 2004. A comparison of the 1998 and 2002 coral bleaching events on the Great Barrier Reef: spatial correlation and predictions. *Coral Reefs*. 23: 74–83.

Berry, P.F. 1978. Reproduction, growth and production in the mussel, *Perna perna* (Linnaeus), on the East Coast of South Africa. *Investigational Report, Oceanographic Research Institute (48): 1-28.*

Berry, P.F. 1982. Biomass and production rate in the ascidian *Pyura stolonifera* on a littoral rock reef on the Natal Coast, South Africa with estimates of biomass of other detritivores. *Investigational Report, Oceanographic Research Institute* (53): 1-12.

Best. P.B. 2007. Whales and dolphins of the southern African subregion. Cambridge University Press. Cambridge: 337 pp.

Bijoux, J.P., Adam, P-A., Alcindor, R., Bristol, R., Decommarmond, A., Mortimer, J.A., Robinson, J., Rosine, G., Rowat, D., Talma, E.S., Wendling, B. and Zialor, V. 2003. Marine biodiversity of the Seychelles Archipelago: the known and unknown. Census of Marine Life Programme in sub-Saharan Africa, Marine Biodiversity of the Seychelles: 22 pp.

Bijoux, J.P., Decomarmond, A. and Aumeeruddy, R. 2008. State of the marine environment report for Seychelles: 92 pp.

Birnie P.W. and Boyle A.E. 2002. International Law and the Environment (2ed) Oxford University Press: 256 pp.

Birrell, C., McCook, L., and Willis, B. 2005. Effects of algae turfs and sedimentation on coral settlement. *Mar. Poll. Bull.* 51: 408-414.

Bjork, M., Mohammed, S.M., Bjorklund, M. and Naaslund, I. 1996. Distribution of coral associated algae at four locations near Zanzibar Town, Tanzania. In: Bjork, M. Semesi, A.K., Pedersen, M. and Bergman, B. (eds.) Current trends in marine botanical research in the East African region. Proceedings of the symposium on the biology of microalgae, macroalgae and seagrasses in the Western Indian Ocean. 3-10 December, 1995. University of Mauritius: 347-357.

Bjork, M., Mohammed, S.M., Bjorklund, M. and Semesi, A.K. 1995. Coralline algae, important coral reef builders threatened by pollution. *Ambio* 24 (7-8): 502-503.

Blaber, S.J.M, Kure N.F., Jackson, S. and Cyrus, D.P. 1983. The benthos of South Lake, St.Lucia following a period of stable salinities. *South African Journal of Zoology* 18(4): 311-319

Blom, J., van der Hagen, H., van Hove, E., van Katwijk, M., van Loon, R. and Meier, R. 1985. Decline of Malindi-Watamu Reef complex. *Lab. of Aqua. Ecolo.* Catholic University: 195 pp.

Bosaso Port Authority, 1997. Ship movement report for the year April 1996 to March 1997. Report to UNDP and Puntland Government.

Bosire, J. 2006. Ecological recovery of reforested mangroves in Kenya. Thesis submitted in fulfilment of the requirements of the Degree of Doctor of Philosophy in Science of the Vrije Universiteit Brussel, Brussels: 138 pp.

Bosire, J.O., Dahdouh-Guebas, F., Kairo, J.G. and Koedam, N. 2003. Colonization of non-planted mangrove species into restored mangrove stands in Gazi Bay, Kenya. *Aquatic Botany* 76: 267–279.

Botte, M.D.M. 2001. Monitoring of coral bleaching at four sites around Mauritius. BSc Thesis. (unpublished). University of Mauritius.

Brito, R., Munguambe,P. and Massingue, F. 2003. Wetlands of Mozambique – Country Report. Presented at IUCN and IWMI workshop in Maputo, Mozambique 2003.

Brix, H. and Lyngby, J.E. 1982. The distribution of cadmium, copper, lead and zinc in eelgrass (*Zostera marina* L). *The Science of the Total Environment* 24 (1): 51-63.

Brouwer, R. and Falcão, P.M. 2004. Wood fuel consumption in Maputo, Mozambique. *Biomass and Miometry* 27: 233-245.

Brown, 2005. See Brown, C., Pemberton, C., Birkhead, A., Bok, A., Boucher, C., Dollar, E., Harding, W., Kamish, W., King, J., Paxton, B. and Ractliffe, S. 2006. In support of water resource planning highlighting key management issues using drift: a case study. *Water SA* 32: 181-191.

Brown, C. and King, J. 2002. Environmental flows: requirements and assessments. In: Hirji, R., Johnson, P., Maro, P. and Chiuta, T.M. (eds.) Environmental Sustainability in Water Resources Management in Southern Africa. SADC, IUCN, SARDC, World Bank: Maseru, Harare, Washington DC.

Brown, P.J. and Taylor, R.B. 1999. Effects of trampling by humans on animals inhabiting coralline algal turf in the rocky intertidal. *J. Exp. Mar. Biol. Ecol.* 235 (1): 45-53

Brown, K, Daw, T., Rosendo, S., Bunce, M. and Cherret, N. (eds.) 2008. Ecosystem services for poverty alleviation: marine and coastal situational analysis. A draft synthesis report submitted to DFID. University of East Anglia: 67 pp

Bruton, M .N. and Cooper, K .H . (eds.) 1980. Studies on the ecology of Maputaland. Rhodes University Press, Grahamstown and the Natal Branch of the Wildlife Society of Southern Africa, Durban: 560 pp.

Bryant, D., L. Burke, J. McManus, and M. Spalding. 1998. Reefs at Risk: A Map-based Indicator of Threats to the World's Coral Reefs. World Resources Institute: 11-15.

Bryceson, I. 2002. Coastal aquaculture developments in Tanzania. Sustainable and non-sustainable experiences. *W. Indian Ocean J. Mar. Sci.* 1: 1–10.

Burgess, N.D. 2000. The biological importance of Tanzania I: Endemic bird areas. WCST. Annual report for 1998-1999. Miombo 23: 27.

Burgess, N.D. and Clarke, G.P. 2000. The Coastal Forests of Eastern Africa. IUCN Forest Conservation Programme, Gland and Cambridge UK: 443 pp.

Burgess, N.D., Clarke, G.P., Madgick, J., Robertson, S. A. and Dickinson, A. 2000. Distribution and Status. In: Burgess, N.D. and Clarke, G.P. (eds.) Coastal Forests of Eastern Africa. IUCN, Gland, Switzerland and Cambridge, UK: 71-81.

Burgess, N.D. and Muir, C. (eds.) 1994. Coastal Forests of Eastern Africa: Biodiversity and Conservation. Proceedings of a workshop held at the University of Dar es Salaam, August 9-11, 1993. Society for Environmental Exploration/ Royal Society for the Protection of Birds, UK.

C

Carbone, F. and Accordi, G. 2000. The Indian Ocean coast of Somalia. *Marine Pollution Bulletin* 41(1-6): 141-159.

Carreiro-Silva M. and McClanahan, T. R. 2001. Echinoid bioerosion and herbivory on Kenyan coral reefs: the role of protection from fishing. *J. Exp. Mar. Biol. Ecol.* 262(2) 133-153.

Catriona, M.O., Macinnis-Ng and Ralph, P. 2002. Towards a more ecologically relevant assessment of the impact of heavy metals on the photosynthesis of the seagrass, *Zostera capricorni*. *Mar. Poll. Bull.* 45(1): 100-106.

Cave, L.C., Beekman, H.E. and Weaver, J.M.C. 2003. Impact of Climate Change on Groundwater Recharge Estimation. Council for Scientific and Industrial Research (CSIR), Stellenbosh.

Celliers, L. and Schleyer, M.H. 2002. Coral bleaching on high latitude marginal reefs at Sodwana Bay, South Africa. *Marine Pollution Bulletin* 44: 180-187.

Celliers, L. and Schleyer, M.H. 2006. Observations on the behaviour and character of an *Acanthaster planci* (L.) aggregation in a high-latitude coral community in South Africa. *Western Indian Ocean Journal of Marine Science* 5: 105-113.

Celliers, L. and Schleyer, M.H. 2008. Coral community structure and risk assessment of high-latitude reefs at Sodwana Bay, South Africa. *Biodiversity and Conservation* 17: 3097-3117.

Centre National de Recherche Environnemental (2007), Rapport national sure les Activités Terrestres, Sources de Pollution et Niveaux de Pollution des Eaux et des Sédiments : 36 pp.

Cesar, H.S. 2000. Coral Reefs: their functions, threats and economic value. In: Cesar H.S. (ed.) Collected Essays on the Economics of Coral Reefs. CORDIO, Kalmar, Sweden: 14-39.

Champion, A. M. 1933. Soil erosion in Africa, *Geogr. J.* 82: 130-139.

Chaperon, P., Danloux, J., Ferry, L. 1993. Fleuves et Rivières de Madagascar. ORSTOM, DMH, CNRE, Montpellier.

Chenje, M. (ed.) 2000. State of the Environment Zambezi Basin 2000. SADC/IUCN/ZRA/SARDC, Maseru/Lusaka/Harare.

CITES, 1973. Convention on International Trade in Endangered Species of Wild Fauna and Flora, 3March 1973, 993 U.N.T.S. 243.

Clark, B.M., Lane, S., Turpie, J.K., van Niekerk, L. and Morant, P.D. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: South Africa National Report Phase 1: Integrated Problem Analysis. March 2002. GEF MSP Sub-Saharan Africa Project (GF/6010-0016) Sponsored by GEF, UNEP, IOC-UNESCO, GPA and ACOPS. http://www.acops.org/African_Process/National_Reports.htm.

CNPS 1997. Seychelles Biodiversity: Economic assessment. Report prepared for National Biodiversity Strategy and Action Plan, Conservation and National Parks Section, Division of Environment, Victoria.

Cockcroft, V., Guissamulo, A. and Findlay, K. 2008. Dugongs (*Dugong dugon*) of the Bazaruto Archipelago, Mozambique.

Coetzee, H., Venter, J. and Ntsume, G. 2005. Contamination of wetlands by Witwatersrand gold mines – processes and the economic potential of gold in wetlands. Pretoria Council for Geoscience: 114 pp.

Colloty, B.M. 2000. Botanical importance of estuaries of the former Ciskei/Transkei region. PhD Thesis, Department of Botany, University of Port Elizabeth.

CORDIO, 2002. Reef Degradation in the Indian Ocean: Status Report 2002. CORDIO.

Constanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Neem, S., O'Neill, R.V., Paruelo, J., Raskin, R. G., and Sutton, P. 1997. The value of world's ecosystem services and natural capital. *Nature* 387: 253-260.

Cooke, A.J., Ratomahenina, O., Ranaivoson, E. and Razafindrainibe, H., 2000. Madagascar. In: Sheppard, C. (ed.) Seas at the Millennium: An environmental evaluation. 2 Ch. 60: 1, 13-131.

Coppejans, E., Beeckman, H. and de Wit, M. 1992. Status, primary productivity and taxonomy of mangroves, seagrasses and algae. *Hydrobiologia* 247: 59-75.

Crona, B. I. and Ronnback, P. 2005. Use of replanted mangroves as nursery grounds by shrimp communities in Gazi Bay, Kenya. *Est. Coastal Shelf Sci*. 65: 535-544.

Crossland C.J., Baird, D., Ducrotoy, J-P. and Lindeboom, H. 2005. The coastal zone – a domain of global interactions. Chapter 2. *In:* Crossland, C.J., Krenner, H.H. Lindeboom, H.I., Marshall Crossland, J.I. and Le Tisser, M.D.A. (eds.) Coastal Fluxes in the Anthropocene – The Land-Ocean Interactions in the Coastal Zone. Project of the International Geosphere-Biosphere Programme Series. Springer, Berlin.

CSIR, 2004. Environmental studies in the Richards Bay offshore outfalls region. Report No. 17: Surveys made during 2003. CSIR Report: ENV-D-C-2004-013. Durban, South Africa.

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

Cunningham, A.B. 1988. An investigation of the herbal medicinal trade in Natal/KwaZulu. *Institute of Natural Resources, Investigational Report* 29. University of Natal, Pietermaritzburg: 149 pp.

D

Daby, D. 2003. Effects of seagrass removal for tourism purposes in a Mauritian Bay. *Environmental pollution,* 125: 313-324.

Dahdouh-Guebas F., Coppejans E. and van Speybroeck, D. 1999. Remote sensing and zonation of seagrasses and algae along the Kenyan coast. *Hydrobiologia* 400: 63-73.

Darwall, W.R.T. and Guard, M. 2000. Southern Tanzania. In: McClanahan, T.R., Sheppard, C.R.C. and Obura, D.O. (eds.) Coral reefs of the Indian Ocean – their ecology and conservation. Oxford University Press, Oxford: 131-166.

Davis, J.R. 2000. Integrated Water Resources Management Strategy for Kenya: Water quality and pollution assessment in freshwater lakes and rivers of Central Kenya. A World Bank Report: 27 pp.

DEAT. 2004. 1994-2004 Department of Environmental Affairs and Tourism: ten year review. 112 pp.

DEAT, 2005. Department of Environmental Affairs and Tourism (2005). State of the Environment of South Africa, *http://soer.deat.gov.za.*

De Clerck, O., Bolton, J. J., Anderson, R.J. and Coppejans, E. 2005. Guide to the Seaweeds of KwaZulu-Natal. National Botanical Gardens of Belgium: 296 pp.

Ecklöf, J.S., De la Torre e Castro, M, Adelsköld, L. Jiddawe. NS and Kautsky, N. 2005 Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms. *Estuarine and Coastal Shelf Science* 63: 385-396.

De la Torre e Castro, M. and Ronnback, P. 2004. Links between humans and seagrasses – an example from tropical east Africa. *Ocean and Coastal Management* 47: 361-387.

Den Hartog, C. 1970. The Seagrasses of the World. North Holland Publication Co. Amsterdam: 275 pp.

De Sousa, T. 1987. Summary of fisheries and resources information for Kenya. In: Sanders, M.J., Sparre, P. and Venema, S.C. eds. Proceeding of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, 14-25 September 1987, Albion. FAO/ UNDP.RAF/79/065/WP/41/88/E. FAO, Rome: 277 pp.

De Young C. ed. 2006. Review of the state of the world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper 488. FAO, Rome: 485 pp.

Direction Régionale de l'Environnement, 2005. Etat des Lieux du District Hydrographique de la Réunion : 211 pp.

DNA 1994. Actual situation of water resources management in Mozambique (Final Draft). Ministério da Construção e Águas. Maputo – Moçambique.

Dominik, F., Dunbar, R. B., McCulloch, M., Mudelsee, M., Vuille, M., McClanahan, T.R., Cole, J.E. and Eggins, S. 2007. East African soil erosion recorded in a 300 year old coral colony from Kenya. *Geophysical Research Letters* 34 L04401, DOI: 10.1029/2006GL028525.

Dorenbosch, M., Groll, M. G., Christianen, M. J., Nagelkerken, I. and Velde, G. 2005. Indo-Pacific seagrass beds contribute to fish density and diversity on adjacent coral reefs. *Mar. Ecol. Progr. Ser.* 302: 63-76.

Dubinsky, Z. and Stambler, N. 1996. Marine pollution and coral reefs. *Global Change Biology* 2: 511 -526

Duke, N.C. 1992. Mangrove floristics and biogeography. *In*: Robertson, A.I. and Alongi, D.M. (eds.), Tropical Mangrove Ecosystems. Washington D.C., USA: 63-100.

Dulymamode, R., Bhikajee, M. and Sanassee, V. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: Mauritius National Report Phase 1: Integrated Problem Analysis. March 2002. GEF MSP Sub-Saharan Africa Project (GF/6010-0016) Sponsored by GEF, UNEP, IOC-UNESCO, GPA and ACOPS. http://www.acops.org/African_Process/National_Reports.htm

Dunne, T. and Ongwenyi, G.S. 1976. A new estimate of sediment rates in the Upper Tana River. *Kenyan Geographer* 2(2): 14-29.

DWAF, 2001. TWP: An overview of the Thukela Water Project Feasibility Study. Department of Water Affairs and Forestry, South Africa, Pretoria.

DWAF, 2004a. Thukela Water Project Decision Support Phase: Reserve Determination Model. Department of Water Affairs and Forestry, South Africa. Pretoria.

DWAF. 2004b. Internal Strategic Perspective: Thukela Water Management Area – Version 1. Department of Water Affairs and Forestry, South Africa, Pretoria.

DWAF, 2004c. Methodology for the Determination of the Ecological Water Requirements for Estuaries. Department of Water Affairs and Forestry, South Africa, Pretoria: 171 pp

E

Earle, A. and Malzbender, D. 2007. Water and the peaceful, sustainable development of the SADC region. Paper produced for the Safer Africa project, entitled, "Towards a Continental Common Position on the governance of natural resources in Africa".

Earle, A., J. Goldin, R., Machiridza.D., Malzbender,E., Manzungu, E. and Mpho, T. 2006. Indigenous and institutional profile: Limpopo River Basin. Working Paper No 112. International Water Management Institute, Colombo.

Edinger, E., Ompa, J., Limmon, G., Widjatmoko, W. and Risk, M. 1998. Reef degradation and coral biodiversity in Indonesia: effects of land-based pollution, destructive fishing practices and changes over time. *Mar. Poll. Bull.* 36(8): 617-630.

Eklof, J.S., de la Torre e Castro, M., Adelskold, L., Jiddawi, N. S. and Kautsky, S. 2005. Differences in Macrofauna and seagrass assemblages in seagrass bed with and without seaweed farms. *Est. Coast. Shelf Sci.* 63: 385-396.

Ekman, S. 1953. Zoogeography of the sea. Sidgwick and Jackson, London: 417 pp.

Engdahl, S., Mamboya, F., Mtolera, M., Semesi, A. and Björk, M. 1998. The brown macroalgae *Padina boergesenii* as an indicator of heavy metal contamination in the Zanzibar channel. *Ambio* 27: 694-700.

Engelhardt, U., Russell, M. and Wendling, B. 2003. Coral communities around the Seychelles Islands 1998 –2002. In: Coral Reef Degradation in the Indian Ocean (CORDIO) – Stat Rep 2002, CORDIO: 212 pp.

Euroconsult, 1980. Identification study on the ecological impacts of the Stiegler's Gorge power and flood control project, Part I, Summary, background and approach to the study.

European Community, 2005. Fishing vessels licence in WIO. See also www.ec.europa.eu/fisheries.

European Community 2008. The economics of ecosystems and biodiversity. Banson, Cambridge: 64 pp.

European Union 2006. Fisheries fact sheet: Réunion.

F

Fabricius, K. 2005. Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Mar. Poll. Bull.* 50: 125-146.

FAO, 1997. Madagascar: FAO/WFP Mission to assess the impact of cyclone Gretelle on food and agriculture. FAO/GIEWS Special Report on Madagascar 04/97.

FAO, 1997. Irrigation potential in Africa: a basin approach: Food and Agriculture Organisation Land and Water Bulletin 4. FAO Land and Water Division. Rome. Italy: 177 pp

FAO, 1997. Review of the State of World Fishery Resources: Marine Fisheries. *FAO Fisheries Circular* No. 920: 173 pp.

FAO, 1999. Land-based sources and activities affecting the marine, coastal and associated freshwater environment in Comoros, Kenya, Mozambique, Seychelles and United Republic of Tanzania. EAF/5. Ed. D. Waruinge and D. Ouya. Nairobi. Kenya: 42 pp.

FAO, 2000. Report of the four GEF/UNEP/FAO regional workshops on reducing the impact of tropical shrimp trawl fisheries. FAO Fisheries Report 627: 40 pp.

FAO. 2001. Tropical shrimp fisheries and their impact on living resources. Shrimp fisheries in Asia: Bangladesh, Indonesia and the Philippines; in the Near East: Bahrain and Iran; in Africa: Cameroon, Nigeria and the United Republic of Tanzania; in Latin America: Colombia, Costa Rica, Cuba, Trinidad and Tobago, and Venezuela. FAO Fisheries Circular 974. FAO, Rome: 378 pp.

FAO, 2001. A synthesis of flood warning and control for the Juba and Shabelle Rivers. Working Paper FAO SOM/SSF/2001/12. FAO, Nairobi, Kenya

FAO, 2003a. Fishery statistics: capture production. Volume 92/1. Year 2001. FAO.

FAO, 2003b. [see Fennessy et al, 2003]

FAO 2005a. Irrigation in Africa: Available at: http://www.fao.org/docrep/w4347e/w4347ey.htm.

FAO 2005b. Country fisheries profile and Information on fisheries management for Kenya and Seychelles. Rome. Available at http://www.fao.org/fi/fcp/fcp.asp.

FAO, 2005c. Status and trends in mangrove area extend worldwide. Working paper No. 64. Forest Resource Division. FAO, Rome: 89 pp.

FAO, 2007a. Fisheries Statistics - capture production. FAO Fisheries series Vol 100/1. Rome: 539 pp.

FAO, 2007b. Fisheries Statistics - commodities. FAO Fisheries series Vol 101. Rome: 237 pp

FAO, 2007c. Fisheries Statistics – aquaculture production. FAO Fisheries series Vol 100/2. Rome: 202 pp.

FAO, 2007d. The world's mangroves 1980–2005. FAO Forestry Paper 153. Rome, FAO.

FAO 2008. Report of the First Working Party on fisheries data and statistics, Mombasa, Kenya 24 -27 April 2007, FAO Fisheries report No. 852.

FAO/UNEP, 1984. Legal Aspects of Protecting and Managing the Marine and Coastal Environment of the East African Region; National Reports; UNEP Regional Seas Reports and Studies 49. UNEP, Nairobi.

FAO/WHO, 1986. Maximum limits for pesticide residues. *Codex Alimentarius* Vol. XIII, 2nd edn. Rome.

Fenner, D., Clark, T.H., Turner, J.R. and Chapman, B. 2004. A checklist of the corals of the island state of Rodrigues, Mauritius. *Journal of Natural History* 38: 3091-3102.

Fennessy, S.T. 1993. An investigation of the ichthyofaunal bycatch of the Tugela Bank prawn trawlers. MSc thesis, University of Natal, Durban: 104 pp.

Fennessy, S.T. 1994. The impact of commercial prawn trawlers on linefish off the north coast of Natal, South Africa. *South African Journal of marine Science* 14: 287-296.

Fennessy, S.T. (ed.) 2007. Newsletter of the IUCN Specialist Group: Groupers and Wrasses 10: 14 pp.

Fennessy, S.T. and Groeneveld, J.C. 1997. A review of the offshore trawl fishery for crustaceans on the east coast of South Africa. *Fisheries Management and Ecology* 4: 135-147.

Fennessy, S.T., Mwatha, G.K. and Thiele, W. 2003. Report of the regional workshop on approaches to reducing shrimp trawl bycatch in the Western Indian Ocean, 13-15 April 2003, Mombasa. FAO Fisheries Report 734. FAO, Rome: 49 pp.

Fennessy, S.T. and van der Elst, R.P. 2004. Lubombo Transfrontier Marine Protected Zone. Report prepared for MITUR. Oceanographic Research Institute, Durban. ORI Unpublished Report 216: 35 pp & 5 appendices.

Fennessy, S.T., Vincent, X., Budeba, Y., Mueni, E.M. and Gove, D.Z. 2008. An update on initiatives to reduce prawn trawl bycatch in the West Indian Ocean. *West Indian Ocean J. Mar.Sci*. 7 (2) 217-222.

Ferletta, M., Bramer, P., Semesi, A. K. and Björk, M. 1996. Heavy metal contents in macroalgae in the Zanzibar channel - an initial study. In: Bjork, M, Semesi, A.K., Pedersen, M. and Bergman, B (eds.) Current Trends in Marine Botanical Research in the East African *Region*. Proceedings of the symposium on the biology of microalgae, macroalgae and seagrasses in the Western Indian Ocean. University of Mauritius, 3-10 December, 1996: 332-346.

Fernandes, A. 1995. Pollution in Maputo Bay: Contamination levels from 1968 to 1996. Instituto Nacional de Saide. *Revista Medica de Mozambique* 6 (34).

Fernandes, A. 1996. Poluicao: Factos e figuras. Proceedings from the Workshop on the Role of Research in Coastal Zone Management, Maputo, 24-25 de Abril, 1996. Departamento de Ciencias Biologicas, Universidade Eduardo Mondlane.

Fielding, P.J. and Mann, B.Q. 1999. The Somalia inshore lobster resource: a survey of the lobster fishery of the north-eastern Region (Puntland) between Foar and Eyl during November 1998 (Somali Natural Resources Management Pogramme). IUCN Eastern Africa, Nairobi: 35 pp.

Fischer, W. and Bianchi, G. 1984. Species identification sheets for fishery purposes: West Indian Ocean. FAO, Rome.Volumes I to VI.

Fishbase, 2006. www.fishbase.org.

Fisheries Department Kenya, 2007. Frame survey report 2007.

Fishing Industry Handbook, 2007. South Africa, Namibia and Mozambique. 35th Edition. George Warman publ. Cape Town: 31-32.

Fleitmann, D. R. B., Dunbar, M., McCulloch, M., Mudelsee, M., Vuille, M., McClanahan, T.R., Cole, J.E. and Eggins, S. 2007. East African soil erosion recorded in a 300 year old coral colony from Kenya, *Geophys. Res. Lett.*, 34, L04401, doi:10.1029/2006GL028525.

Fletcher W.J. and Amos, M. 1994. Stock assessment of coconut crabs. Canberra, ACIAR Monograph No. 29: 32 pp.

Forbes, A.T., Demetriades, N.T., Bosman, C., Leuci, R., Sinclair, D., Smith, A.M., Fennessy, S., Robertson, W.D., Sink, K., Kruger, A., Everett, B.I., Fielding, P.J. and Celliers, L. 2002. Impacts of proposed dams on the Thukela estuary and inshore marine environment, Kwa-Zulu-Natal, South Africa. In: Arthurton, R.S., Kremer, H.H., Odada, E., Salomons, W. and Marshall Crossland, J.I. (eds.) African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment-Coastal Sea Interaction and Human Dimensions. LOICZ Reports and Studies No. 25, LOICZ, Texel, The Netherlands: 168-173.

Francis, J., Wagner, G.M., Mvungi, A., Ngwale, J. and Salema, R. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: Tanzania National Report Phase 1: Integrated Problem Analysis. Part of the GEF MSP Sub-Saharan Africa Project (GF/6010-0016): "Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa". UNEP, Nairobi. http://www.acops.org/African_Process/National_Reports.htm

Frazier, J.1980. Exploitation of marine turtles in the Indian Ocean. *Human Ecology* 8: 329-370.

G

Gabries, C., Vasseur, P., Randriamiarana, H., Maharavo, J. and Mara, E. 2000. The coral reefs of Madagascar. In: McClanahan, T.R., Sheppard, C.R.C. and Obura, D.O. eds. Coral reefs of the Indian Ocean – their ecology and conservation. Oxford University Press, Oxford: 411-444.

Gallienne, C.P. and Smythe-Wright, D. 2005. Epipelagic mesozooplankton dynamics around the Mascarene Plateau and Basin, Southwest Indian Ocean. *Phil. Trans. Roy Soc. Lond.* A 363, (1826): 191-202.

Gammelsrød, 1996. Cited by ZRA, 1998.

Gaudian, G., Koyo, A. and Wells, S. 2003. A global representative of Marine Protected Areas marine region. East Africa. A report to the World Bank Environment. Department.

GEF/MSP 2001. Regional Consolidated Analysis of the first phase of the GEF MSP Sub-Saharan Project, GEF MSP Sub-Saharan Africa Project (GF/6010-0016).

GEO Data Portal 2003. Global Environment Outlook Data Portal. Retrieved Jan., 2003, from http://geodata.grid.unep.ch/.

Githitho, A. N. 2004. The coastal terrestrial forests of Kenya: A Report on Resources, threats and investments. WWF – EARPO, Nairobi: 29 pp

Glavovic B.C., Browne, J. and Coetzee, M. 2001. Integrated Coastal Zone Management in South Africa. In: Voabil and Engdahl (eds.), The Voyage from Seychelles to Maputo; Successes and Failures of Integrated Coastal Zone Management in Eastern Africa and Island States 1996-2001, Vol I (SEACAM, 2001); Maputo: 67-120.

GoK, 1979. 1979-1983 Development plan, Government of the Republic of Kenya. Government Press, Nairobi, Kenya.

Gössling, S. 2006. Towards sustainable tourism in the Western Indian Ocean. *W. Indian Ocean J. Mar. Sci.* 5(1): 55-70.

Gössling, S. and Hörstmeier, O. 2003. High-value conservation tourism: integrated tourism management in the Seychelles? In: Gössling, S. (ed.) Tourism development in tropical islands: political ecology perspectives. Cheltenham: Edward Elgar Publishing: 203-221.

GoT, 2006. National land use framework plan, existing situation, trends and issues. The national land use planning commission. Government of Tanzania, Dar es Salaam.

Gove D.Z. 1995. The coastal zone of Mozambique. In: O. Lindén (ed.), Workshop and policy conference on integrated coastal zone management in Eastern Africa including the Island

States. Coastal Management Center (CMC), Conference Proceedings, Metro Manila, Philippines: 251-273.

Government of the Republic of Kenya, 2007. Kenya Vision 2030: 32 pp.

Graham, N.A.J., Wilson, S.K., Jennings, S., Polunin, N.V.C., and Bijoux, J.P. 2006. Dynamic fragility of oceanic coral reef ecosystems. *Proc Natl Acad Sci U SA* 103: 8425–8429.

Grandcourt, E.M. 2003. The effect of intensive line fishing on the virgin biomass of a tropical deepwater snapper, the crimson jobfish - *Pristipomoides filamentosus. Fishery Bulletin* 101: 305-311.

Grant, D.K.S. 1938. Mangrove woods of Tanganyika Territory: Their silviculture and dependent industries. *Tanganyika Notes and Records* 5: 5-16.

Green Policy Paper 1998. Towards sustainable coastal development in South Africa. Department of Environmental Affairs and Tourism. Cape Town: 155 pp.

GTA, 2007. Towards sustainable mangrove management in Mozambique through reduction of anthropogenic pressure on the ecosystem. Project document submitted to UNEP/GEF WIO-LaB Project Management Unit: 54 pp.

Grubb, P. 1971. Ecology of terrestrial decapod crustaceans on Aldabra. *Phil. Trans. Roy. Soc. Lond. Ser B.* 260: 411-416.

Grundlingh, M.L. 1989. Drift of the SAA Helderberg wreckages in the Indian Ocean. *S.A.J.Sci.* 85: 209-211.

Guillaumin, A. 1928. Les régions florales du Pacifique d'aprés leur endémisme et la répartition de quelques plantes phanérogames. *Proc. 3rd Pan Pacific Sci. Cungr., Tokyo* 1: 920-938.

Gullström M., de la Castro Torre M., Bandeira S.O., Björk M, Dahlberg M., Kautsky N., Rönnbäck, P .and Öhman, M.C. 2002. Seagrass ecosystems in the Western Indian Ocean. *Ambio* 31: 588-596.

Gupta, R.K. 2001 The ecology of riverine fish of Kenya in the Athi-Galana-Sabaki River drainage system. *International Journal of Water Resources Development,* 17 (1): 125-147.

Gurib-Fakim, A. 2002. Mauritius through its medicinal plants. Éditions le Printemps : 216 pp.

Gurib-Fakim, A. 2003. An illustrated guide to the flora of Mauritius and the Indian Ocean Islands. Mauritius: 206 pp.

H

Hamerlynck, O., Richmond, M.D., Mohamed, A. and Mwaitega, S.R. 2008. Fish and invertebrate life histories and important fisheries of the Pangani River Basin, Tanzania Final Report. Pangani River Basin Flow Assessment - Specialist Study. IUCN/PBWO: 74 pp.

Hamilton, H.G.H. and Brakel, W.H. 1984. Structure and coral fauna of East Africa. *Bulletin of Mar. Sci.* 334: 248-266.

Hartnoll, R.G. 1976. The Ecology of some rocky shores in Tropical East Africa. *Est. Coast. Mar. Sci.* 4 (1): 1-10.

Hatziolos, M., Lundin, C.G. and Alm, A. 1996. Africa: A framework for integrated coastal zone management. The World Bank, Washington D.C.: 150 pp.

Hawkins, J. and Roberts, C. 1993. Effects of recreational scuba diving on coral reefs: trampling on reef flat communities. *J. Appl. Ecol* 30: 25-30.

Hill, M. and Currie, D. 2007. Wildlife of Seychelles. HarperCollins Publishers Ltd., London. 272 pp.

Hirji, R., Johnson, P., Maro, P. and Chiuta, T.M. (eds.) 2002. Environmental Sustainability in Water Resources Management in Southern Africa. SADC, IUCN, SARDC, World Bank: Maseru, Harare, Washington DC.

Hirji, R., Partorni, F.M. and Rubin, D. (eds.) 1996. Seminar on integrated water resources management in Kenya. Proceedings Sponsored by Government of the Netherlands and the World Bank. The Economic Development Institute of the World Bank: 227 pp.

Hoagland, P. and Jin, D. 2008. Accounting for marine economic activities in large marine ecosystems. *Ocean and Coastal Management* 51: 246-258.

Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research*. 50: 839–866.

Hogan, A.R., Nandi, R.X.L., Mtiga, M.O., Chirwa, E.B., Kilonzo, P. and Peter, J. 1999. Selection of pilot villages: A report on the rapid appraisal methodology used and the selections made, together with eleven individual village profiles. REMP Technical Report No. 2.

Hoguane, A.M., 1997a. Hydrodynamics, temperature and salinity in mangrove swamps in Mozambique. Ph.D. thesis. University of North Wales, Bangor, UK.

Hoguane, A.M. 1997b. Shrimp abundance and river runoff in Sofala Bank - The role of Zambezi. Presented at the workshop on sustainable development of the Cahora Bassa Dam and the Valley of Zambezi.

Hoguane, A.M. 2000. Salt intrusion in the Incomati river. Proceedings of the second national conference on coastal zone research. Maputo, 27-29 September 2000. CDS-ZC/MICOA, SECAM/UEM. 29-35.

Hoguane, A.M. 2007. Diagnosis of Mozambique Costal Zone. *Revista de Gestão Costeira Integrada* 7(1): 69-82.

Hoguane, A.M., Motta, H., Lopes, S. and Menete, Z. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: Mozambique National Report Phase 1: Integrated Problem Analysis. 113 pp. March 2002. GEF MSP Sub-Saharan Africa Project (GF/6010-0016) Sponsored by GEF, UNEP, IOC-UNESCO, GPA and ACOPS.

Hoguane, A.M., Dove, V.F., Sete, C.I., and Ibrahimo, N.V. 2003. Coastal Erosion in Mozambique: The Macaneta Peninsula Case Study. A report prepared for UNEP/GPA, UNEP and WIOMSA.

Hoguane, A.M., Dove, V.F., and Sete, C.I. 2003. Physical alterations and destruction of habitats in Mozambique. Report to UNEP/GPA and WIOMSA: 27pp.

Hoguane, A.M., Taucala, F., Magaia, E. 2009. Environmental Profile of the Inkomati River Basin. Report prepared for the Ministry for the Coordination of Environmental Affairs: 81 pp.

Hoff, H., Noel, S. and Droogers, P. 2007. Water use and demand in the Tana basin: analysis using the water evaluation and planning tool (WEAP). Green Water Credits Report 4, ISRIC – World Soil Information, Wageningen: 38pp.

Horril, J.C., Kamkuru, A.T., Mgaya, Y.D. and Risk, M. 2000. Northern Tanzania and Zanzibar. In: McClanahan, T.R., Sheppard, C.R.C. and Obura, D.O. (eds.) Coral reefs of the Indian Ocean – their ecology and conservation. Oxford University Press, Oxford: 167-198.

Horrill, J. C., Kalombo, H. and Makoloweka, S. 2001. Collaborative reef and reef fisheries management in Tanga, Tanzania. IUCN EAP, Nairobi: 37 pp.

Howell, K.H. 1993. A review of the conservation status of sea turtles in Tanzania. Wildlife Conservation Society of Tanzania.

Hoyle, B. 2000. Port development – Growth, competition and revitalization. In Hoorweg, J., Foeken, D., and Obudho, R.A. (eds.) Kenya Coast Handbook: Culture, resources and development in the East African littoral. Transaction Publishers, Hamburg-London: 527 pp.

Hughes, G.R. 1974a. The sea turtles of south-east Africa, 1: Status, morphology and distributions. ORI Investigational Report 35. Oceanographic Research Institute, Durban: 144 pp.

Hughes, G.R., 1974b. The sea turtles of south-east Africa, 2: The biology of the Tongaland loggerhead turtle *Caretta caretta* L. with comments on the leatherback turtle *Dermochelys coriacea* L. and the green turtle *Chelonia mydas* L. in the study region. ORI Investigational Report 36. Oceanographic Research Institute, Durban: 96pp.

Hughes, R.H., Hughes, J.S. and Bernacsek, G. 1992. A directory of African wetlands. http://ramsar.wetlands.org/ADirectoryofAfricaWetlands/tabid/824/Default.aspx : accessed on 18 February 2009.

Hulme, M., R.M. Doherty, T. Ngara, M.G. New, and D. Lister. 2001. African Climate Change: 1900– 2100. *Climate Research* 17: 145–68.

Huxham, M., Kimani, E., and Augley, J. 2004. Mangrove fish: a comparison of community structure between forested and cleared habitats. *Estuarine, Coastal and Shelf Science* 60: 637-647.

Humphrey, S.L. and R.V. Salm (eds.) 1996. Status of Sea Turtle Conservation in the Western Indian Ocean. UNEP Regional Seas Reports and Studies No. 165. IUCN/UNEP, Nairobi, Kenya: 162 pp.

Hydro oil & gas, Mozambique, 2006. Proposed offshore seismic surveys of Areas 2 and 5, Rovuma Basin, Mozambique: 15 pp.

I

IOC-UNEP-WMO-SAREC 1994. Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their impacts. Zanzibar, Tanzania, 17-21 January 1994. IOC - Workshop report no. 96 (incl. 2 supplements).

IDPPE 2004. Censo Nacional da Pesca Artesanal Águas Maritimas (2002), IDPPE. Maputo: 76 pp.

Ingram, J. C. and Dawson, T. P. 2001. The impacts of a river effluent on a coastal seagrass habitat of Mahé, Seychelles. *South African Journal of Botany* 67: 483-487.

IPCC 2001. Special Report on Emissions Scenarios. In: N. Nakicenovic and R. Swart (eds.) Special Report of the Intergovernmental Panel. Cambridge University Press, Cambridge, UK: 598 pp.

IPCC 2005. Special Report on Carbon Dioxide Capture and Storage ch.7. Prepared by working group III of the Intergovernmental Panel on Climate Change. Metz, B., O.Davidson, H. C. de Coninck, M. Loos, and L.A. Meyer (eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA: 442 pp.

IPCC 2007. "Technical Summary." In Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Working Group II Contribution to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IOTC 2008. Report of the eleventh session of the scientific committee of the Indian Ocean tuna Commission, Victoria, Seychelles: 166 pp.

Iqbal, M.S. 1992. Assessment of the Eastern Africa action plan and the effectiveness of its legal instruments, UNEP Regional Seas Reports and Studies No.150.

IUCN 1997. Strategic framework for sustainable natural resource management in Somalia. Somali natural resources management programme. IUCN-EARO. Nairobi : 29 pp.

IUCN 2005. Advancing the understanding and management of small scale fisheries. Jakarta Mandate. Unpublished Report- IUCN-EARO, Nairobi 54 pp

IUCN, 2003. Pangani Basin - A situation analysis. IUCN:EARO, Nairobi, Unpublished Report 59 pp.

IUCN 2003.Tana River, Kenya: Integrating downstream values into hydropower planning. Case studies in wetland valuation, No.6, May 2003. IUCN – The World Conservation Union. http://www.iucn.org/themes/wani/econ/CaseStudy06Tana.pdf

IWMI 2006. IWMI Global Wetland Initiative – Madagascar country overview. Accessed at www.iwmi.cgiar.org/wetlands/pdf/Africa/Region6/MADAGASCAR.pdf on 13/10/2007.

Izidine, S. and Bandeira, S.O. 2002. Mozambique. In: Golding, J. (ed.) Southern African Red Data Lists. Southern African Botanical Diversity Network Report No. 14: 43-60.

J

Jaasund, E. 1976. Intertidal seaweeds in Tanzania, University of Tromso: 160 pp.

Jacquet, J. and D. Zeller.2007. National conflict and fisheries: reconstructing marine fisheries catches for Mozambique. Fisheries Research Report. University of British Columbia: 13 pp.

Jacquet, J., Fox, H., Motta, H., Ngusaru, A. and Zeller, D. 2008. Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. WWF-EAME Policy series-fisheries. Dar es Salaam: 19 pp.

Jahengers, I. 2004. Country review: Mauritius. Ministry of Fisheries.

Japp, D.W. and James, A. 2005. Potential exploitable deepwater resources and exploratory fishing off the South African coast and the development of the deepwater fishery on the south Madagascar ridge. In: Shotton, R. (ed.) Deep Sea 2003: Conference on governance and management of deep-sea fisheries. Part 1: Conference reports. Queenstown, New Zealand.

Jenning, S., Marshall, S. and Polunin, N. 1996. Seychelles's Marine Protected Areas: Comparative structure and status of reef fish communities. *Biological Conservation* 75: 201-209.

Jiddawi, N.S. 1998. The reef dependant fisheries of Zanzibar. In: Johnstone R.W., Francis, J. and Muhando C.A. (eds.) Proceeding of the National conference on coral reefs Zanzibar: values, threats and solutions. December 1997: 22-35.

Jiddawi, N.S, and Shehe, M.S. 1999. The status of shark fishery in Zanzibar, East Africa: a case study. *In:* Jiddawi, N.S.and R. Stanley (eds.) Fisheries Stock Assessment in the Traditional Fishery Sector: The Information Needs. Proceedings of the National Workshop on the Artisanal Fisheries Sector, Zanzibar. September, 22-24, 1997, Zanzibar, Tanzania Institute of Marine Sciences, University of Dar es Salaam, Zanzibar, Tanzania: 87-92.

Jiddawi, N.S. and Stanley, R.D. (eds.) 1999. Fisheries Stock Assessment in the Traditional Fishery Sector: The Information Needs. Proceedings of the National Workshop on the Artisanal Fisheries Sector, Zanzibar. Sept, 22-24, 1997, Zanzibar, Tanzania IMSISBN 0-662-28909-9, IMS-UDSM, Zanzibar, Tanzania: 192 pp.

Jiddawi, N.S. and Öhman, M.C. 2002. Marine fisheries in Tanzania. *Ambio* 31(7): 518-527.

Johnson DS. 1965. Land crabs. *J. Malayan Branch R. Asiatic Soc.* 38: 43-66.

Jones, T., Payet, R., Beaver, K. and Nalletamby, M. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: Seychelles National Report Phase 1: Integrated Problem Analysis. March 2002. GEF MSP Sub-Saharan Africa Project (GF/6010-0016) Sponsored by GEF, UNEP, IOC-UNESCO, GPA and ACOPS.

Jones, S. and Ibrahimo, H. (2008). The contribution of tourism in Mozambique – present and future. National Directorate of Studies and Policy Analysis. Ministry of Planning and Development, Republic of Mozambique: 18 pp.

Joottun, L., Gangapersad, D., Ragoonaden, S., Dunputh, K., and Ujodha, I. 1994. Status of coastline changes in Mauritius. In: IOC (ed.) IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal 19 Regional Report Erosion, Sea Level Changes and their impacts. Zanzibar, Tanzania, 17-21 January 1994. IOC - Workshop report no. 96. supp.1.: 29-63.

K

Kairo, J.G., Dahdouh-Guebas, F., Gwada, P.O., Ochieng, C., Koedam, N. 2002. Regeneration status of mangrove forests in Mida Creek, Kenya: a compromised or secured future? *Ambio* 31: 562-568.

Kairo, J.G. and Dahdouh-Guebas, F. 2008. Conservation status of mangroves in Kenya. In: Ashton, E. (ed.) Mainstreaming conservation of coastal biodiversity through formulation of a code of conduct for sustainable management of mangrove forests. World Bank, ISME.

Kairu, K.K. 1997. Vulnerability of the Kenya shoreline to coastal instability. UNESCO-Kenya National Seminar on sustainable development, Mombasa, Kenya: 13-25.

Kairu, K.K, 2003. Coastal Erosion in Kenya: Malindi – Ungwana Bay Case Study. A report prepared for UNEP/GPA, UNEP and WIOMSA.

Kairu, K. and Nyandwi, N. (eds.) 2000. Guidelines for the study of shoreline change in the Western Indian Ocean region. IOC Manuals and Guides No. 40. UNESCO 2000: 55 pp.

Kajia, Y.S. 2000. Assessment of the effects of rice farming in the mangrove forests of the Rufiji delta, mainland Tanzania. MSc. Thesis in ecological marine management, Faculty of Science, Free University of Brussels. (cited in Shagude, 2004).

Kalk, M. (ed.) 1995. A natural history of Inhaca Island, Mozambique. Witwatersrand University Press, South Africa: 395 pp.

Kalugina-Gutnik, A., Perestenko, L. and Titlyanova, T. 1992. Species composition, distribution and abundance of algae and seagrasses of the Seychelles Islands. *Atoll Research Bulletin*. 359(5): 1-68.

Kamau, J. N. 2001. Heavy metals distribution in sediments along the Kilindini and Makupa creeks, Kenya. *Hydrobiologia* 459: 235-240.

Kanagev, V.F., Morgan, J.R. and Verlaan, P.A. eds. 2009. Indian Ocean. *Encyclopaedia Britannica*. http://www.britannica.com/EBchecked/topic/285876/Indian-Ocean, accessed on 20 January 2009.

Kanji, F., Albano, G., Macucule, A., Sato, S., and Massago, H. A. 2004. The Coastal Forests of Mozambique. WWF – EARPO, Nairobi.

Kaponda, A. 2005. Ruvuma River Basin: Water Resources Development and Management. Unpublished Report for Ruvuma river and Southern Coast Basin.

Kariuki J. 2005. Review of the state of world marine capture fisheries management: Indian Ocean. Rome. FAO Technical Paper 489.

Kathiresan, K. and Bingham, B.L. 2001. Biology of mangroves and mangrove ecosystems *Adv. Mar. Sci*. 40: 81-251.

Kaunda-Arara, B. and Rose, G. 2004. Effects of marine reef national parks on fishery CPUE in coastal Kenya. *Biological Conservation* 118: 1-13.

Kazungu, J.M., Munga, D., Mwaguni, S.M. and Ochiewo, J. 2002. Development and protection of the coastal and marine environment in sub-Saharan Africa: Kenya national report Phase 1: Integrated problem analysis. March 2002. GEF MSP Sub-Saharan Africa Project (GF/6010-0016) Sponsored by GEF, UNEP, IOC-UNESCO, GPA and ACOPS.

Kent, P.E., Hunt, J.A. and Johnstone, D.W. 1971. The geology and geophysics of coastal Tanzania. Geophysical 6, HMS Stationary Office London: Institute of Geophysical Sciences: 101 pp.

Kijazi, A.S. 2002. Catchment and mangrove management programmes: activities and environmental concerns in the Pangani Basin. Report of a Workshop held at the Kilimanjaro Crane Hotel, Moshi, Tanzania, 8-10 May 2002. December 2002. Nairobi, IUCN – EARO: 38-43.

King, M.D., King, A., Manghubhai, S., Tunje, I., Muturi, I., Mueni, E. and Onganda, H. 2003. Review of marine fisheries resources for Kenya. FMSP Project R8196. Understanding fisheries associated livelihoods and the constraints to their development in Kenya and Tanzania: 105 pp.

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

Kitheka, J.U. 2002b. Freshwater and sediment discharge in Ungwana Bay: The role of the Tana and Sabaki Rivers. In: Current status of the trawl fishery of Malindi-Ungwana Bay. KMFRI Report 2002: 97 pp.

Kitheka, J.U., Ongwenyi, G.S and Mavuti, K.M. 2002. Dynamics of suspended sediment exchange and transport in a degraded mangrove Creek in Kenya. *Ambio* 31 (7-8): 580-587.

Kitheka, J.U., Nthenge, P. and Obiero, M. 2003a. Sabaki estuary sediment transport dynamics and resultant sediment fluxes in the monsoon-driven Malindi Bay. LOICZ-START AfriCAT Report, Nov. 2003: 58 pp.

Kitheka, J.U., Obiero, M. and Nthenge, P. 2003b. Dynamics of sediment transport and exchange in the Tana Estuary in Kenya. Project Report- KMFRI, Mombassa: 40 pp.

Kitheka, J.U., Ochiewo, J., Nthenge, P. and Obiero, M. 2003c. Coastal impacts of damming and water abstraction in the Tana and Athi-Sabaki river basins. LOICZ-START AfriCAT Project Report, Dec. 2003: 70 pp.

Kitheka, J.U., Ongwenyi, G.S and Mavuti, K.M. 2003d. Fluxes and exchange of suspended sediments in tidal inlets draining a degraded mangrove forest in Kenya. *Estuarine and Coastal Shelf Science* 56: 655-667.

Kitheka, J.U., J. Ochiewo., Nthenge, P. and Obiero, M. 2004. Land-use change and climatic variability in the Tana and Athi-Sabaki River Basins and associated impacts on coastal resources in Kenya. Paper for START-LOICZ AfriCAT Workshop, February 18-21, 2004.

Kitheka, J.U., Obiero, M. and Nthenge, P. 2005. River discharge, sediment transport and exchange in the Tana Estuary, Kenya. *Estuarine and Coastal Shelf Science*. 63: 455-468.

Krantz, L., Sorensen, N.K., Olesen, J. and Kotalova, J. 1989. The fisheries in Mozambique: a sector study. Fisheries Research Institute, Maputo: 103 pp.

Kulindwa, K., Sosovele, H. and Mgaya, Y.D. 2001. Socio-economic dimensions of biodiversity loss in Tanzania. Dar es Salaam University Press.

Kulshrestha, U.C., Jain, M., Mandal, T.K., Gupta, P.K., Sarkar, A.K. and Parashar, D.C. 1999. Measurements of acid rain over Indian Ocean and surface measurements of atmospheric aerosols at New Delhi during INDOEXpre-campaigns *Curr. Sci.* 76 (7): 968-976.

Kyewalyanga, M.S. 2004. Physical alteration and destruction of habitat (PADH) In: Tanzania. UNEP, Nairobi.

L

Lablache, G., de Mossac, G.A. and Shah, N.J. 1987. Summary description of the marine fisheries and resources for Seychelles. In: Sanders, M.J., Sparre, P. and Venema, S.C. (eds.) Proceeding of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, 14-25 September 1987, Albion Mauritius. FAO, Rome: 277 pp.

Lacerda, L. D. 1997. Trace metals in mangrove plants: why such low concentrations? In: Kjerve, B., Lacerda, L.D. and Diop, E.H.S. (eds.) Mangrove ecosystem studies in Latin America and Africa. UNESCO, Paris: 171-178.

LaRoche, J. and Ramanarivo, N. 1995. A preliminary survey of the artisanal fishery on coral reefs of the Tulear Region (southwest Madagascar). *Coral Reefs* 14: 193-200.

Lee, S.Y. 1999. Tropical mangrove ecology: physical and biotic factors influencing ecosystem structure and function. *Australian Journal of Ecology* 24: 355-366.

Lewis, S., May, S., Donkin, N. and Deplege, H. 1997. The influence of copper and heatshock on the physiology and cellular stress response of *Enteromorpha intestinalis*. *Marine Environmental Research* 46 (1-5): 421-424.

Lindahl, U. 1998. Low-Tech Rehabilitation of Degraded Coral Reefs through Transplantation of Staghorn Corals. *Ambio*, Vol. 27, No.8.

Lindén, O. and Sporrong, N. (eds.) 1999. Coral Reef degradation in the Indian Ocean - Status reports and project presentations 1999. CORDIO, Sweden.

Lindén, O., Souter, D., Wilhelmsson, D. and Obura, D. 2002. Coral reef degradation in the Indian Ocean: status report 2002. CORDIO, University of Kalmar, Sweden.

Lindén, O. and Lundin, G.C. (eds.) (1996). Integrated coastal zone management in Tanzania Sida-Sarec and World Bank: 166 pp.

Little, M.C., Reay P.J., Grove, S.J. 1988. The fish community of an East African mangrove creek. *J. Fish Biol.* 32: 729-747.

Louw, A., and F. Gichuki. 2003. Limpopo Basin Profile: Strategic research for enhancing agricultural water productivity. Challenge program on water and food http://www.waterforfood.org.

Lovatelli, A. 1995. Artisanal fisheries. Final report. EC rehabilitation programme for Somalia. EC Somalia Unit, Nairobi : 209 pp.

Lugeiyamu, J.E. 2002. TANESCO activities and environment in the Pangani River basin. In: The Pangani River basin: options for management. Report of a workshop held at the Kilimanjaro Crane Hotel, Moshi, Tanzania, 8-10 May 2002. December 2002. Nairobi, IUCN-EARO: 62-63.

Lutjeharms J.R.E. 2006. The Agulhas Current. Springer-Verlag, Berlin, Germany: 329 pp.

Lyngby, J. E., Brix, H. and Schierup, H. 1992. Absorption and translocation of zinc in eelgrass (*Zostera marina* L). *J. Exp. Mar. Biol. Ecol.* 58: 259-270.

M

Maarouf, M. 2008. Rapport national sur la gestion des eaux usées municipales aux Comores. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 20 pp.

Macdonald, A.H.H., Sampayo, E.M., Ridgeway, T. and Schleyer, M.H. 2008. Latitudinal symbiont zonation in *Stylophora pistillata* from southeast Africa. *Marine Biology* 154 (2): 209-217.

Machiwa, J.F. 2000. Heavy metals and organic pollutants in sediments of Dar es Salaam harbour prior to dredging in 1999. *Tanzania Journal of Science* 26: 29-46.

Macia, A. 2004. Primary carbon sources for juvenile penaeid shrimps in a mangrove-fringed Bay of Inhaca Island, Mozambique: a dual carbon and nitrogen isotope analysis. *W Indian Ocean J. Mar. Sci.* 3 (2): 151-161.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forest in the Indo-West Pacific region. *Adv. Mar. Biol.* 63: 73-270.

Maharavo, J. 2003. Rapport national sur le suivi de l'état de santé des récifs coralliens.

MAIFDS, 2007. Ministry of Agro-Industry, Food Production and Security. Annual report 2007. Ministry Agro-Industry, Food Production and Security, Republic of Mauritius.

Malzbender, D. and Earle, A. 2007. The Impact and Implications of the Adoption of the 1997 UN watercourse conventions for countries in Southern Africa. African Centre for Water Research Cape Town, South Africa.

Mangi, S.C. and Roberts, C.M. 2007. Factors influencing fish catch levels on Kenyan's coral reefs. *Fisheries management and Ecology* 14 (4): 245-253.

Mann, K.H. 1972a. Introductory remarks. *Memoire dell'Instituto Italiano di Idrobiologica* 29 (Supple): 13-16

Mann, K.H. 1972b. Macrophyte production and detritus food chains in coastal waters. *Memoire dell'Instituto Italiano di Idrobiologica* 29 (Supple): 353-383.

Marshall, N. Milledge, S.A.H and Afonso, P.S (eds.) 2001. Stormy seas for marine invertebrates: trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique. TRAFFIC East/Southern Africa, Nairobi, Kenya: 70 pp.

Martin, A.K. and Flemming, B.W. 1988. Physiography, structure and geological evolution of the Natal continental shelf. In: Schumann, E.H. (ed.) Coastal Ocean studies off Natal, South Africa. Springer-Verlag, New York: 11-46.

Masekesa, I. 2003. Coastal tourism. In: State of the Coast Report 2003. The National ICM Strategy and Prospects for Poverty Reduction. Coastal Management Report No. 2002 TCMP: 51-56.

Massingue, A. and Bandeira, S.O. 2005. Distribution of seagrasses and common seaweeds around Nampula Province (northern Mozambique) with emphasis on Mozambique Island. *W.Indian Ocean J. Mar.Sci.* 4(2): 175-185.

Massinga, A. and Hatton, J. 1997. Status of the coastal zone of Mozambique. In: C.G. Lundin and O. Lindén (eds.) Integrated Coastal Zone Management in Mozambique. Proceedings of the National Workshop on Integrated Coastal Zone Management in Mozambique. Inhaca Island and Maputo, Mozambique, May 5-10, 1996: 7-68.

Masundire, H. and Mackay, H. 2002. The role and importance of aquatic ecosystems in water resources management. In: Hirji, R., Johnson, P., Maro, P. and Chiuta, T.M. (eds.) Environmental Sustainability in Water Resources Management in Southern Africa. SADC, IUCN, SARDC, World Bank: Maseru, Harare, Washington DC.

Mather, A.A. 2008. Sea level rise for the East Coast of southern Africa. COPEDEC. VII, Dubai, UAE. Conference Paper.

Mathieu, S. 2005. Country review: Madagascar. In: De Young, C. (ed.) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper. No. 488. Rome, FAO. 2006: 458 pp.

Maud, R.R. 1980 The climate and geology of Maputaland. In: Bruton, M.N. and Cooper, K.H. (eds.) Studies on the ecology of Maputaland. Rhodes University & Wildlife Society; Cape and Transvaal Printers, Cape Town: 1-7.

McClanahan, T.R. 2004. The relationship between bleaching and mortality of common corals. *Mar. Biol.* 144(6): 1239-1245.

McClanahan, T.R., Maina, J., Sarger, C., Herran-Perez, P. and Deisek, E. 2005. Detriments to post-bleaching recovery of corals. *Coral Reefs* 24: 230-246.

McClanahan, T.R. and Obura, D.O. 1995. Status of Kenyan coral reefs. *Coastal Management* 23: 47-76.

McClanahan, T.R. and Obura, D.O. 1997. Sedimentation effects on shallow coral communities in Kenya. *J. Exp. Mar. Biol. Ecol.* 209:103-122.

McClanahan, T.R., Glaesel, H., Rubens, J., and Kiambo, R.W. 1997. The effects of traditional fisheries management on fisheries yields and the coral-reef ecosystems of southern Kenya. *Environmental Conservation* 24 (2): 105-120.

McClanahan, T. R., Mwaguni, S., Muthiga, N.A. 2005. Management of the Kenyan coast. *Ocean and Coastal Management,* 48*: 901-931*.

McClanahan, T.R. 1988. Seasonality in East Africa's coastal waters. *Marine Ecology – Progress Series* 44: 191-199.

McClanahan, T.R. and Young, T.P. 1996. East African ecosystems and their conservation. Oxford University Press, New York: 452 pp.

McClurg, T. P., Parsons, G. A., Simpson, E. A., Mudaly, R., Pillay, S., Newman, B. K. 2007. Sea disposal of sewage Environmental surveys in the Durban outfalls region. Report No. 25. Surveys made in 2006. CSIR Report: CSIR/NRE/PW/ER/2007/0080/C. Durban, South Africa.

McLeod, E. and Salm, R.V. 2006. Managing Mangroves for Resilience to Climate Change. IUCN, Gland, Switzerland: 64 pp.

McMahon, K.M., Waycott, M. 2009. New record for Halophila decipiens (Ostenfeld) in Kenya based on morphological and molecular evidence. Aquatic Botany, 91(4): 318-320.

McPherson, J.M. and Vincent, A.C.J. 2004. Assessing East African trade in seahorse species as a basis for conservation under international controls. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 521-538

Mengesha, S., Dehairs, F., Elskens, M. and Goeyens, L. 1999. Phytoplanton nitrogen nutrition in the Western Indian Ocean: Ecophysiological adaptations of neritic and oceanic assemblages to ammonium supply. *Estuarine, Coastal and Shelf Science* 48(5): 589-598.

Metz, H.C. (ed.) 1994. Comoros: A country study. Washington GPO for the Library of Congress 14: 521-538.

Mgana, S.S. and Mahongo, S. 1997. Land-based sources and activities affecting the quality and use of the marine, coastal and associated freshwater environment – Tanzania mainland. Paper presented at a workshop on the Implementation of the Global Programme of Action for the Protection of the marine environment from land-based activities in the East African region. Zanzibar, Tanzania, 6-9 October 1997.

Mgana, S.S. and Mahongo, S. 2002. Strategic Action Plan for Land-Based Sources and Activities Affecting the Marine, Coastal and Associated Fresh Water Environment in the Eastern African Region. A Report prepared by Food and Agriculture Organisation of the United Nations project for the Protection and Management of the Marine and Coastal Areas of the Eastern African Region (EAF/5).

Millennium Ecosystem Assessment 2005a. Ecosystems and human well-being: synthesis. Pp 47–70. Washington DC, Island Press. Also- www.millenniumassessment.org/documents/document.353.aspx.pdf.

Millennium Ecosystem Assessment 2005b. Section 6: Concepts of ecosystem value and valuation approaches. Washington DC, Island Press: 127-147.

Millennium Ecosystem Assessment 2005c. Section 4: Drivers of change in ecosystems and their services. Washington DC, Island Press: 85-106.

Ministry of Fisheries, 2003. Annual report 2000. Fisheries. Republic of Mauritius.

Miyake, M.P., Miyabi, N. and Nakano, H. 2004. Historical trends of tuna catches in the world. FAO Fisheries Technical Paper 467. FAO, Rome: 74p.

Moberg, F., and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics* 29: 215-233.

Mohammed, K. and Betlem, J. 1996. Proceedings of the National workshop on coastal erosion Zanzibar, 11-12 April 1996. Zanzibar environmental study series No. 20.

Mohammed, S.M., Machiwa, J., Njau, K.N., and Mato, R.R.A.M. 2008. National status report on land-based activities, sources of pollution and pollutant levels in water and sediment: Tanzania. Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 121 pp.

Mollion, J., 1998. The Seaweed Resources of Madagascar and Reunion Islands. In: Critchley A.T. and Ohno M. (eds.) Seaweed Resources of the World. Japan International Cooperation Agency, Yokosuka: 398–402.

Mong, Y. 2007. National Report on the Status of Municipal Wastewater Management in Madagascar. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 47 pp.

Mong, Y., Rejo, R., Randriamanarivo, R., Ranaivoson, J., Rakotorinjanahary, H., Ralaimaro, J., Manera, J.Y. 2009. Rapport national sur les activités terrestres, les sources de pollution et niveaux de pollution des eaux et des sédiments : Madagascar. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 115 pp.

Montaggioni L. and Faure, G. 1980. Les Récifs corallines des Mascareignes (Océan Indien). Coll. Trav. Univ. Fr. O. Indien: 151 pp.

Montano, M. 2008. National Report on the Status of Municipal Wastewater Management in Seychelles. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 62 pp.

Motta, H., Pereira, M.A.M., Gonçalves, M., Ridgway, T. and Schleyer, M.H. 2002. Coral reef monitoring in Mozambique. II: 2000 report. MICOA/CORDIO/ORI/WWF. Maputo, Mozambique Coral Reef Management Programme: 31 pp.

Motta, H., Pereira, M.A.M. and Schleyer, M.H. 2002. Coral reef degradation in Mozambique, results of the monitoring 1999-2000. In: Lindén, O., Souter, D., Wilhelmsson, D. and Obura, D. eds. Coral reef degradation in the Indian Ocean – Status report 2002. CORDIO, Kalmar: 55-60.

Moothien-Pillay R, Terashima H, Kawasaki H. (2002). The extent and intensity of the 1998 mass bleaching event on the reefs of Mauritius, Indian Ocean. Galaxea 4: 43–52

Mremi, S.D. and Machiwa, J.F. 2003. Heavy metal contamination of mangrove sediments and the associated biota in Dar es Salaam, Tanzania. *Tanzanian Journal of Science* 29 (1): 61-76.

Muhammed, S.M., Muhando, C.A., Machano, H., Jiddawi, N. and Yahya, S. 2005. Status of coral reefs in Tanzania. In: Souter, D. and Lindén, O. (eds.) Coral Reef Degradation in the Indian Ocean: Status Report 2005: 36-47.

Muir, C. 2006. The use of TEDS to reduce turtle bycatch in the WIO region. In: Kambona, J.J. and Marashi, S.H. 1996. Process for the establishment of the Indian Ocean Tuna Commission. FAO Fisheries Circular 913. FAO, Rome: 53 pp.

Mumby, P.J., Edwards, A.J., Arias-Gonzalez, J.E., Lindeman, K.C., Blackwell, P.G., Gall, A., Gorczynska, M.I., Harborne, A.R., Pescod, C.L., Renken, H., Wabnitz, C.C.C. and Llewellyn, G. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature* 427: 533-536.

Munga, D., S. Mwangi, J., Kamau, M.M., Nguli, P.O., Gwada, L.N., Daudi, H., Ong'anda, S.M., Mwaguni, H.S., Massa, M., Tole, J.M., Onyari, J., Makopa, A., Gachanja, G., Opello, A., Kheir, M. and Machua, S. 2007. National status report on land-based activities, sources of pollution and pollutant levels in water and sediment: Kenya. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 56 pp.

Munissi, J.J.E. 1998. A comparative study of polluted and unpolluted intertidal floral communities near Tanga Town. A report submitted for the fulfilment of the forth term programme at the University of Dar es Salaam. Department of Zoology and Marine Biology: 17 pp.

Munissi, J.J.E. 2000. Dissolved oxygen, biochemical oxygen demand and selected green algae as indicators of marine pollution near Dar es Salaam. A report submitted in partial fulfilment of the Degree of Bachelor of Science at the University of Dar Es Salaam. Department of Zoology and Marine Biology, University of Dar Es Salaam: 18 pp.

Murchiri, M. 1998. Biodiversity of the inland fishes of Kenya: A systematic review and conservation status. African Fisheries and Fisheries Diversity and Utilisation. Poissons et Pêches Africains Diversité et Utilisation. FISA/PARADI, Grahamstown: 62 pp.

Murdoch, W. 2004. A comprehensive account of the biology and conservation issues. Website. in association with the University of Nottingham and the British Marine Life Study Society.

Murray, M. and Henri, K. 2005. An economic assessment of Seychelles biodiversity. A report prepared under GEF Project Development facility to prepare for a full project application "Mainstreaming biodiversity in production landscapes and sectors."

Muthiga, N.A. 2005.Testing for the effects of seasonal and lunar periodicity on the reproduction of the edible sea urchin *Tripneustes gratilla* (L) in Kenyan coral reef lagoons. *Hydrobiologia* 549: 57-64.

Mvungi, A. 2003. Coastal Population Growth. In: State of the Coast Report 2003. The National ICM Strategy and Prospects for Poverty Reduction. Coastal Management Report No. 2002 TCMP: 45-47.

Mwaipopo, R. and Lufumbi, J.M. 2003. An assessment of the socio-economic implications of PADH due to coastal tourism, mangrove destruction, mining/sediment movement, ports and land reclamation and damming of rivers.

Mwalyosi, R.B.B. 2004. Management of the Rufiji Delta as a wetland. Institute of Resource Assessment. University of Dar es Salaam.

Mwanguni and Munga, 1997. Land-based sources and activities affecting the quality and uses of the marine coastal and associated fresh water environments along the Kenya Coast. http://seawaste.uwc.ac.za/archive/socio-economic.doc

Mwanguni, S. 2002. Public health problems in Mombasa district. A case study on sewage management. MSc. Thesis, University of Nairobi: 86 pp.

Mwaguni, S.M. 2008. National Report on the Status of Municipal Wastewater Management in Kenya. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 87 pp.

Mwevura, H., Othman, C. and Mhehe, G.L. 2002. Organochlorine pesticide residues in sediments and biota from the coastal area of Dar es Salaam city. *Mar. Poll. Bull.* 45: 262-267.

N

Nakamura T., van Woesik R. 2001. Differential survival of corals during the 1998 bleaching event is partially explained by water-flow rates and passive diffusion. *Mar. Ecol. Progr. Ser.* 212: 301–304.

Nepad, 2002. Mauritius national report: phase 1: integrated problem analysis: 87 pp.

NEPAD, 2003. New Partnership for Africa's Development (NEPAD), Action Plan for the Environment Initiative of NEPAD. http://www.nepad.org/2005/files/reports/action_plan/action_plan_english2.pdf.

New, A.L., Stansfield, K., Smythe-Wright, D. Smeed, D.A., Evans, A.J. and Alderson, S.G. 2005. Physical and biochemical aspects of the flow across the Mascarene Plateau in the Indian Ocean. *Philosophical Transactions of the Royal Society A* 363: 151-166.

Ngoile, M.A.K and Horrill, C. 1993. Coastal Ecosystems, Productivity and Ecosystem Protection: coastal ecosystem management. *Ambio* 22:461-467.

Ngoile, M.A.K. and Shunula, J.P. 1992. Status and exploitation of the mangroves and associated fishery resources in Zanzibar. In: Jaccarini, V., Martens, E. (eds.) The ecology of mangroves and related ecosystems. *Hydrobiologia* 247: 229-234.

Ngusaru, A. 2002. Geological history. In: Richmond, M.D. (ed.) A field guide to seashores of Eastern Africa and the Western Indian Ocean Islands. SIDA, SAREC and University of Dar es Salaam: 461 pp.

Nhwani, L.B. 1988. Summary of fisheries and resources information for mainland Tanzania. In: Sanders, M.J., Sparre, P. and Venema, S.C. (eds.) Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean, 14-25 September 1987, Albion. FAO/UNDP: RAF/79/065/WP/41/88/E, FAO, Rome: 277 pp.

Noble, R.G and Hemens, J. 1978. Inland water ecosystems in South Africa - a review of research needs. Council for Scientific and Industrial Research (CSIR), Pretoria: 150 pp

O

Obura, D.O. 2001. Kenya. *Mar. Poll. Bull.* 42 (8): 1264-1278.

Obura D.O. (ed.) 2002. Proceedings of the International Coral Reef Initiative (ICRI) Regional Workshop for the Indian Ocean, 2001. ICRI/UNEP/ICRAN/CORDIO.

Obura, D.O. 2005. Resilience and climate change: Lessons from coral reefs and bleaching in the Western Indian Ocean. *Est. Coast. Shelf Sci.* 62: 353-372.

Obura, D. and Abdulla, A. 2005. Assessment of tsunami impacts on the marine environment of the Seychelles. IUCN/UNEP: 17 pp.

Ochieng, C., Erftemeijer, P.L.A. 2001. The status of seagrass ecosystems in Kenya and Tanzania. Draft paper submitted to the UNEP-WCMC Global Seagrass Workshop, St Pete's Beach, Florida, 5-9 November, 2001. Unpublished Report.

Ochieng, C.A., Erftemeijer, P.L.A. 2003. Seagrasses of Kenya and Tanzania. In: Green, E.P. and Short, F.T. (eds.) World Atlas of Seagrasses. WCMC: 82-92.

Ochiewo, J. 2004. Changing fisheries practices and their socioeconomic implications in South Coast Kenya. *Ocean and Coastal Management* 47: 389-408.

Okemwa, E. and Wakabi, E. 1993. Integrated coastal zone management of Kenya. In: Lindén, O. (ed.) Proceedings of the workshop and policy conference on integrated coastal zone management in eastern Africa including the island states, 21-23 April 1993, Arusha. Coastal Management Center, Manila: 183-204.

Okemwa, E.N. 1998. Application of the large marine ecosystem concept to the Somali Current. In: Sherman, K., Okemwa, E.N. and Ntiba, M.J. (eds.) Large marine ecosystems of the Indian Ocean: assessment, sustainability and management. Blackwell Science, London: 73-100.

Oliveira E.C., Österlund, K., Mtolera, M.S.P. 2005. Marine Plants of Tanzania. A field guide to the seaweeds and seagrasses. Stockholm University: 267 pp.

Olsen, S.B., Sutinen, J.G., Juda, L., Hennessey, T.M., Grigalunas, T.A. 2006. A handbook on governance and socioeconomic of large marine ecosystems University of Rhode Island.

Ongwenyi, G.S. 1979. Problems of soil erosion and sedimentation in selected water catchment areas in Kenya with special reference to the Tana River. UN Water E/CONF 70/TP 23.

Ongwenyi, G.S. 1983. Development of water resources. In: Ojany. F.F and Olson, S. (eds.) The Kenyan Geographer. Special issue on the Proceedings of the Nairobi workshop (4-8th August 1981) Strategies for developing the resources of the semi-arid areas of Kenya: 36-47.

Otieno, F.A.O and Maingi, S.M. 1983. Sedimentation Problems of Masinga Reservoir, paper presented at the 4^{th} Land and Water Management Workshop Feb. 15-19, 1993, Nairobi, Kenya.

P

Palgrave, K.C. 2002. Trees of Southern Africa. Struik Publishers, Cape Town: 1212 pp.

Pallet, J. (ed.) 1997. Sharing water of Southern Africa. The Desert Research Foundation of Namibia, Windhoek.

Panray, K.B. 2007. The construction of artificial reefs for octopus using discarded concrete electric poles. 5th WIOMSA Symposium. Poster. Durban: 90.

Payet, R. 2003. Seychelles country report on physical alteration and destruction of habitats. A Report prepared for UNEP/GPA.

Payet , R. 2005. Research, assessment and management on the Mascarene Plateau: a large marine ecosystem perspective. *Philosophical Transactions of the Royal Society 363*: 295-307.

PBWO/IUCN, 2006a. Hydrology of the Pangani River Basin. PBWO, Moshi, Tanzania and IUCN Eastern Africa Regional Program, Nairobi, Kenya.

PBWO/IUCN, 2006b. Pangani River Health Assessment. PBWO, Moshi, Tanzania and IUCN Eastern Africa Regional Program, Nairobi, Kenya.

PBWO/IUCN, 2007. Pangani River System – State of the Basin Report – 2007. PBWO, Moshi, Tanzania and IUCN Eastern Africa Regional Program, Nairobi, Kenya.

Pooley, E. 1994. The complete field guide to trees of Natal, Zululand and Transkei. Natal Flora Publications Trust. Durban: 512 pp.

Prayag, R., Jootun, L. and Bheeroo, R.A. 1995. Integrated coastal zone management. Protection and management of marine and coastal areas of the Eastern African Region. Report prepared for UNEP/FAO/IOC/IUCN EAF5 project. Ministry of Environment and Quality of Life, Mauritius: 92 pp.

Pybus, Ph. 2008. National Report on the Status of Municipal Wastewater Management in South Africa. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 44 pp.

Q

Quod, J-P, Turquet, J. Conejero, S and Ralijaona, C. 2001. Ciguatera risk assessment in the Indian Ocean following 1998 coral bleaching event. Proceedings of the 9th international conference on harmful algal blooms. Tasmania. CORDIO Report 19.

R

Rabesandratana, R.N. 1996. Ecological distribution of seaweeds in two fringing coral reefs at Toliara (SW of Madagarsacar). In: Bjork, M., Semesi A. K., Pedersén M. and Bergman, B. (eds.) Current trends in Marine Botanical Research in East Africa Region. SIDA/SAREC, Uppsala: 141-161 pp.

Radegonde, V. 1997. Update Seychelles National Overview on land-based sources and activities affecting the marine, coastal and associated freshwater environment. Seychelles Bureau of Standards, Seychelles: 31 pp.

Radhay, A. 2007. National Report on the Status of Municipal Wastewater Management in Mauritius. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 161 pp.

Radhika, D. 2006. Mangrove Ecosystems of Southwest Madagascar: An Ecological, Human Impact, and Subsistence Value Assessment. *Tropical Resources Bulletin* 25: 7–13.

Rajonson, J. 1993. Mangroves and coral reefs in Mauritius. In: LINDÉN, O. ed. Proceedings of the workshop and policy conference on integrated coastal zone management in eastern Africa including the Island States, 21-23 April 1993, Arusha. Coastal Management Centre, Manila: 205-216.

Ralison, S. 1987. Summary of fisheries and resources information for Madagascar. In: Sanders, M.J., Sparre, P. and Venema, S.C. (eds.) Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. Albion, Mauritius, 4-25 Sept. 1987. RAF/79/065/WP/41/85/E: 277 pp.

Ramsar Convention, 1971. Convention on Wetlands of International Importance especially as Waterfowl Habitat, 2 February 1971, 996 U.N.T.S. 245.

Ramsay, P.J. 1996. Quaternary marine geology of the Sodwana Bay continental shelf, northern KwaZulu-Natal. *Bulletin of the Geological Survey of South Africa* 117: 1-86.

Ramsay, P.J. and Mason T.R. 1990. Development of a type zoning model for Zululand coral reefs, Sodwana Bay, South Africa. *J. Coastal Res.* 6: 829-852.

Ramessur, R.T. 2002. Anthropogenic-driven changes with focus on the coastal zone of Mauritius, south western Indian Ocean. *Regional Environmental Change* 3 (13): 99-106.

Ramessusr, R.T., Parry, S.J. and Jarvis, K.E. 1998. Characterization of some trace metals from the export processing zone and a costal tourist area in Mauritius using inductively coupled plasma mass spectrometry. *Environment International* 24 (7): 773-781.

Rasolofoharinoro, M., Blasco, F. and Denis, J. 1997. Aquaculture in Madagascar's Mahajamba Bay. Intercoast Network Special Edition 1. http://www.crc.uri.edu/comm/download/IC_Mangrove.pdf

Rawlins, S. 1957. The East African Mangrove Trade. Unpublished typescript in the East Africa Herbarium, NMK, Nairobi.

Regional Seas 2002. Shoreline changes in the Western Indian Ocean region. Report of regional coastal erosion workshop, November 2002. UNEP, Nairobi: 21 pp

Republic of Kenya 1997: Kilifi District Development Plan 1997-2001. Office of the Vice-President and Ministry of Planning and National Development. Government Printers, Nairobi: 193 pp.

Republic of Kenya 2005. Statistical Abstract 2005. Central Bureau of Statistics: Ministry of Planning and National Development, Government Printers, Nairobi.

Republic of Kenya 2006. Statistical analysis of tourism trends, (globally and locally). Ministry of Tourism and Wildlife, Kenya: 21 pp

Région Réunion 2008. Développent durable et solidaire. Conseil Régionale de La Réunion : 34 pp.

Resource Analysis – EDC 1999. Feasibility of desiltation of lagoons in Rodrigues, Mauritius. Ribbink, A.J. and Roberts, M. 2006. African coelacanth Programme Overview: an overview of the conference contributions. *South African Journal of marine Science* 102: 409-415.

Richmond, M.D. 2001. The marine biodiversity of the Western Indian Ocean and its biogeography: How much do we know? p. 241-262. In: Richmond M.D. and Francis, J. (eds.) Marine Science Development in Tanzania and Eastern Africa. Proceedings of the 20th Anniversary Conference on Advances in Marine Science in Tanzania. 28 June - 1 July, 1999, Zanzibar, Tanzania. IMS/WIOMSA: 569 pp.

Richmond, M.D. and Mohamed, A. 2005. Assessment of marine biodiversity, ecosystem health and resource status of intertidal (non-mangrove) and sub-tidal (non-coral) habitats in MBREMP. Final Report. Samaki Consultants Ltd., Dar es Salaam, Tanzania for IUCN-EARO, Nairobi, Kenya: 61 pp.

Richmond, M.D., Wilson, J.D.K., Mgaya, Y.D. and Le Vay, L. 2002. An analysis of smallholder opportunities in fisheries, coastal and related enterprises in the floodplain and delta areas of the Rufiji River, Tanzania. Rufiji Environment Management Project, IUCN.

Ridler, N. and Hishamunda, N. 2001. Promotion of sustainable commercial aquaculture in sub-Saharan Africa. FAO Fisheries Technical Paper 408/1. FAO, Rome: 67 pp.

Robertson, A. I. and Duke, N.C. 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. *Mar. Biol.* 96: 193-206.

Robertson, W.D., Schleyer, M.H., Fielding, P.J., Tomalin, B.J., Beckley, L.E., Fennessy, S.T., van der Elst, R.P., Bandera, S., Macia, A. and Gove, D. 1996. Inshore marine resources and associated opportunities for development of the coast of southern Mozambique: Ponta Do Oura to Cabo de Santa Maria. Unpublished Report. Oceanographic Research Institute, (130): 1-51.

Robinson, J. and Shroff, J. 2004. The fishing sector in Seychelles. An overview with an emphasis on artisanal fisheries. SFA. Republic of Seychelles, *Seychelles Medical and Dental Journal* special issue. 7(1): 52-56.

Røhr and Killingtveit, (2002). Study of two catchments on the hillside of Mt. Kilimanjaro. In Ngana, J. O. (ed.) Water resources management: the case of Pangani River Basin. Issues and Approaches. Dar es Salaam, Dar es Salaam University Press: 211 – 231.

Rönnbäck, P., Macia, A., Almqvist, G., Schultz, L., Troell, M. 2002. Do penaeid shrimps have a preference for mangrove habitats? Distribution pattern analysis on Inhaca Island, Mozambique. *Est. Coast. Shelf Sci.* 55: 427-436.

Rowat, D. and Engelhardt, U. 2007. Seychelles: A case study of community involvement in the development of whale shark ecotourism and its socio-economic impact. *Fisheries research* 84(11): 109-113.

RSA 1998. National Water Act - Act No 36 of 1998. ftp://ftp.hst.org.za/pubs/govdocs/acts/1998/act36.pdf

RSA DWAF 1995. South African water quality guidelines for coastal marine waters. Volume 1. Natural Environment, Volume 2. Recreational Use. Volume 3. Industrial Use. Volume 4. Mariculture. Pretoria.

RSA DWAF 2004a. Water Quality Management Series Sub-Series No. MS 13.4. Operational policy for the disposal of land-derived water containing waste to the marine environment of South Africa – Appendices. Edition 1. Pretoria (www.dwaf.gov.za/Documents).

RSA DWAF 2004b. Water Quality Management Series Sub-Series No. MS 13.3. Operational policy for the disposal of land-derived water containing waste to the marine environment of South Africa – Guidance on Implementation. Edition 1. Pretoria (www.dwaf.gov.za/documents).

RSA DWAF 2004c. Water resource protection and assessment policy implementation process. Resource directed measures for protection of water resource: Methodology for the Determination of the ecological water requirements for Estuaries. Version 2. Pretoria.

Ruwa, R.K. 1996. Intertidal wetlands. In: East African Ecosystems and their conservation, eds. T.R.MacClanahan and T.P.Young, Oxford University Press: 101-130 pp.

Ruwa, R.K. 2006. The state of the marine environment: Regional Assessments. Chapter 3: Eastern Africa. Report published by the United Nations Environmental Programme - Global Programme of Action for the Protection (UNEP/GPA) Coordination Office, The Hague, Netherlands. Retrieved from http://www.gpa.unep.org/.

Ruwa, R.K., Habib, G., Mukira, M., Okoth, G. and Mwatha, G. 2003. Profile of Kenya Marine and Fisheries – Country Working Resource Document. GEF-South-West Indian Ocean Fisheries Project (SWIOFP) in Kenya. Publication No. 1 (2003): 71 pp.

Ryan, P. 2006. Assessment of current status on marine litter in South Africa. Unpublished report prepared as input data to Land (2006). DST/NRF Centre of Excellence at the Percy FitzPatrick Insititute University of Cape Town, Rondebosch 7701, South Africa.

S

SADC 2000. Protocol on shared watercourse systems in the Southern African Development Community (SADC) Gaborone.

Saenger, P. 2002. Mangrove ecology, silviculture and conservation. Kluwer Academic Publishers, Dordrecht, the Netherlands: 361 pp.

Saket, M. and Matusse, R.V. 1994. Study for the determination of the rate of deforestation of the mangrove vegetation in Mozambique. FAO/PNUD, MOZ/92/013.

Salomon, J.N. 1987. Le Sud-ouest de Madagascar, E´ tude de Ge´ographie Physique. Presses Universitaires Bordeaux, Bordeaux : 998 pp.

Samboo, C.R. and Mauree, D. 1987. Summary of fisheries and resources information for Mauritius. In: Sanders, M.J., Sparre, P. and Venema, S.C. (eds.) Proceeding of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, 14-25 September 1987, Albion. FAO/UNDP.RAF/79/065/WP/41/88/E. FAO, Rome: 277 pp.

Sanders M.J. and Morgan, G.R. 1989. Review of the fisheries resources of the Red Sea and Gulf of Aden. FAO Fisheries Technical Paper 304: 112-117

Sanders, M.J. Gidhere, S.G., Nzioka, R.M. 1990. Report of Kenya Marine Fisheries. Sub-sector study. SWIOFP-FAO.

Sangeu, M., 2008. National Report on the Status of Municipal Wastewater Management in Tanzania. Unpublished Report submitted to UNEP/WIO-LaB Project/Nairobi Convention Secretariat, Nairobi, Kenya: 136 pp.

Santana-Afonso S.P. 2004. Country review: Mozambique. Institute for Fisheries Research (IIP) 13 pp. In: De Young C. 2006. (ed.).Review of the state of marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper 488. FAO, Rome: 458 pp.

SARDC 2003. Limpopo River Basin – Factsheet 1. SADC Water Sector. http://www.sardc.net/imercsa/Limpopo/pdf/Limpopo1.pdf accessed on 21 September 2006.

Sasol 2005. Offshore Seismic and Drilling, Block 16 and 19 – (Bazaruto) Parts A, B, C.

Schleyer, M.H. 1998. Observations on the incidence of crown-of-thorns starfish in the Western Indian Ocean. *Reef Encounter* (23): 25-27.

Schleyer, M.H. and Celliers L. 2002. Biodiversity on Southern African coral reefs: what does the future hold? CORDIO Annual Report, 2002.

Schleyer, M.H. and Celliers, L. 2005. An assessment of the coral reefs at Tamatave on the east coast of Madagascar for a proposed marine outfall: 2005 survey. Oceanographic Research Institute, Durban: 18 pp.

Schleyer, M.H. and Celliers, L. 2005. Modelling reef zonation in the Greater St. Lucia Wetland Park, South Africa. *Estuarine, Coastal and Shelf Science*. 63 (3): 373-384.

Schleyer M.H.,Macdonald A.H.H., Starzak D.E., Mann B.Q., Paula J.P., Silva I, Costa A, Macia A. and Abreu D. 2007. Assessing habitat connectivity in the TRANSMAP project. 5th WIOMSA Scientific Symposium, Durban, 22-26 October 2007. Poster.

Schouten, M.W., de Ruijter, W.P.M., van Leeuwen, P.J. and Ridderinkhof, H. 2003. Eddies and variability in the Mozambique Channel. *Deep-Sea Research II* 50 (12-13): 1987-2003.

SEACAM 2001. The Voyage from Seychelles to Maputo: Successes and Failures of Integrated Coastal Zone Management in Eastern Africa and Island States 1996-2001.Vols. 1& II.

Semesi, A.K. 1991. Management plan for the mangrove ecosystem of mainland Tanzania. Vol. 11. Dar es Salaam: Ministry of Tourism, Natural Resources and Environment (MTNRE), Forestry and Beekeeping Division, Catchment Forestry Project.

Semesi., A.K. 1998. Mangrove management and utilization in eastern Africa. *Ambio* 27:620-626.

Semesi, A.K. and Ngoile, M. 1993. Status of the coastal and marine environment in the United Republic of Tanzania. In: Lindén, O. (ed.) Proceedings of the workshop and policy conference on integrated coastal zone management in eastern Africa including the Island States, 21-23 April 1993, Arusha. Coastal Management Center, Manila: 291-314.

Semesi, A. K., Muruke, M.H.S., and Mgaya, Y.D.1999. Introduction to the mangroves, seagrasses, seaweeds and coral reefs, Workshop proceedings on coastal resources of Bagamoyo District Tanzania; 18 –19 December 1997. Bagamoyo.

Shaghude, Y., Mutakyahwa, and Mohamed, S. 1994. National report on the status of coastal erosion, sea-level changes and their impacts, Tanzanian case. In: IOC (ed.) IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their impacts. Zanzibar, Tanzania, 17-21 January 1994. IOC - Workshop report no. 96. supp.1.: 85-106.

Shaghude, Y.W. 2004. Coastal impacts of water abstraction and impoundment by damming in Africa: The case of Rufiji river, Tanzania. Final Report Submitted to START, Washington DC.

Shah, N.J. 1993. The coastal zone of Seychelles. In: Lindén, O. ed. Proceedings of the workshop and policy conference on integrated coastal zone management in eastern Africa including the Island States, 21-23 April 1993, Arusha. Coastal Management Center, Manila: 275-290.

Shah, N. 1994. Seychelles National report: coastal erosion, sea-level changes and their impacts. In: IOC (ed.) IOC-UNEP-WMO-SAREC Planning workshop on an integrated approach to coastal erosion, sea level changes and their impacts. Zanzibar, Tanzania, 17-21 January 1994. IOC - Workshop report no. 96. supp.1.: 64-8.

Shah, N. 2002. Bikinis and biodiversity: tourism and conservation on Cousin Island. In: F. diCastri, and V. Balaji (eds.) Tourism, Biodiversity and Information: Leiden, Neth: Backhuys Publishers. 185-196.

Shahin, M. 2003. Hydrology and Water resources of Africa. Kluwer, New York.

Sheppard, C.R.C 1987. Biodiversity, productivity and system integrity. *Mar. Poll. Bull.* 34: 680-681.

Sheppard, C.R.C. 2000. Coral reefs of the Western Indian Ocean: An overview. In: McClanahan, T.R., Sheppard, C.R.C. and Obura, D.O. (eds.) Coral reefs of the Indian Ocean – their ecology and conservation. Oxford University Press, Oxford: 3-38.

Sheppard, C. 2003. Predicted recurrences of mass coral mortality in the Indian Ocean. *Nature* 425: 294-297.

Sheppard, C., Dixon, D., Gourlay, M., Sheppard, A., and Payet, R. 2005. Coral mortality increases wave energy reaching shores protected by reef flats: Examples from Seychelles. *Est. Coast Shelf Sci.* 64: 223-234.

Sherman, K. 2003. Physical, biological and human forcing of biomass yields in large marine ecosystems. ICES Conference September 2003. Estonia. 26 pp.

Short F.T., Coles R.G. and Pergent-martini, C. 2001. Global Seagrass Distribution. In: Short, F.T. and Coles R. (eds.) Seagrass Research Methods. Elsevier Publishing, Amsterdam: 5-30.

Short, F.T. and Coles, R. (eds.) 2003. Seagrass Research Methods. Elsevier Publishing, Amsterdam.

Short, F.T. and Neckles, H.A. 1999. Review: The effects of global climate change on seagrasses. *Aquatic Botany* 63: 169-196.

Silva, C. and Sousa M.I. 1987. Summary description of the marine fisheries and resources for Mozambique. In: Sanders, M.J., Sparre, P. and Venema, S.C. (eds.) Proceeding of the workshop on the assessment of the fishery resources in the southwest Indian Ocean, 14-25 September 1987, Albion. FAO/UNDP.RAF/79/065/WP/41/88/E. FAO, Rome: 277 pp.

Simpfendorfer, C.A. 2000. Predicting population recovery rates for western Atlantic sawfish using demographic analysis. *Environ. Biol. Fishes* 58 (4): 371-377.

Slingo, J., Spencer, H., Hoskings, B., Berriford, P. and Black, E. 2005. The meteorology of the Western Indian Ocean and the influence of the East African highlands. *Philosophical Transactions of the Royal Society A* 363: 25-42.

Snoussi, M., Kitheka, J., Shaghude. Y. and Kane, A. 2004. Coastal impacts of damming and water abstraction in African catchments – a synthesis of Africa. START, Washington DC.

Snow, G.C., Adams, J.B. and Bate, G.C. 2000. Effect of river flow on estuarine microalgal biomass and distribution. *Est. Coast. Shelf Sci.* 51: 255–266.

Sookocheff, W. and Muir, C. 2006. A literature review of marine fisheries bycatch data in the United Republic of Tanzania. In: Kiszka, J. and Muir, C. (eds.) Incidental catch of non-targeted marine species in the Western Indian Ocean: problems and mitigation measures. Workshop proceeding, 13-15 November 2006, Mayotte: 92-99.

Souter D, Obura D and Lindén O. (eds.) 2000. Coral reef degradation in the Indian Ocean: Status report 2000. CORDIO, Stockholm: 205 pp.

Souter D and Lindén O (eds.) 2005. Coral reef degradation in the Indian Ocean: Status report 2000. CORDIO, Stockholm: 285 pp.

Souter, D. and Lindén, O. 2000. The health and future of coral reef systems. *Ocean and Coastal Management* 43: 657-688.

South African Tourism Strategic Research Unit 2007. 2006 Annual Tourism Report: 121 pp.

Spalding, M.D., Blasco, F. and Field, C.D. (eds.) 1997. *World Mangrove Atlas*. The International Society for Mangrove Ecosystems, Okinawa, Japan: 178 pp.

Spalding, M.D., Ravilious, C. and Green, E.P. 2001. *World Atlas of Coral Reefs*. University of California Press, Berkeley, CA.

Spencer T., Teleki, K.A., Bradshaw, C. and Spalding, M.D. 2000. Coral Bleaching in the Southern Seychelles During the 1997–1998 Indian Ocean Warm Event. *Mar. Poll. Bull* 40: 569–586.

Spencer , T. and Viles, H. 2002. Bioconstruction, bioerosion and disturbance on tropical coasts: Coral reefs and rocky limestone shores. *Geomorphology* 48 (1-3, 1) 23-50.

Spurgeon, J.P.G. and Lindahl, U. 2000. Economics of Coral Reef Restoration. In: Cesar, H.S.J. (ed.) Collected Essays on the Economic of Coral Reefs. CORDIO, Kalmar, Sweden.

Stabrawa, A. 1999. Western Indian Ocean Environmental Outlook. United Nations Environment Programme: 89 pp.

Stramma, L. and Lutjeharms, J.R.E. 1997. The flow field of the subtropical gyre of the South Indian Ocean. *J. Geophys. Res.* 102 (3): 5513–5530.

Stoddart, D.R., 1984. Biogeography and ecology of the Seychelles Islands. *Monographia biologica* v55. Junk, The Hague: 691 pp.

Stoddart, D.R. and Fosberg, F.R. 1984. Vegetation and floristics of Western Indian Ocean coral islands. In: Stoddart, D.R. (ed.) Biogeography and ecology of the Seychelles Islands. Dr. W. Junk Publishers, The Hague: 221-238.

SWIOC, 2006. FAO, South West Indian Ocean Fisheries Commission. Report of the first session of the Scientific Committee. Dar es Salaam, United Republic of Tanzania, 31 May–3 June 2006. FAO Fisheries Report No. 806: Appendix E. Rome, FAO. 2006: 79 pp.

T

Taljaard, S., Van Ballegooyen, R.C. and Morant, P.D. 2000. False Bay Water Quality Review. Volume 2: Specialist Assessments and Inventories of Available Literature and Data. Report to the False Bay Water Quality Advisory Committee. CSIR Report ENV-S-C 2000-086/2. Stellenbosch.

Taljaard, S., Morant, P.D., Van Niekerk, L. and Iita, A. 2006. The state of the marine environment: Regional Assessments. Chapter 2: Southern Africa. Report published by the United Nations Environmental Programme - Global Programme of Action for the Protection (UNEP/GPA) Coordination Office, The Hague, Netherlands.

Talla, P., De Young, C. and Gallène, J. 2004. Refonte du cadre juridique et définition d'une stratégie opérationnelle de gestion des pêcheries Union des Comores. Rapport Final et compendium des documents du projet TCP/COI/2902. Rome, FAO.

Taylor, M., Ravilious, C. and Green, E.P. 2003. Mangroves of East Africa. UNEP, Cambridge: 24 pp.

TCMP, 2001. State of the Coast 2000. People and the Environment. Dar-es, Salaam, Tanzania: Tanzania Coastal Management Partnership. October 2001: 53 pp

Temple, P.H. and Sundborg, A.1973. The Rufiji river, Tanzania: Hydrology and sediment transport. In: Rapp, A. Berry, L. and Temple, P. (eds.) Studies on Soil Erosion and Sedimentation in Tanzania. Research Monograph No. 1. Institute of Resource Assessment and Land use Planning: 345-368.

Tinley, K.L. 1985. Coastal dunes of South Africa. South African National Scientific Programmes Report. No 109. FRD/NRF. Pretoria: 300 pp.

Titlyanov, E., Cherbagdy, I. and Kolmakov, P. 1995. Daily variations of primary production and dependence of photosynthesis on irradiance in seaweeds and seagrass *Thalassodendron ciliatum* of the Seychelles Islands. *Photossyntetica* 31: 101-115.

Tomlison, C.B. 1986. The Botany of Mangroves. Cambridge Tropical Biology Series, Cambridge, University Press, Cambridge, New York, U.S.A.

TPTC. 2001. Joint Incomati Basin Study. Tripartite Permanent Technical Committee: Kingdom of Swaziland, Republic of Mozambique, Republic of South Africa.

Transmap, 2008. http://www.transmap.fc.ul/pt and http://wwwtransmapmetadat.org.za/

Schleyer, M .H. and Tomalin, B.J. 2000. Ecotourism and damage on South African coral reefs with an assessment of their carrying capacity. *Bulletin of Marine Science 67*: 1025-1042.

Turner J., Hardman E., Klaus R., Fagoone I., Daby, D., Baghooli R., Persands S. 2000. The reefs of Mauritius. Pages 94–107 In: Souter D., Obura D., Lindén O. (Eds.) *Coral reef degradation in the Indian Ocean. Status Report 2000*. CORDIO/SAREC Marine Science. Stockholm, Sweden.

Turner, J. and Klaus, R. 2005. Coral reefs of the Mascarenes, Western Indian Ocean. *Phil. Trans. R. Soc. A* 363 (1826): 229-250.

Turner, R.E. 1977. Intertidal vegetation and commercial yields of Penaeid shrimp. *Trans. American Fisheries Soc.* 106 (5): 411-416.

Turpie, J.K. and Lamberth, S. 2005. Economic value of the Thukela Banks crustacean and line fish fisheries and the potential impacts of changes in the Thukela River flow. In: Turpie, J.K. and Hosking, S.G. (eds.) Proceedings of a national workshop on resource economics in South Africa, 10-11 March 2005, Velddrif. Anchor Environmental Consultants CC, Rhodes Gift: 61-75.

Turpie, J.K. 2006. The valuation of riparian fisheries in southern and eastern Africa. Southern Waters, Cape Town.

Turton, A.R., Hattingh, H.J., Maree, G.A.,Roux, D.J., Claassen, M.,Strydom, W.F. (eds.) 2007. Governance as a Trialogue: Government-Society-Science in Transition Series: Water Resources Development and Management,:354 pp.

Tychsen, J. 2006 . Environmental Sensitivity Atlas for Coastal Area of Kenya: 76 pp. Copenhagen; Geological Survey of Denmark and Greenland (GEUS).

U

Uku, J.N. 1995. An Ecological Assessment of Littoral Seagrass Communities in Diani and Galu Coastal Beaches, Kenya. M.Sc. Thesis. University of Nairobi: 185 pp.

Uku, J.N. 2005. Seagrasses and their epiphytes: Characterization of abundance and productivity in tropical seagrass beds. PhD thesis. Botany Department, Stockholm University. (See http://www.diva-portal.org/su/abstract.xsql?dbid=527)

Uku, J.N. and Björk, M. 2005. Productivity aspects of three tropical seagrass species in areas of different nutrient levels in Kenya. *Estuarine, Coastal and Shelf Science*. 63: 407 – 420.

Uku J, S, Beer, Björk, M. 2005. Buffer Sensitive Photosynthetic Carbon Acquisition by East African seagrasses. Marine Biology 147: 1085 – 1090.

Uku, J.N. and Ndirangu, S. 2001. Seagrass Habitats of the Diani-Chale area. In: Muthiga, N. (ed.) TheBiophysical and Ecological Profile of Diani-Chale. An ICAM project.

Uku, J., Ndirangu S., Muhtama, C. and Kimathi, A. 2005. An evaluation of the effect of sea urchin herbivory in the Diani-Chale lagoon. Preliminary report No 1.A KMFRI/CORDIO collaborative project report: 8 pp.

Uku, J., Ndirangu S., Muhtama, C., Kimathi, A. and Kilonzi, J. 2007. An evaluation of the effect of sea urchin herbivory in the Diani-Chale lagoon: recovery potential of the seagrass habitat. Preliminary Report II. A KMFRI/CORDIO collaborative project report: 13 pp.

Uku, J. and Francis, J. 2007. Report on educational needs assessment for the Western Indian Ocean region. Report prepared by WIOMSA for the UNEP/GEF WIO-LaB Project: 49 pp.

UNDP 2003. Poverty reduction and human rights. A practice note. http://www.hshr.org/hrpovertyresources.htm

UNDP 2006. Human Development Report 2006: Beyond scarcity: power, poverty and global water crisis. "includes: the ecosystem effects of climate change; Also the highest per capita GDP ".. Viewed on 2 October 2007 at http://hdr.undp.org/hdr2006/statistics/indicators/5.html.

UNEP 1998a. Eastern Africa atlas of coastal resources 1: Kenya. UNEP Regional Reports and Studies, UNEP and BADC (Government of Belgium): 119 pp.

UNEP 1998b. Overview of land-based sources and activities affecting marine, coastal and associated freshwater environment in the eastern Africa region. UNEP Regional; Seas Reports and Studies No. 167.

UNEP, 2001. Eastern Africa Atlas of Coastal Resources: Tanzania. UNEP and BADC (Government of Belgium): 111 pp.

UNEP, 2002a. Preliminary Transboundary Diagnostic Analysis on Land Based Activities for the WIO Region, UNEP, Nairobi. 122 pp

UNEP, 2002b, Preliminary Strategic Action Programme for the WIO Region, UNEP, Nairobi: 38 pp.

UNEP 2005. Hydropolitical vulnerability and resilience along international waters. Africa, Nairobi, United Nations Environment Programme.

UNEP, 2006a. Africa Environment Outlook 2, Our Environment, Our Wealth. United Nations Environment Programme, Nairobi, Kenya: 542 pp.

UNEP, 2006b. Challenges to International Waters – Regional Assessments in a Global Perspective. United Nations Environment Programme, Nairobi, Kenya.

UNEP 2006c. Ecosystem-based management. Markers for assessing progress. UNEP/GPA, The Hague, Netherlands.

UNEP and WIOMSA, 2008. Regional Overview and Assessment of Marine Litter Related Activities in the Western Indian Ocean Region, UNEP, Nairobi, Kenya: 67 pp.

UNEP/FAO/PAP/CDA 2000. Progress in integrated coastal management for sustainable development of Kenya's coast: The case of Nyali-Bamburi-Shanzu Area. East African Regional Seas Technical Reports Series No. 6. Split UNEP/FAO/PAP/CDA: 66 pp.

UNEP/GPA and WIOMSA 2004a. Overview of physical alteration and destruction of habitats in the Eastern African region using Geographical Information System (GIS). UNEP, Nairobi, Kenya: 82 pp.

UNEP/GPA and WIOMSA 2004b. Regional overview of the physical alteration and habitat destruction (PADH) in the Western Indian Ocean. UNEP, Nairobi, Kenya: 74 pp.

UNEP/GPA and WIOMSA 2004c. An assessment of the socio-economic implications of PADH due to coastal tourism, mangrove destruction, mining, sediment movement, ports, land reclamation and damming of rivers. UNEP, Nairobi, Kenya: 82 pp.

UNEP/GPA and WIOMSA 2004d. Review of national legislations and institutions relevant to tourism, ports, land reclamation and damming of rivers in selected countries along the Western Indian Ocean, UNEP, Nairobi, Kenya: 86 pp.

UNEP/GPA and WIOMSA 2004e. Shoreline changes in the Western Indian Ocean region, UNEP, Nairobi, Kenya: 21 pp.

UNEP/Institute of Marine Sciences-University of Dar es Salaam/FAO/SIDA, 1998. Overview of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the Eastern African Region, UNEP Regional Seas Reports and Studies No. 167.

UNEP/Nairobi Convention Secretariat and CSIR. 2009. Guidelines for the establishment of environmental quality objectives and targets in the coastal zone of the Western Indian Ocean (WIO) Region. WIO-LaB Technical Report Series No. 01/2009, United Nations Environment Programme, Kenya, Nairobi: 146 pp.

UNEP/Nairobi Convention Secretariat, ACWR and WIOMSA, 2009a. Regional Overview and Assessment of River-coast Interactions in the Western Indian Ocean Region. UNEP, Nairobi, Kenya.

UNEP/Nairobi Conversion Secretariat, CSIR and WIOMSA, 2009b. Regional Assessment of the State of Pollution in the Western Indian Ocean Region. UNEP. Nairobi, Kenya.

UNEP/Nairobi Conversion Secretariat and SAIEA, 2009. Environmental Assessment in the WIO region: An Overview of the Policy, Legal, Regulatory and Institutional Frameworks related to Environmental Impact Assessment in the Western Indian Ocean Region, UNEP, Nairobi, Kenya.

UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a. The Status of Municipal Wastewater (MWW) Management in the Western Indian Ocean Region. UNEP, Nairobi, Kenya.

UNEP/Nairobi Convention Secretariat and WIOMSA, 2009b. Regional Review of Policy, Legal and Institutional Frameworks for Addressing Land-based Sources and Activities in the Western Indian Ocean Region. UNEP, Nairobi, Kenya.

UNEP/Nairobi Convention Secretariat and WIOMSA, 2009c. Regional Review of the Status of Ratification of International Conventions related to Land-based Sources and Activities Management in the Western Indian Ocean Region. UNEP, Nairobi, Kenya.

V

Valiela, I., Bowen, J.L., and York, J.K. 2001. Mangrove forests: one of the world's threatened major tropical environments. Biosciences 51 (10): 801 – 815.

Van der Elst, R.P. 1990. Aspects of the biology and sport fishery for billfishes in the S.W Indian Ocean. In: Stroud, R.H. ed. Planning the future of billfishes: Part 2. Savannah. National Coalition for Marine Conservation, Georgia: 147-158.

Van der Elst, R.P. 2000. Hope for Africa's troubled Horn? Africa Geographic 8 (5): 45-55.

Van der Elst, R.P. and Salm, R.V. 1998. Overview of the biodiversity of the Somalia coastal and marine environment. Somali Natural Resources Management Programme. IUCN-EAP. Nairobi: 45 pp.

Van der Elst, R.P., Everett, B., Jiddawi, N., Mwatha, G., Afonso, P.S. and Boulle, D. 2005. Fish, fishers and fisheries of the West Indian Ocean: their diversity and status. A preliminary assessment. Philosophical Transactions of the Royal Society. 363 (1826): 263-284.

Van der Elst R.P., Everett BI, Afonso PS, Jiddawi N, Torres R, Okemwa G, Fondo E, Robinson J, Dorizo J, Assan C and Lesperance A. 2009. WIOFish: A possible tool to evaluate progress towards achieving MDG's relating to small-scale fisheries of the WIO. Presentation: 6th WIOMSA scientific symposium, University La Réunion. August 2009.

Van der Zaag, P. and Carmo Vaz, A. 2003. Sharing the Incomati waters: cooperation and competition in the balance. Water Policy 5: 349-368.

Van der Zaag, P. 2000. The Pungwe river basin. Webworld.unesco.org.

Van Katwijk, M.M., Meier, N.F., van Loon, R., van Hove, E.M., Giesen, W.B.J.T., van der Velde, G. and C. den Hartog, C. 1993. Sabaki River sediment load and coral stress: correlation between sediments and condition of the Malindi-Watamu reefs in Kenya (Indian-Ocean), Mar. Biol. 117: 675– 683.

Van Wyk, N. 2007. Personal Communication via e-mail on 21/8/2007.

Van Wyk, A. and Smith, G. 2001. Regions of Floristic Endemism in Southern Africa. A Review with Emphasis on Succulents. Undamus Press, South Africa.:1999 pp.

Vasseur, P. 1997. Ecosystemes cotiers en dangers la region de Tulear. Analyse des agressiones humaines et problémes de gestion. In: Mileux et sociétés dans le Sud-Ouest de Madagascar. University of Province: 244 pp.

Vetter, W., Weichbrodt, M., Scholz, E., Luckas, B. and Oelschläger, H. 1999. Levels of organochlorine (DDT, PCBs, Toxaphene, Chlordane, Dieldrin, and HCHs) in blubber of South African fur seals (*Arctocephalus pusillus pusillus*) from Cape Cross/Namibia. *Mar. Poll. Bull.* 38 (9): 830-836.

W

Wafar, M.V.M. and Wafar, S. 2001. 101 Questions: Chapter 3 In: Coral Resources, National Institute of Oceanography, Goa and Administration of the U.T. of Lakshadweep, India.

Wakibia, J.G. 1995. The potential human induced impacts on the Kenya seagrasses. UNESCO reports in Marine science, No.66.

Walmsley, S., Purvis, J. and Ninnesa, C. 2006. The role of small-scale fisheries management in the poverty reduction strategies in the Western Indian Ocean region Ocean and Coastal Mgt. 2006, Environmental Issues in the Western Indian Ocean, Environmental Issues in the Western Indian Ocean: 812-833.

Wang Y., Bonynge, G., Nugranad, J., Traber, M., Ngusaru, A., Tobey., J., Hale, L., Bowen, R. and Makota, V. 2003. Remote Sensing of Mangrove Change Along the Tanzania Coast. Marine Geodesy, 26: 35–48.

Wanyonyi, I, Tuda, P. and Obura, D. 2009. Assessment of compliance to licensing and ban on illegal fishing gears as a tool for effective fisheries management in tropical artisanal fisheries at the Kenyan south coast. 6th WIOMSA Symposium. University La Réunion, August 2009. Poster.

Wass, P. (ed.) 1995. Kenya's indigenous forests: status, management and conservation. IUCN, Grand, Switzerland, and Cambridge, UK: xii + 205 pp.

Watermeyer, Legge, Piesold, and Uhlman 1981. Athi river basin preinvestment study. For: TARDA (Tana and Athi- River Development Authority), Nairobi. Agrar and Hydrotechnik GmbH, Essen.

Waycott, M., McMahon, K., Mellors, J., Calladine, A. and Kleine, D. 2004. A guide to tropical seagrasses of the Indo-West Pacific. Copyright James Cook University, Townsville: 72 pp.

Weaver, A.B., Greyling, T, van Wilgen, B and Kruger. 1996. Impact assessment: proposed dune mining at St Lucia in South Africa. Journal of Environmental Management 14: 325-342.

Weber, M., Lott, C. and Fabricius, K. 2006. Sedimentation stress in a scleractinian coral exposed to terrestrial and marine sediments with contrasting physical, organic and geochemical properties. J Exp. Mar. Biol. Eco. 336: 18-32.

Weerts, S, Taljaard, S and Dubula, O. 2009. UNEP/ GEF/WIO-LaB Project Addressing Land Based Activities in the Western Indian Ocean. Land-Based Activities, Pollution Sources and Levels in Water and Sediment in the Coastal and Marine Area of South Africa. Report submitted to the WIO-LaB Project Management Unit, Nairobi, Kenya: 79 pp.

Wekwe, W.W., Othman, O.C. and Khan, M.R .1989. Seaweeds as heavy metal pollution indicators. In: Environmental Pollution and its Management in Eastern Africa. In: Khan, M.R. and Gijzen, H.J. (eds.) Proceedings of a Symposium on Environmental Pollution and its Management in Eastern Africa 11- 15 September, 1989, Dar es Salaam.

Weller, R.A., Baumgartner, M.F., Josey, S.A., Fischer, A.S. and Kindle, J.C. 1998. Atmospheric forcing in the Arabian Sea during 1994-1995: observations and comparisons with climatology and models. *Deep Sea Research Part II: Topical studies in Oceanography* 45(10-11): 1961-1999.

Westmacott, S., Cesar, H. S. J., Pet-Soede, L., and Lindén, O. 2000. Coral Bleaching in the Indian Ocean: Socio-Economic Assessment of Effects. In: Cesar, H.S.J. (ed.) Collected Essays on the Economic of Coral Reefs. CORDIO, Kalmar, Sweden.

WGIPA-I, 2000. Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. First Meeting of the Working Group on Integrated Problem Analysis (WGIPA-I) Paris, 5-7 December 2000. http://www.environnement.gouv.sn/IMG/pdf/1-WGIPA-I.pdf.

White, F. 1983. The Vegetation of Africa. United Nations, Paris. 356 pp.

WHO, 1982. World Health Organisation: Rapid assessment of sources of air, water and land pollution, WHO offset publication No. 62, Geneva.

WIOFish, 2008. West Indian Ocean Fisheries Database: a catalogue of small-scale fisheries. www.wiofish.org.

Wild, H. Barbosa, L.A. Grandvaux, L.A. 1967. Vegetation map (1:2 500 000) of the flora Zambeziaca area. Descriptive memoir, Collins, Salisbury, Rhodesia: 71 pp.

William, J. 1988. Summary of the fisheries and resources information for the Comores. *In*: M.J. Sanders, P. Sparre and S.C. Venema (eds.) Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean, Albion, Mauritius, 4-25 September 1987. RAF/79/065/WP/41/85/E.

Wilkinson, C R. 1999 - Global and local threats to coral reef functioning and existence: review and prediction. *Marine and Freshwater Research* 50: 867 - 878.

Wilkinson C.R. 2000. Status of coral reefs of the world: 2000. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville, Australia: 363 pp.

Wilkinson, C.R. 2004. Status of coral reefs of the world: 2004. Australian Institute of Marine Science.

Wilkinson, C.R., Lindén, O., Cesar, H., Hodgson, G., Rubens, J. and Strong, A.E. 1999. Ecological and socio-economic impacts of 1998 coral mortality in the Indian Ocean: an ENSO impact and a warning for future change? *Ambio* 28: 188-196.

WIOMSA 2007. Sheet 13: Mariculture. In: Managing Marine Protected Areas: A toolkit for the Western Indian Ocean. www.wiomsa.org/mpatoolkit/Themesheets/I3_Mariculture.pdf.

WRI 2007. World Resources Institute. Climate Analysis Indicators Tool. http://www.wri.org/climate/project_description2.cfm?pid=93.

World Bank,2000. Can Africa claim the 21st Century? World Bank, Washington D.C

World Bank 2006. http://web.worldbank.org/external/projects/main?pagePK=104231&piPK=73230&theSitePK=40941&menuPK=228424&Projectid=P001799.

World Bank 2007. Key Development Data and Statistics. http://econ.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS accessed on 11 August 2007.

World Bank 2007. World Development Indicators database.

World Bank 2009a. World development report: reshaping economic geography. World Bank. Parts I and II: 149 & 261 pp.

World Bank 2009b. Kenya's tourism. Polishing the jewel. World Bank Private sector and finance section- Africa: 170 pp

WHO 1982. Rapid assessment of sources of air, water and land pollution. WHO Offset Publication No. 62, Geneva.

WHO 2003. Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO. Expert Consultation, Geneva, 28 January - 1 February 2002, WHO technical report series: 916. World Health Organization, Geneva.

WHO and UNICEF 2000. Global Water Supply and Sanitation Assessment 2000 Report: 41 pp.

World Resources Institute 2007. The Value of Coastal Ecosystems. http://www.earthtrends.wri.org/updates/node/118 accessed on 22nd February 2008.

World Resources Institute 2007. Nature's Benefits in Kenya: An Atlas of Ecosystems and Human Well-Being. WRI and Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Kenya; Central Bureau of Statistics, Ministry of Planning and National Development, Kenya; and International Livestock Research Institute. Washington, DC and Nairobi: World Resources Institute.

World Resources Institute 2008. Empowering people: A good governance analysis of electricity (India , Indonesia, Philippines, Thailand).

WWF 2006. The Eastern Africa coastal forests ecoregion. Strategic framework for conservation: 2005 – 2025. WWF-EARPO, Nairobi.

WWF 2004. The Eastern African Marine Ecoregion Vision: A large scale conservation approach to the management of biodiversity. WWF: Dar es Salaam, Tanzania; 53 pp.

WWF 2009. Actions needed to make current offshore oil and gas and production less environmentally damaging in EAME countries. Policy series: oil and gas. Issues 2. WWF Tanzania: 6 pp

WWF-EAME 2004. Towards a Western Indian Ocean duging conservation strategy. The status of dugongs in the Western Indian Ocean and priority conservation actions. WWF-EAME, Dar es Salaam: 68 pp.

Y

Younge, A., Negussie, G. and Burgess, N.D. 2002. Eastern Africa coastal forest programme. regional workshop report. WWF-EARPO, Nairobi.

Z

Zanting, H.A., Nacueve, C. and Novela, B. 1994. Salt intrusion in the Pungwe estuary. Conflict prevention and cooperation in international water resources handouts DNA. Maputo / Companhia de Aguas da Beira E.E., Beira: 1-3, 19, 29-32. http://unesdoc.unesco.org/images/0013/001333/133316e.pdf

ZRA 1998. Environmental Impact of Expanding Utilisation of Water Resources from the Basin. Sector Studies under ZACPLAN. Sector Study No. 7. Zambezi River Authority, Lusaka.

ANNEXES

Annex 1 Main contributors to the TDA

Members of the TDA Task Team

Prof. Jan GLAZEWSKI
Institute of Marine and Environmental Law
University of Cape Town
Capet Town, SOUTH AFRICA

Mr. Jude BIJOUX
Centre for Marine Research & Technology - Marine Parks Authority
Victoria, SEYCHELLES

Ms. Susan TALJAARD
Council for Scientific and Industrial Research (CSIR),
Natural Resources and the Environment
Stellenbosch, SOUTH AFRICA

Dr. Salomao BANDEIRA
Universidade Eduardo Mondlane,
Maputo, MOZAMBIQUE.

Dr. James KAIRO
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Dr. Sixtus KAYOMBO
University of Dar es Salaam
Dar es Salaam, TANZANIA

Mr. Akunga MOMANYI
Faculty of Law
University of Nairobi
Nairobi, KENYA

Mr. Jacob OCHIEWO
Kenya Marine and Fisheries Research Institute (KMFRI)
Mombasa, KENYA

Dr. Narriman JIDDAWI
Institute of Marine Sciences
Stone Town, ZANZIBAR

Mr. Anton EARLE
African Centre for Water Research
Cape Town, SOUTH AFRICA

Mr. Daniel MALZBENDER
African Centre for Water Research
Cape Town, SOUTH AFRICA

TDA/SAP Coordinators

Dr. Peter SCHEREN
UNEP-GEF WIO-LaB Project Management Unit.
Nairobi, KENYA

Dr. Johnson U. KITHEKA
UNEP-GEF WIO-LaB Project Management Unit.
Nairobi, KENYA

Scientific and Technical Advisory Committee

Prof. John MACHIWA
Faculty of Aquatic Sciences and Technology
University of Dar es Salaam
Dar es Salaam, TANZANIA

Dr. Daniel OLAGO
Department of Geology
University of Nairobi,
Nairobi, KENYA

Prof. Kennedy M. MAVUTI
School of Biological Sciences
University of Nairobi
Nairobi, KENYA

Dr. Pierre RAVELONANDRO
Centre National de Recherches sur l'Environnement (CNRE)
Antananarivo, MADAGASCAR

Dr. Rakotondralambo ANDRIANTAHINA
Association Nationale d'Actions Environnementales Madagascar
Antananarivo, MADAGASCAR

Prof. Antonio HOGUANE
School of Marine and Coastal Sciences
Eduardo Mondlane University
Quelimane, MOZAMBIQUE

Dr. Louis CELIER
Oceanographic Research Institute (ORI)
Durban, SOUTH AFRICA

Dr. Christine Fiona MACKAY
Oceanographic Research Institute
Durban, SOUTH AFRICA

Dr. Adriano Alfonso MACIA
University of Eduardo Mondlane
Maputo, MOZAMBIQUE

Prof. P.J. A KABUDI
Faculty of Law
University of Dar es Salaam
Dar es Salaam, TANZANIA

Prof. Francis SITUMA
Faculty of Law
University of Nairobi
Nairobi, KENYA

Prof. Patricia KAMERI-MBOTE
Faculty of Law
University of Nairobi
Nairobi, KENYA

Forum of Academic and Research Institutions (FARI)

- Centre National de Recherches Environnemental (CNRE), Madagascar
- Council for Scientific and Industrial Research (CSIR), South Africa
- Fisheries Research Institute, Mozambique
- Institut Halieutique et des Sciences Marins (IHSM), Madagascar
- Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement (INRAPE), Comoros
- Institute for Hydrography and Navigation (INAHINA), Mozambique
- Institute of Marine Sciences (IMS), Zanzibar, Tanzania
- Kenya Marine and Fisheries Research Institute (KMFRI), Kenya
- Kenyatta University, Kenya
- Mauritius Oceanographic Institute (MOI), Mauritius
- Oceanographic Research Institute (ORI), South Africa
- Tanzania Fisheries Research Institute (TAFIRI), Tanzania
- Université de Comores, Comoros
- University of Dar es Salaam (UDSM), Tanzania
- University of Eduardo Mondlane (UEM), Mozambique
- University of Nairobi, Kenya
- Western Indian Ocean Marine Sciences Association (WIOMSA), Zanzibar, Tanzania

National Focal Point Institutions

- Association National pour la Gestion des Aires Protégés (ANGAP), Madagascar
- Department of Environmental Affairs (DEA), South Africa
- Direction National pour l'Environnement et des Forets (DNEF), Comoros
- Ministry for Coordination of of Environmental Affairs (MICOA), Mozambique
- Ministry of Environment and National Development Unit (MENDU), Mauritius
- Ministry of Environment, Natural Resources and Transport (MENRT), Seychelles
- National Environment Management Authority (NEMA), Kenya
- National Environment Management Council (NEMC), Tanzania

Regional Task Force on Municipal Wastewater Management

Mr. Soulé Hamidou HAMADA
Direction Nationale de l'Environnement et des Forets
Moroni, COMOROS

Mr. Ahmed Bacar ABDALLAH
Adjoint Maire - Commune de Mutsamudu
COMOROS

Mr. Abdallah Ahmed SOILIHI
Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement
Moroni, COMOROS

Prof. Mwakio TOLE
Department of Environmental Sciences
Kenyatta University
Nairobi, KENYA

Mr. Abdulrahim KHEIR
Mombasa Water and Sewerage Company Ltd.
Mombasa, KENYA

Dr. Daniel MUNGA
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Mr. Saeed MWAGUNI
Coast Development Authority
Mombasa, KENYA

Mr. Yves Jean Michel MONG
Centre National de Recherches sur l'Environnement
Antananarivo, MADAGASCAR

Mrs. Alcina MANHICA
Ministry of Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Dr. Susan TALJAARD
Council for Scientific and Industrial Research
Stellenbosch, SOUTH AFRICA

Dr. Yazeed PETERSON
Department of Environmental Affairs and Tourism
Cape Town, SOUTH AFRICA

Mr. Ayanda MATOTI
Department of Environmental Affairs and Tourism
Cape Town, SOUTH AFRICA

Mr. Ashley NAIDOO
Council for Scientific and Industrial Research
Durban SOUTH AFRICA

Mr. Roland DAVID
Council for Scientific and Industrial Research
Durban SOUTH AFRICA

Dr. Karoli NJAU
University of Dar es Salaam
Dar es Salaam, TANZANIA

Dr. Mohammed SALIM
Institute of Marine Sciences
Zanzibar, TANZANIA

Mr. Alexis RADHAY
Wastewater Management Authority
Port Louis, MAURITIUS

Mrs. Daisy Ratna TATUR RAMASAMY
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Prof. Antonio HOGUANE
School of Marine and Coastal Sciences, Eduardo Mondlane University,
Quelimane, MOZAMBIQUE

Mr. Manuel Victor POIO
Ministry of Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Dr. Sixtus KAYOMBO
Ministry of Water and Irrigation
Water Resources Institute
Dar es Salaam, TANZANIA

Ms. Melania SANGEU
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Juma B. ALAWI
Department of Environment
Zanzibar, TANZANIA

Mr. Flavien JOUBERT
Ministry of Environment and Natural Resources
Victoria, SEYCHELLES

Mr. Marlon MONTANO
Des iles Environnemental Solutions
Beau Vallon, SEYCHELLES

Regional Task Force on Physical Alteration and Destruction of Habitats

Mr. Anfani MSOILE
Ministère de l'Environnement de Mohéli
Fomboni, COMOROS

Mr. Said AHAMADA
AIDE
Moroni, COMOROS

Dr. James KAIRO
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Ms. Salome MACHUA
National Environment Management Authority
Nairobi, KENYA

Ms. Caroline ANYANGO
National Environment Management Authority
Nairobi, KENYA

Mr. Richard Noelson RAHARIJAONA
F.T.M.
Antananrivo, MADAGASCAR

Mr. Jogeeswar 'Shiv' SEEWOOBADUTH
Ministry of Environment
Port Louis, MAURITIUS

Dr. Jared BOSIRE
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Dr. Jacqueline UKU
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Dr. Rakotondralambo ANDRIANTAHINA
Association Nationale d'Actions Environnementales de Madagascar
Antananarivo, MADAGASCAR

Mrs. Rondro Domoina RAKOTOMALALA
Association Nationale pour la Gestion des Aires Protégées
Toliare, MADAGASCAR

Ms. Chantal ANDRIANARIVO
Association Nationale pour la Gestion Des Aires Protégés
Antananarivo, MADAGASCAR

Mr. Vineshwar Sharma GOPAL
National Parks and Conservation Service
Reduit, MAURITIUS

Mr. Kevin RUHOMAUN
National Parks and Conservation Service
Reduit, MAURITIUS

Ms. Nanette PORT-LOUIS
Department of Environment
Victoria, SEYCHELLES

Dr. Salomao BANDEIRA
Department of Biological Sciences,
University Eduardo Mondlane
Maputo, MOZAMBIQUE

Ms.Veronica Fernando DOVE
Grupo de Trabalho Ambiental (GTA)
Maputo, MOZAMBIQUE

Prof. Rudy VAN DER ELST
Oceanographic Research Institute (ORI)
Durban, SOUTH AFRICA

Dr. Steven WEERTS
Council for Scientific and Industrial Research
Durban, SOUTH AFRICA

Mr. Daudi J. MSANGAMENO
Institute of Marine Sciences
Zanzibar, TANZANIA

Dr. Christopher A MUHANDO
Institute of Marine Sciences
Zanzibar, TANZANIA

Mr. Jeremiah M. DAFFA
Tanzania Coastal Management Programme
Dar es Salaam, TANZANIA

Regional Working Group on Water, Sediment and Biota Quality

Dr. Daniel MUNGA
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Prof. Mwakio TOLE
Department of Environmental Sciences
Kenyatta University
Nairobi, KENYA

Mr. Benjamin LANGWEN
National Environment Management Authority
Nairobi, KENYA

Dr. Daniel Shilla
Faculty of Aquatic Sciences and Technology
University of Dar es Salaam
Dar es Salaam, TANZANIA

Dr. Mohammed SALIM
Institute of Marine Sciences
Zanzibar, TANZANIA

Dr. John MACHIWA
Faculty of Aquatic Sciences and Technology
University of Dar es Salaam
Dar es Salaam, TANZANIA

Dr. Desiderius MASALU
ODINAFRICA Project Representative
Institute of Marine Sciences (IMS)
Zanzibar, TANZANIA

Mr. Leandri S. KINABO,
Tanzania Bureau of Standards
Dar es Salaam, TANZANIA

Mr. Mong Yves JEAN MICHEL
Centre National de Recherches sur
l'Environnement
Antananarivo, MADAGASCAR

Dr. Manera JEAN YVES
Institut Halieutique et des Sciences Marins
Antananarivo, MADAGASCAR

Mr. Helison R RAZAFINDRAKUTO
Autorité Nationale de l'Eau et de l'Assainissement
Antananarivo, MADAGASCAR

Mr. Bertin Pierre RAKOTONIRINA
Institut Halieutique et des Sciences Marins
Toliare, MADAGASCAR

Mr. Farid ANASSE
Ministère de l'Agriculture, de la Pêche et de
l'Environnement
Moroni, COMOROS

Mr. Hamza Abdou AZALI
Institut National pour la Recherche d'Agriculture, de
la Peche et de l' Environnement
Moroni, COMOROS

Mr. Ahmed Ali MOURIDI
Institut National pour la Recherche d'Agriculture, de la Peche et de l' Environnement
Moroni, COMOROS

Dr. Said Omar HAMIDOU
Pharmacie Nationale Autonome des Comores
Moroni, COMOROS

Mr. Abd-El MALIK
Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement
Moroni, COMOROS

Ms. Chadhouliati Abdou CHAKOUR
Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement
Moroni, COMOROS

Mr. Afretane YSSOUFA
Civil Engineer/Supervisor Water Quality Control
Fomboni-Moheli, COMOROS

Mr. Polycarpo NAPICA
Ministry of the Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Ms. Roda MUVUNGA-LUIS
National Laboratory for Food and Safety
Ministry of Health
Maputo, MOZAMBIQUE

Dr. Antonio HOGUANE
Eduardo Mondlane University
Maputo, MOZAMBIQUE

Mr. Manuel POLO
Ministry of the Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Manuel MENOMUSSANGA
Centre for Sustainable Coastal Zone Management
Praia De Xai- Xai, MOZAMBIQUE

Ms. Balgia Blasa MABUNDA
Eduardo Mondlane University
Maputo, MOZAMBIQUE

Ms. Alcina Olivia VALENTE
Ministry for the Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Steven WEERTS
Council for Scientific & Industrial Research
Durban, SOUTH AFRICA

Dr. Susan TALJAARD
Council for Scientific and Industrial Research
Stellenbosch, SOUTH AFRICA

Mr. Ashley NAIDOO
Council for Scientific and Industrial Research
Durban SOUTH AFRICA

Mr. Roland DAVID
Council for Scientific and Industrial Research
Durban SOUTH AFRICA

Mr. Mulalo TSHIKOTSHI
Department of Environmental Affairs & Tourism
Cape Town, SOUTH AFRICA

Ms Thilivhali MEREGI
Department of Environmental Affairs & Tourism
Cape Town, SOUTH AFRICA

Mr. Dindyal DEVINDRANATH
National Environmental Laboratory
Ministry of Environment
Reduit, MAURITIUS

Ms. Nashreen SOOGUN
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Ms. Daisy Ratna Tatur RAMASAMY
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Mr. Shameem JAUFFUR
Wastewater Management Authority
Port Louis, MAURITIUS

Mrs. Sushma MATTAN-MOORGAWA
Ministry of Environment
Port Louis, MAURITIUS

Mr. R. Vivian RADEGONDE,
Seychelles Bureau of Standards
Mahe, SEYCHELLES.

Dr Stephen J de MORA
Marine Environmental Studies Laboratory
International Atomic Energy Agency
PRINCIPALITY OF MONACO

Regional Task Force on Environmental Impact Assessment

Mr. Ismael BACHIROU
Direction Nationale de l'Environnement et des Forets.
Moroni, COMOROS

Ms. Fatouma Ali ABDALLAH
D Direction Nationale de l'Environnement et des Forets.
Moroni, COMOROS

Farid ANASSE
Direction Nationale de l'Environnement et des Forets.
Moroni, COMOROS

Mr. Abderemane Ben OUSSEINE
Direction Nationale de l'Environnement et des Forets.
Moroni, Comoros

Mr. Benjamin LANGWEN
National Environment Management Authority
Nairobi, KENYA

Mr. Maurice MBEGERA
National Environment Management Authority
Nairobi, KENYA

Mr. Zephania OUMA
National Environment Management Authority
Nairobi, KENYA

Ms. Salome MACHUA
National Environment Management Authority
Nairobi, KENYA

Mr. Heritiana RAMIARAMANAN
Office National pour l'Environnement,
Antananarivo, MADAGASCAR

Ms. Chantal ANDRIANARIVO
Association Nationale pour la Gestion des Aires Protégés
Antananarivo, MADAGASCAR

Mr. Keshore Kumar HEERAMUN
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Mrs. Doolaree BOODHUN
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Mr. Jogeeswar SEEWOOBADETH
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Mr. Inacio BUCUANE
Ministry for Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Felicio FERNANDO
Ministry for Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Policarpo Napica
Ministry for Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Joseph RATH
Ministry of Environment and Natural Resources
Victoria, SEYCHELLES

Mr. Jason JACQUELINE
Ministry of Environment and Natural Resources
Victoria, SEYCHELLES

Ms. Joanna ADELINE
Ministry of Environment and Natural Resources
Victoria, SEYCHELLES

Mr. Fredrick RUGIGA
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Danford MWAIPOPO
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Godlove John MWAMSOJO
National Environment Management Council
Dar es Salaam, TANZANIA

Mrs. Melania SANGEU
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Hamza Z. RIJAL
Department of Environment
Zanzibar, TANZANIA

Dr Peter TARR
Southern African Institute for Environmental Assessment
Windhoek, NAMIBIA

Mr. Juma B. ALAWI
Department of Environment
Zanzibar, TANZANIA

Ms. Maureen A BABU
IUCN-EARO
Nairobi, KENYA

Regional Legal and Technical Review Task Force

Ms. Fatouma ALI ABDALLAH
Institut National de Recherches pour l'Agriculture, la Pêche et l'Environnement
Moroni, COMOROS

Mr. Farid ANASSE
Direction National de l'Environnement
Moroni, COMOROS

Mr. Ahamada HASSANI
Direction National de l'Environnement
Moroni, COMOROS

Mr. Nidhoim ATTOUMANE
Conseiller Juridique du Vice Président
Moroni, COMOROS

Mr. Tom Mark MBOYA
Attorney General's Office
Nairobi, KENYA

Ms. Salome MACHUA
National Environment Management Authority
Nairobi, KENYA

Mr. Stephen M. KATUA
National Environment Management Authority
Nairobi, KENYA

Ms. Grace KIMANI
National Environment Management Authority
Nairobi, KENYA

Mr. Ali MOHAMED
National Environment Management Authority
Nairobi, KENYA

Ms. Lalaoarisoa RAHELIARIJAONA
Service des Domaines
Antananarivo, MADAGASCAR

Mr. Ninah ANDRIANAIVO
Association Nationale pour la Gestion des Aires Protégées
Antananarivo, MADAGASCAR

Ms. Chantal ANDRIANARIVO
Association Nationale pour la Gestion des Aires Protégées
Antananarivo, MADAGASCAR

Ms. Jane RAZANAMIHARISOA
Ministry of Environment, Water and Forests
Antananarivo, MADAGASCAR

Mr. Jogeeswar SEEWOOBADUTH
Ministry of Environment and National Development Unit
Port Louis, Mauritius

Ms. Gaitree MANNA
Attorney General's Office and Ministry of Justice & Human Rights
Port Louis, MAURITIUS

Mr. Renato S. MAZIVILA
Ministry for Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mrs. Nashreen SOOGUN
Ministry of Environment and National Development Unit
Port Louis, MAURITIUS

Mr. Numidio MANHIQUE
Ministry of Foreign Affairs and Cooperation
Maputo, MOZAMBIQUE

Mr. Domingos Z. GOVE
Centre for sustainable Development for coastal zones - Ministry for Coordination of Environmental Affairs
Maputo, MOZAMBIQUE

Mr. Mongezi NQORE
Department of Environmental Affairs and Tourism
Cape Town, SOUTH AFRICA

Ms. Marisa KASHORTE
Department of Environmental Affairs and Tourism
Cape Town, SOUTH AFRICA

Prof. Jan GLAZEWSKI
Institute of Marine and Environmental Law
University of Cape Town
Rondebosch, SOUTH AFRICA

Ms. Feziwe RENQE
Department of Environmental Affairs and Tourism
Cape Town, SOUTH AFRICA

Mr. Shavhani MUKWEVHO
Department of Environmental Affairs & Tourism
Cape Town, SOUTH AFRICA

Ms. Anne FONTAINE
Ministère de l'écologie, de l'énergie, du développement durable et de l'aménagement du territoire
Paris, FRANCE

Mr. Lionel GARDES
Direction Régionale de l' Environnement
St Denis, La Réunion - FRANCE

Mr. Jason JACQUELINE
Ministry of Environment, Natural Resources and Transport
Victoria, SEYCHELLES

Ms. Julian LEGAIE
Ministry of Environment, Natural Resources and Transport
Victoria, SEYCHELLES

Ms. Joanna ADELINE
Ministry of Environment, Natural Resources and Transport
Victoria, SEYCHELLES

Mr. Bonventure BAYA
National Environment Management Council
Dar es Salaam, TANZANIA

Dr. Robert NTAKAMULENGA
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Francis K. STOLLA
Legal Consultant - National Environment Management Council
Dar es Salaam, TANZANIA

Ms. Alicia B. MAGABE
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Rajab HASSAN
National Environment Management Council
Dar es Salaam, TANZANIA

Mrs. Melania SANGEU
National Environment Management Council
Dar es Salaam, TANZANIA

Mr. Akunga MOMANYI
Faculty of Law - University of Nairobi
Nairobi, KENYA

Non-Governmental Organisations

- Coastal Oceans Research and Development in the Indian Ocean (CORDIO)
- Conservation International (CI)
- Consortium for the Conservational of the Coastal and Marine Ecosystems of the Western Indian Ocean (WIO-C)
- East African Wildlife Society (EAWS)

- Forum of Academic and Research Institutions in the Western Indian Ocean (FARI)
- International Union for the Conservation of Nature (IUCN)
- Western Indian Ocean Marine Science Association (WIOMSA)
- Wetlands International (WI)
- World Conservation Society (WCS)
- World Wide Fund for Nature (WWF)

International Organisations

- East African Community (EAC)
- Food and Agricultural Organisation of the United Nations (FAO)
- Global Environment Facility (GEF)
- Indian Ocean Commission (IOC)
- Inter-Governmental Oceanographic Commission of UNESCO (IOC-UNESCO)
- International Maritime Organisation (IMO)
- New Partnership for Africa's Development (NEPAD)
- Southern African Development Community (SADC)
- Swedish International Water Institute (SIWI)
- United Nations Agency for Human Settlements (UN-HABITAT)
- United Nations Development Programme (UNDP)
- United Nations Educational, Scientific and Cultural Organisation (UNESCO)
- United Nations Environment Programme (UNEP)
- United Nations Industrial Development Organisation (UNIDO)
- World Bank

Annex 2 Overview of sectors, stakeholder groups and governing institutions involved in LBSA Management

Sectors	Stakeholder groups	Governing institutions
Fisheries (including aquaculture)	Artisanal fishers Industrial fishers Seaweed farmers Industrial prawn farmers Fish and shellfish farmers	Fisheries dept. Environment dept. Conservation dept.
Agriculture and forestry	Charcoal makers Small-scale loggers Industrial loggers Small-scale farmers Large-scale farmers Pastoralists Ranchers Poultry farmers Dairy farmers Beekeepers	Environment dept. Agriculture dept. Forestry dept. Conservation dept. Livestock dept.
Tourism	Tourists Hotel owners and operators Small-scale traders Tourist boat and SCUBA operators	Tourism dept. Infrastructure dept.
Mining	Coral/lime miners Sand miners Small-scale salt producers Industrial salt works Small-scale miners Industrial mining companies Fuel suppliers and stations Oil and gas production	Minerals dept. Energy dept. Infrastructure dept.
Industry	Heavy manufacturing industry Light manufacturing industry Agro-processing industries Oil refining	Infrastructure dept.
Transportation	Ports Dredging companies Clearing and forwarding Railway Roads Airports Airlines Shipping	Harbour dept. Infrastructure dept. Transport dept. Water mngmt dept.
Energy production	Hydro-dam operators Power station operators Renewable energy producers	Infrastructure dept. Energy dept.

Urbanisation and Coastal Development	Solid waste operators Sewage managers Property developers Town planners Coastal community	Local authorities Infrastructure dept.

Annex 3 Criteria for the prioritization of transboundary problems

LEVEL 1: PRIORITIZATION OF TRANSBOUNDARY PROBLEMS

Simple Rating Form:

	Severity	Scope	Overall rating
Problem 1			
Problem 2			
Problem 3			
Problem 4			
Problem 5			

Rating Criteria for Transboundary Problems

Severity - The level of damage to the WIO coastal and marine ecosystem that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- Very High: Likely to *destroy or eliminate* part of the ecosystem.
- High: Likely to *seriously degrade* part of the ecosystem.
- Medium: Likely to *moderately degrade* part of the ecosystem.
- Limited: Likely to only *slightly impair* part of the ecosystem.

Scope - Most commonly defined spatially as the geographic scope of impact on the ecosystem integrity that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- Very High: Likely to be *widespread or pervasive* in its scope and affect the ecosystem *throughout the WIO region.*
- High: Likely to be *widespread* in its scope and affect the ecosystem in many parts of the *WIO region.*
- Medium: The threat is likely to be *localized* in its scope and affect the ecosystem in *some parts of the WIO region.*
- Limited: Likely to be *very localized* in its scope and affect the ecosystem *in limited parts of the WIO region.*

Overall rating:

Use this table to derive an overall rating. If you don't feel comfortable with the results, you might prefer to revise the table.

		Scope			
		Very High	High	Medium	Limited
Severity	Very High	Very High	High	Medium	Limited
	High	High	High	Medium	Limited
	Medium	Medium	Medium	Medium	Limited
	Limited	Limited	Limited	Limited	Limited

LEVEL 2: PRIORITIZATION OF DIRECT CAUSES

Simple Rating Form

For each transboundary problem, list and rank the immediate causes, using the criteria below. For example:

Problem 1: Microbial contamination

	Contribution	Irreversibility	Overall rating
Direct Cause 1: *(e.g. Disposal of un- or under-treated municipal wastewater*	*VH, H, M, or L*	*VH, H, M, or L*	*VH, H, M, or L*
Direct Cause 2			
Direct Cause 3			

Rating Criteria for Direct Causes:

Contribution - The expected contribution of the cause, acting alone, to the full expression of a threat (as determined in the threat assessment) under current circumstances (i.e. given the continuation of the existing management situation).

- Very High: The cause is a very large contributor of the particular problem.
- High: The cause is a large contributor of the particular problem.
- Medium: The cause is a moderate contributor of the particular problem.
- Limited: The cause is a limited contributor of the particular problem.

Irreversibility - The degree to which the effects of a cause of problem can be restored.

- Very High: The cause produces a problem that is not reversible (e.g., destruction of coral reefs due to unsustainable fishing practices).
- High: The cause produces a problem that is reversible, but not practically affordable (e.g. changed river flow regime due to damming).
- Medium: The cause produces a problem that is reversible with a reasonable commitment of resources (e.g. conversion of mangrove wetland into fish pond).
- Limited: The cause produces a problem that is easily reversible at relatively low cost (e.g. degenerated water quality due to wastewater discharge).

Overall rating:

Overall Rating is calculated from the matrix below; for example, if the Irreversibility is Very High and the Contribution is Medium, the overall rank of the source is High.

		Contribution			
		Very High	High	Medium	Limited
Irrevers-ibility	Very High	Very High	High	High	Limited
	High	Very High	High	Medium	Limited
	Medium	High	Medium	Medium	Limited
	Limited	High	Medium	Limited	Limited

LEVEL 3: COMBINING RATINGS

Combining problems (level 1) and causes (level 2) ratings results in a combined rating and it done using the threat matrix below.

		Cause			
		Very High	High	Medium	Limited
Problem	Very High	Very High	Very High	High	Medium
	High	High	High	Medium	Limited
	Medium	Medium	Medium	Limited	Limited
	Limited	Limited	Limited	Limited	Limited

Annex 4 Results of the prioritization exercise

PHYSICAL ALTERATION AND DEGRADATION OF HABITATS

LEVEL 1 PRIORITARIZATION OF TRANSBOUNDARY PROBLEMS

Problem area	Severity	Scope	Overall rating
Mangroves	VH	H	H
Seagrasses	H	H	H
Coral Reefs	VH	H	H
Coastal forests	VH	VH	VH
5. Shoreline change	M	M	M

LEVEL 2 PRIORITIZATION OF DIRECT CAUSES

Problem 1: Degradation of Mangroves

Direct Cause	Contribution	Irreversibility	Overall rating
Coastal flooding due sea level rise	H	VH	H
Sedimentation due to heavy rainfall	H	H	H
Alteration of freshwater flow	M	H	M
Clearance for human settlement	L	L	L
Pollution due wastewater discharge	L	M	L
Conversion for aquaculture	L	H	M
Conversion for industrial use	L	VH	L
Conversion for salt works	H	H	H
Deforestation for timber/poles, fuel wood, etc	VH	M	H

Problem 2: Degradation of Seagrass beds

Direct Cause	Contribution	Irreversibility	Overall rating
Sedimentation due to heavy rainfall	H	M	H
Alteration of freshwater flow	L	L	L
Pollution from wastewater discharge	M	H	M
Land reclamation	L	M	L
Sea urchin grazing	H	M	M
Seaweed farming	L	L	L

Overfishing & bad fishing practices	M	M	M
Seagrass removal for clam collection & swimming (tourism)	H	H	H

Problem 3: Degradation of Coral Reef ecosystem

Direct Cause	Contribution	Irreversibility	Overall rating
Sedimentation due to heavy rainfall	L	H	M
Pollution from wastewater discharge	L	M	L
Land reclamation	L	L	L
Increased reef activity causing anchor damages on the reef	H	M	M
Overfishing & bad fishing practices	H	M	M
Coral bleaching	VH	VH	VH
Alteration of freshwater flow	L	L	L

Problem 4: Degradation of Coastal Forests

Direct Cause	Contribution	Irreversibility	Overall rating
Salt water intrusion	L	H	L
Clearance for human settlement	H	H	H
Pollution due to wastewater discharge	L	L	L
Conversion for aquaculture	L	L	L
Conversion for industry	M	H	M
Alteration of freshwater flow & sediment load due to dam construction	L	L	L
Conversion for salt works	L	L	L
Deforestation for fuel wood & timber	VH	VH	VH
Overgrazing	L	L	L
Land clearance for agriculture	H	VH	H
Uncontrolled wild fires	M	M	M

Problem 5: Shoreline change

Direct Cause	Contribution	Irreversibility	Overall rating
Coastal flooding due to climate change/sea level rise	M	H	M
Destruction & degradation of wetlands	M	H	M
Clearance of natural vegetation	H	H	H
Land reclamation	L	L	L
Land conversion for aquaculture	L	L	L

Mining of beach sand and removal of fossil corals	M	M	M
Dredging for ports and harbours	L	L	L
Alteration in freshwater flow and sediment loads due to dam construction	H	H	H
Conversion of habitat for salt works	L	M	L
Land clearance for agriculture	M	M	M

LEVEL 3 OVERALL RANKING

TRANSBOUNDARY PROBLEM					Direct causes
Mangroves	Seagrasses	Coral reefs	Coastal forests	Shore-line change	
H				L	Coastal flooding as a result of sea level rise
H	H	M			Sedimentation associated with heavy river sediment discharge
M	L				Alteration of fresh water flow
			M		Salt water intrusion
				L	Destruction and/or degradation of wetlands
L			VH	M	Clearance of natural vegetation for human settlement
L	M	L	M		Pollution (discharge of municipal wastewater agricultural and industrial effluents, including accidental oil spillage)
	L	L		L	Land reclamation
	M				Increased sea urchin population associated with reduction in predators (due to inappropriate fishing practices or changes in environmental conditions)
	L				Seaweed harvesting for commercial purposes
		M			Increased reef activity
		M			Anchor damage
	M	M			Over-fishing and bad fishing practices
		VH			Coral bleaching
M			M	L	Conversion of habitats for aquaculture/mariculture
L			H		Conversion of habitats to industrial zones
				L	Mining of beach sand and removal of corals
				L	Dredging for port and harbours
M	L	L	M	M	Alteration in freshwater flows and sediment loads due to dam construction
H			M	L	Conversion of habitats for saltworks
H			VH		Deforestation to meet timber and fuelwood needs
	H				Seagrass beds removal for clam collection and bathers (tourists)
H			VH		Over-harvesting for supply of fuelwood and charcoal
			M		Overgrazing associated with high cattle population
			VH	L	Land clearance for agriculture
			H		Uncontrolled wild fires

Key: L: Limited M: Medium H: High VH: Very High

DEGRADATION OF WATER AND SEDIMENT QUALITY

Level 1 Prioritization of Transboundary problems

Problems	Severity	Scope	Overall rating
Microbiological contamination	H	H	H
High Suspended Solids Concentration	H	H	H
Chemical pollution	M	L	L
Marine litter and debris	L	L	L
Eutrophication	L	L	L

LEVEL 2 PRIORITIZATION OF DIRECT CAUSES

Problem 1: Microbial contamination

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of un- or under-treated municipal wastewater	VH	H	VH
Industries[a] discharging un- or under-treated industrial effluents	L	H	L
Waste from coastal mining and minerals (oil, gas, etc) exploration activities	L	H	L
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	H	H	M
River discharges transporting high suspended sediment loads (as a result of basin soil erosion) and/or transporting municipal/ industrial wastes and agrochemicals from catchment areas	M	H	M
Runoff from livestock rearing areas	L	H	L
Inadequate collection, treatment and disposal of solid waste in urban areas	L	H	L

Problem 2: Eutrophication

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of un- or under-treated municipal wastewater	H	H	H
Industries[a] discharging un- or under-treated industrial effluents	L	H	L
Waste from coastal mining and exploration activities	L	H	L

Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)	M	H	M
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchment areas	M	H	M
Leaking of agrochemical (fertilizer and pesticide residues) from storage facilities, dumping or return-flows	L	H	L
Runoff from livestock rearing areas	L	H	L

Problem 3: Marine litter and Debris

Direct Cause	Contribution	Reversibility	Overall rating
Contaminated surface and sub-surface runoff from municipal, industrial and agricultural areas, as well as from accidental spills)	M	M	M
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchments	M	H	M
Inadequate collection, treatment and disposal of solid waste	H	H	H
Public littering on beaches and in areas where marine litter can be transported into coastal areas	H	H	H

Problem 4: High suspended sediment concentration

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of un- or under-treated municipal wastewater	M	H	H
Industries discharging un- or under-treated industrial effluents	H	H	H
Dredging activities in ports and harbours	L	H	L
Waste from coastal mining and exploration activities	M	H	M
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	VH	H	VH
Destruction of coastal forests contributing to high suspended solid loads	M	H	M

River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchment areas	VH	H	VH
Waste products from aquaculture farms - high in nutrients and suspended solid loads	L	H	L

Problem 5: Chemical pollution

Direct Cause	Contribution	Reversibility	Overall rating
Industries[a] discharging un- or under-treated industrial effluents	VH	H	VH
Dredging activities in ports and harbours	L	L	L
Waste from coastal mining and mineral (oil, gas, etc) exploration activities	L	L	L
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	H	H	H
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/industrial waste and agrochemicals from catchment areas	H	L	M
Leaking of agrochemical (fertilizer and pesticide residues) from inadequate storage facilities, dumping or return-flows	L	L	L
Inadequate collection, treatment and disposal of solid waste in urban areas	L	L	L

LEVEL 3 OVERALL RANKING

TRANSBOUNDARY PROBLEM					DIRECT CAUSE
Microbial contamination	Eutrophi-cation	Marine litter and debris	Suspended solids	Chemical Pollution	
H	L		H		Disposal of un- or under-treated municipal wastewater
L	L		H	L	Industries a discharging un- or under-treated industrial wastewater
			L	L	Dredging activities in ports and harbours
L	L		M	L	Waste from coastal mining and mineral (oil, gas, etc) exploration activities
M	L	L	H	L	Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)
			M		Destruction of coastal forests contributing to high suspended solid loads
M	L	L	H	L	River discharges transporting high suspended sediment loads (as a result of soil erosion) and/ or transporting municipal/ industrial waste and agrochemicals from catchment areas
	L			L	Leaking of agrochemical (fertilizer and pesticide residues) from inadequate storage facilities, dumping or return-flows
L	L				Runoff from livestock rearing areas
L		L		L	Inadequate collection, treatment and disposal of solid waste
		L			Public littering on beaches and in areas where litter can be transported into coastal areas
			L		Waste products from aquaculture farms that are high in nutrients and suspended solid loads

Key: L: Limited M: Medium H: High VH: Very High

ALTERATION OF FRESHWATER FLOW AND SEDIMENT LOAD

LEVEL 1 PRIORITARIZATION OF TRANSBOUNDARY PROBLEMS

	Severity	Scope	Overall rating
Alteration of River Flow	H	H	H
Water Quality Degradation	M	M	M
Increased Sediment Loads	H	M	M
Decreased Sediment Loads	M	M	M

LEVEL 2 PRIORITIZATION OF DIRECT CAUSES

Problem 1: Alteration of river flows

	Contribution	Irreversibility	Overall rating
Damming of rivers	VH	M	H
Direct abstraction of freshwater	VH	L	H
Inter-basin water transfers	H	H	H
Hydrological variability	L	VH	L
Alteration of climatic conditions	H	H	H

Problem 2: Water quality degeneration

	Contribution	Irreversibility	Overall rating
Damming of rivers	L	H	L
Direct abstraction of freshwater	L	M	L
Poor land use in river basins	H	M	M
Agricultural run-off	VH	H	VH
Wastewater discharges	VH	H	VH
Storm water run-off	H	H	H

Problem 3: Increased sediment Loads

	Contribution	Irreversibility	Overall rating
Poor land use in river basins	VH	H	VH
Changes in vegetation types and patterns	H	H	H
Alteration in climatic conditions	L	H	L
Unsustainable agricultural practices	VH	H	VH
Deforestation of catchment areas	VH	H	VH
Encroachment on river banks	H	H	H
Sand mining in river courses	VH	H	VH
Road development in river basins	H	M	M

Problem 4: Decreased sediment loads

	Contribution	Irreversibility	Overall rating
Damming of rivers	VH	H	VH
Inter-basin water transfers	H	H	H
Changes in vegetation types and patterns	H	H	H
Alteration of climatic conditions	L	H	L
Canalization and impoundment of rivers for navigation purposes	L	H	L

LEVEL 3 OVERALL RANKING

TRANSBOUNDARY PROBLEM				IMMEDIATE CAUSES
Alteration of river flow	Water quality degradation[1]	Increased sediment loads	Decreased sediment loads	
H	L		M	Damming of rivers
H	L			Direct water abstraction for urban water supply and irrigation agriculture
H			M	Inter-basin water transfer
L				Hydrological variability
	L	H		Poor land-use in river basins
	M			Agricultural runoff of nutrients and pesticide residues
	M			Wastewater discharges
	M			Stormwater runoff
		H	M	Changes in vegetation types and patterns
H		L	L	Alteration of climatic conditions
		H		Unsustainable agricultural practices/ techniques (e.g. slash and burn)
		H		Deforestation of catchment areas
		H		Encroachment on river banks
		H		Mining of sand and aggregates within river courses
		M		Road development in rural and urban areas
			L	Canalization and impoundment of rivers for navigation purposes

Key: L: Limited M: Medium H: High VH: Very High

1 Whereas the overall ranking is low, water quality degeneration is a problem in some hot-spots

PRIORITIZATION OF OVERNANCE RELATED ISSUES:

Problem	Severity	Scope	Overall rating
Inadequate updating, implementation, enforcement and monitoring of legislation	VH	VH	VH
Inadequate awareness, understanding and appreciation of economic value of coastal-marine ecosystem goods and services at the level of policy makers and legislators, civil society and the private sector	VH	H	H
Inadequate financial mechanisms and resources for dealing with LBSA-related issues	VH	H	H
Lack of mechanisms for effective coordination and inter-sectoral governance	H	H	H
Inadequate human resources and technical capacity in institutions dealing with LBSA-related issues	H	H	H
Inadequate ratification and domestication of relevant international and regional instruments	H	H	H
Lack of adequate scientific and socio-economic data and information to support policy making, monitoring and enforcement	M	M	M

Key: L: Limited M: Medium H: High VH: Very High

Annex 5 Framework for SAP development

PROBLEM AREA 1: Water and sediment quality degeneration due to pollution from land-based sources

Type of intervention	Activities/solutions	Implementing Partners
Monitoring and Assessment	Fill gaps (e.g. identified in the national pollution status reports) in knowledge of priority pollutants, including major sources of pollution and the driving forces, with special emphasis on the identified coastal hotspots of pollution.	National & Local Government Industries Research Institutions
Management Tools	Develop specific regional guidelines and demonstrate best practice technologies and management approaches for: · Municipal and industrial wastewater and solid waste (including governance aspects such as holding products manufacturers responsible for the treatment and recycling of their packaging, applying the 'polluter pays' and 'cradle to grave' principles and introducing economic incentives for low-waste packaging). · Ports and harbours (including issues related to on- and offloading, disposal of waste from vessels, disposal of used oil and oil related products, and contingency planning in instances of accidental spills). · Agricultural activities (including issues related to soil erosion, agrochemical application and livestock raising).	UNEP/NCS UNEP/GPA Industries IMO Port Authorities National & Local Government Research Institutions
	Develop regional guidelines for setting effluent limit values (ELV) / standards for different industry types based on a Technology-based Approach or Environmental Quality Objective (EQO)-based approach	UNEP/NCS National Government Industries Research Institutions
	Develop targeted investment plans and proposals for the establishment of appropriate wastewater and solid waste management infrastructure in priority hot spots of pollution, e.g. based on the above-mentioned guidelines and lessons learnt from the demonstration projects.	National & Local Government Industries
Governance	Establish sector-specific effluent limit values (ELV) / standards for different industry types based on a Technology-based Approach and/or Environmental Quality Objective (EQO)-based approach and develop mechanisms to convert such scientifically set standards into legally enforceable mechanisms.	National Government Industries Research Institutions
	Mainstream the above-mentioned guidelines and investment plans into national policies, strategies, legislation and budgets.	National & Local Government
	Enforce legislations/regulation for industries to conduct EIA studies and regular audits to assess and evaluate potential impacts on the coastal marine environment - in alignment with the overarching EQOs and sector-specific ELVs – and ensure that local level ('on the ground') mechanisms are in place to audit and enforce compliance (e.g. monitoring programmes, incentive systems and penalty systems).	National Government Industries
	Develop a register of municipal wastewater and solid waste management facilities for each country (working towards a permitting system particularly for central wastewater treatment facilities and landfills).	National & Local Government
	Develop a register of manufacturing industries working towards a permitting system for such facilities.	National & Local Government Industries
	Develop a register of agro-chemical use (e.g. fertilizers, pesticides, herbicides, etc), specifying allowable products and dosages (working towards legally enforcing such specifications).	National & Regional Government Farmers
	Identify and establish sustainable financial mechanisms for investments in the field of wastewater and solid waste management, and cleaner production technology (including through development of public-private partnerships).	UNEP/NCS National Governments IFIs

Type of intervention	Activities/solutions	Implementing Partners
Information management, capacity building and awareness raising	Develop and enroll regional training programmes to build capacity in wastewater and solid waste management (in many instances focusing on local municipalities and harbour authorities).	UNEP/GPA UNEP/NCS National Government Educational Institutions
	Develop and enroll regional education and awareness programmes to inform all sectors of society (e.g. general public, politicians and managers) on their roles and responsibilities in the generation, collection, treatment and disposal of wastewater and solid waste, as well as the consequences on the environment and socio-economic wellbeing.	UNEP/NCS National Government Education Institutions
	Develop and maintain a web-based regional information management system that includes information on best practice technologies, registers (listed above) as well as tools and guidelines for the selection of appropriate technology, institutional and policy frameworks and financial mechanisms.	UNEP/NCS UNEP/GPA National Government IT Institution

PROBLEM AREA 2: Physical Alteration and Destruction of Habitats (PADH)

Type of intervention	Activities/solutions	Implementing Partners
Monitoring and assessment	Assess the current status of the critical coastal and marine habitats (mangroves, seagrasses, coral reef, coastal forests etc), including threats to their long term sustainability.	UNEP/NCS Research institutions NGOs (WWF, IUCN)
	Undertake an assessment of ecosystem goods and services, including an economic valuation of coastal and marine habitats.	UNEP/NCS ASCLMEs Project Research institutions
	Undertake an assessment of the vulnerability of coastal and marine habitats to climate change and variability (as far as not already done as part of IPCC assessment reports).	UNEP/NCS ASCLMEs Project Research institutions
Management tools	Generate thematic coastal-marine habitat GIS maps for the WIO region.	UNEP/NCS National & Local Gov NGOs (WWF, IUCN)
	Develop guidelines and demonstrate appropriate (management) approaches, technologies and actions to reduce and prevent the degradation of the coastal and marine environment caused by PADH.	UNEP/NCS UNE P/GPA National & Local Gov Research institutions
	Develop guidelines and demonstrate appropriate (management) approaches, techniques and actions for the rehabilitation and/or restoration of degraded critical coastal-marine habitats.	UNEP/NCS GovDepartments NGOs (WWF, IUCN)
	Develop guidelines and demonstrate appropriate (management) approaches, techniques and actions for mitigation of and adaptation to impacts related to climate change and variability.	UNEP/NCS ASCLMEs Project National & Local Gov Research institutions
Governance	Enforce legislations/regulation for EIA studies and audits to assess and evaluate potential impacts of coastal developments on the coastal marine environment and ensure that local level ('on the ground') mechanisms are in place to audit and enforce compliance (e.g. monitoring programmes, incentive systems and penalty systems).	National & Local Gov.
	Develop targeted conservation and rehabilitation plans for critical coastal habitats in selected areas in the WIO Region.	National & Local Gov. NGOs Research institutions
	Develop specific mitigation and adaptation plans for areas (in particular critical coastal and marine habitats) vulnerable to climate change and variability.	National & Local Gov. Research institutions
	Mainstream above-mentioned guidelines and conservation and rehabilitation plans into national policies, strategies, legislation and budgets.	National & Local Gov.

Type of intervention	Activities/solutions	Implementing Partners
Information management, capacity building and awareness raising	Strengthen local capacity in the conservation and rehabilitation of marine and coastal habitats through training and workshops.	UNEP/GPA UNEP/NCS National Gov. Educational institutions NGOs (WWF, IUCN)
	Develop and implement educational and awareness raising programmes with regard to the value of critical coastal habitats in selected areas in the WIO Region.	UNEP/NCS National Gov. Educational Institutions, NGOs
	Maintain an online regional toolkit for PADH management, including the above-mentioned guidelines.	UNEP/NCS UNEP/GPA National Gov. IT Institutions

PROBLEM AREA 3: Alteration in fresh water flows and sediment loads from rivers

Type of intervention	Activities/solutions	Implementing Partners
Monitoring and assessment	Develop detailed environmental profiles (including river-coast interactions) for selected major river systems in the WIO region, including desktop and field research.	UNEP/NCS River Basin Organizations Research institutions
	Review gaps in existing political, legal and institutional frameworks for dealing with river-coast interactions affecting the coastal and marine environment, in particular as they concerns transboundary river basins.	UNEP/NCS River Basin Organizations National Government Research Institutions
	Undertake an assessment of the potential impact of climate change and variability on main river basins, including river-coast interaction.	UNEP/NCS ASCLMEs Project Research institutions
	Perform an assessment of the water-related infrastructure planned on the major river basins of the WIO region and assess their potential impacts on the marine ecosystem and possible mitigative strategies which may be implemented.	UNEP/NCS River Basin Organizations National Departments of Water Research Institutions
Management tools	Based upon experiences from the region and beyond, develop a toolkit for ICARM in the WIO Region.	UNEP/NCS UNEP/GPA Research Institutions GWP (link with IWRM Toolbox)
Governance	Develop detailed ICARM plans (or related instruments) for the main river basins, linking up with existing or planned basin management plans.	River Basin Organizations National Government GWP Research Institutions
	Mainstream the ICARM Plans (or related instruments) into national policies, strategies, legislation and budgets.	River Basin Organizations National Departments of Water
Information management, capacity building and awareness	Promote and enhance the integrated management of river basin and coastal zones through the application of the ICARM principles and their incorporation into national and regional IWRM planning processes.	UNEP/NCS UNEP/GPA River Basin Organizations National Government GWP
	Strengthen capacity in the field of ICARM through training and workshops, including topics such as environmental water requirements, environmental management plans for dams and options assessment.	UNEP/NCS UNEP/GPA River Basin Organizations National Governments GWP Educational institutions
	Maintain an online regional toolkit for ICARM, including the above-mentioned guidelines.	UNEP/NCS UNEP/GPA National Governments IT Institution

CROSS-CUTTING ISSUES

Type of intervention	Activities/solutions	Implementing Partners
Monitoring and assessment	Prepare biennial State of the Coast Environment Reports Update, identifying information and activity gaps.	UNEP/NCS National Governments
Management tools	Develop framework environmental legislation for LBS/A Management.	UNEP/NCS UNEP/DELC National Governments
	Develop basic GIS products (regional maps, overlays) to support regional monitoring and assessments of the coastal and marine environment and its threats.	UNEP/NCS UNEP/DEWA
Governance	Mainstream LBS/A Management in national policy, legal and institutional frameworks, including the ratification and implementation of relevant multilateral environmental agreements.	UNEP/NCS UNEP/DELC National Governments
	Develop realistic national strategies for managing LBS/A in the form of National Programmes of Action (NPAs) or related instruments such as ICZM plans, NEAPs, etc.	UNEP/NCS UNEP/GPA National Governments
	Catalyze implementation of NPAs (or related instruments) through political awareness raising, public debates and the development of targeted interventions including investment plans.	National & Local Governments
	Strengthen the Nairobi Convention EAF/RCU as the recognized and effective Regional Seas coordinating unit for all regional policies and activities related to coastal and marine resources.	UNEP/NCS
	Develop and ratify Protocol on Environmental Assessment to the Nairobi Convention and promote the development of similar Protocols at the level of the Regional Economic Commissions (SADC, IOC, etc.).	UNEP/NCS UNEP/DELC National Governments
	Mainstream the implementation of the Strategic Action Programme in national and regional policies, strategies and budgets and undertake monitoring thereof.	UNEP/NCS National Governments
	Develop and strengthen regional and national Public-Private Partnerships related to LBS/A management.	UNEP/NCS National Governments
	Strengthen stakeholder involvement in LBS/A management.	UNEP/NCS National Governments
	Develop regional sustainable financing mechanisms to address marine and coastal environment management issues.	UNEP/NCS National Governments IFIs
Information management, capacity building and awareness raising	Operate and continuously update the Nairobi Convention Clearing House Mechanism (a regional information system on the WIO marine and coastal environment and its management).	UNEP/NCS National Governments IT Institution
	Develop and maintain relevant institutional and thematic expert networks related to LBS/A management as a means of regional capacity building and knowledge exchange.	UNEP/NCS WIOMSA
	Provide support to the development and implementation of relevant environmental educational and awareness raising programs at all levels on LBS/A issues.	UNEP/NCS National Governments Educational institutions NGOs