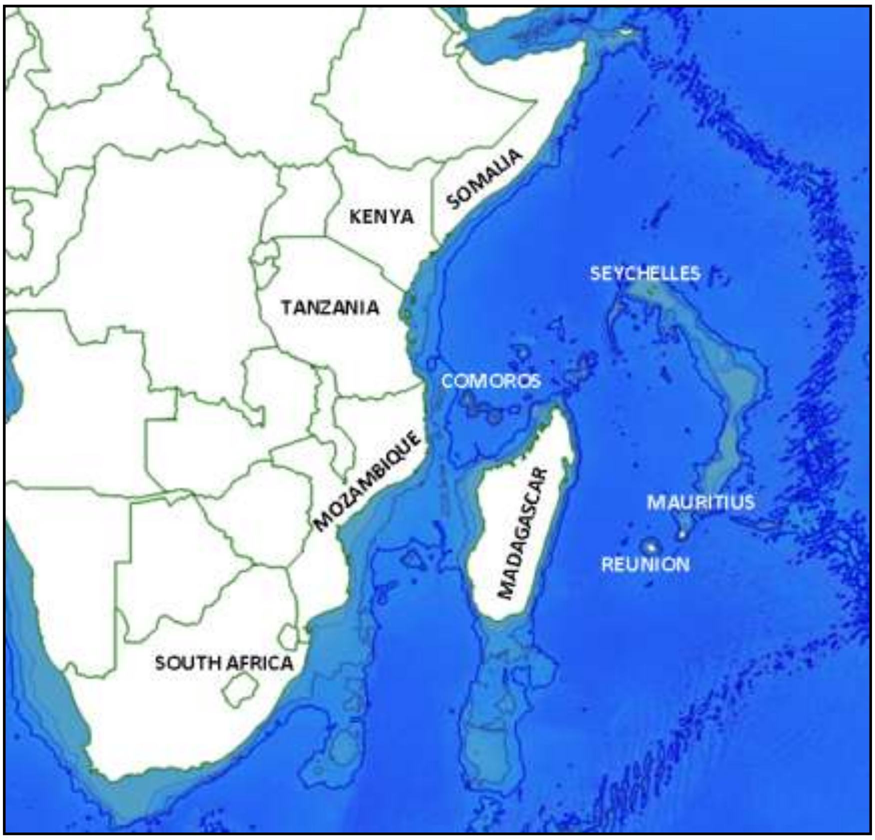
TRANSBOUNDARY DIAGNOSTIC ANALYSIS

OF THE

Western Indian Ocean Coastal and Marine Environment



VOLUME 1: BASELINE ENVIRONMENTAL CONDITIONS

1st September 2022

First published in Kenya in 2022 by the United Nations Environment Programme (UNEP)-Nairobi Convention Secretariat and Western Indian Ocean Marine Sciences Association (WIOMSA).

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For citation purposes this document may be cited as:
UNEP-Nairobi Convention Secretariat, 2022. Transboundary Diagnostic Analysis of the Western Indian Ocean Coastal and Marine Environment: Part I-Baseline Environmental Conditions, Nairobi, Kenya.

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List of abbreviations and 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 the Western Indian Ocean (WIO) coastal and marine environment. In this regard, UNEP-Nairobi Convention Secretariat and WIOMSA would like to extend their 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 (FARI) in the WIO region, which reviewed the various sections of the TDA and made comments that led to the production of the final version of the TDA.

Members of the various Regional and National Task Forces established under the auspices of the Nairobi Convention WIO-LaB, WIO-SAP and SAPPHIRE Projects are also thanked for their contributions especially in 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, the Global Environment Facility (GEF), Government of Norway, World Bank and UNDP, are thanked for providing funds that enabled the successful implementation of the WIO-LaB, ASCLME, SWIOFP, WIO-SAP and SAPPHIRE Projects in the period 2004-2023. These projects delivered various thematic reports that were used in the preparation of the WIO-LaB and ASCLME-SWIOFP TDAs that formed the basis for this Joint TDA for the WIO.

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.

Executive Summary

Global and local significance

The Western Indian Ocean (WIO) region extends from approximately latitude 12°N to 34°S and longitude 30°E to 80°E, an area of some 22-30 million km^2, equivalent to 8.1% of the global ocean surface. The Agulhas and Somali Current and Mascarene region are three Large Marine Ecosystems (LMEs) found in the WIO situated off the east coast of Africa. These LMEs and their adjacent seas are very closely linked ecologically and culturally. The region is floored by deep abyssal plains and bounded to the west by non-volcanic continental shelves. The Mascarene Plateau is the most prominent bathymetric feature of the region extending as a submerged part-continental and part-volcanic plateau for over 1500km. The width of the continental shelf of the WIO region tends to increase southwards from the Somali coast in the north and on average basis reaches a depth of 150m. Approximately 700 seamounts identified in the region are known to be hotspots of biodiversity and marine biomass in the pelagic ecosystem. The WIO coastline, including mainland and island states, is over 15,000 km long. It includes a wide diversity of coastal habitats including rocky shores, sandy beaches, coral reefs, mangrove systems, seagrass beds and estuaries which, in combination, supply a wealth of ecosystem services to the human populations along the coast. However, coastal habitats tend to be at high risk because of their proximity to land and marine based impacts and because they are typically easily accessible from land and vulnerable to overexploitation if not managed properly.

Oceanography and ocean water circulation patterns in the WIO are influenced by prevailing winds and ocean currents, especially the westward-flowing South Equatorial Current, the seasonally reversing 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 oceanographic patterns are also influenced by the seafloor bathymetry, continental masses, input of water from surrounding oceans, and interaction with the atmosphere. As such 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 and the island states are Mauritius, Comoros, Seychelles, Madagascar and La Réunion (France). Most of the region falls into the Tropical Western Indian Ocean biogeographical region that is characterised by Indo-Pacific biota. The subtropical East Coast Province starts in southern Mozambique and extends to the Eastern Cape of South Africa. The WIO region is also endowed with many river systems, 12 of which are major rivers with 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 WIO region is characterised by high diversity of species and communities. 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 sponges, 3,000 species of molluscs, 300 species of crabs and more than 400 echinoderms. It is estimated that 11,257 marine species are found in the region. The biodiversity includes a total of 37 marine mammal species. 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. 11 seabird families occur as breeding species in the WIO region. Less than 200 cartilaginous fishes have been recorded in the WIO and, except for South Africa, little is known about the status of sharks and rays in the region. This limited knowledge is of concern given that sharks and rays are likely to be heavily impacted by fisheries and other activities. Approximately 2,200 species of teleost fish have been recorded in the region, consisting of 270 families. Many of these species are transboundary and shared between the WIO countries. The fishes of the region are subjected to a number of negative impacts which place them at differing levels of risk. The impacts arise from factors that include ecosystem and habitat destruction, climate change and fishing, including targeted fishing or as bycatch.

The coral reefs, mangroves and seagrass beds are critically important tropical habitats in the WIO region as they provide habitat and other services for coastal species and for coastal human populations which depend on them for food, livelihoods and other ecosystem services. These habitats are under threat from a range of human impacts including pollution, sedimentation, physical removal, human settlements, damaging effects of fishing and climate change.

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. This is produced by fisheries ranging from traditional subsistence and artisanal activities using a wide variety of different gears, to large-scale industrial operations fishing mainly with longlines, purse seines and trawling. The fisheries of the region generate a resource rent estimated at approximately USD 68 million per year, of which about USD 59 million are generated by WIO countries and the remainder by countries outside of the region. It is estimated that effective management of the fisheries and rebuilding of stocks of the WIO could result in an additional USD 221 million in annual economic rent. Most of the economic benefits from the coastal and marine resources of the WIO remain in the countries of the region. In the fisheries sector, the workers, for example the fishers, receive an estimated USD 366 million per year in wages compared to earnings of USD 60 million by the fishing enterprises that employ them. 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. The underlying causes of declining in fish catches in the WIO include lack of effective management of the fisheries due to inadequate data on the priority species; generally limited understanding of the linkages between fisheries and biodiversity, and lack of national fisheries laws that adequately incorporate the binding obligations of international fisheries instruments and reflect currently accepted "best practices" in fisheries legislation. Other concerns include the absence of regional management strategies for shared and transboundary stocks in the demersal and crustacean fisheries, overcapacity due to rapidly increasing coastal populations coupled with high levels of unemployment and poverty and inadequate monitoring, control and surveillance.

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 160 million people reside in the WIO region countries and approximately more than 60 million people, or more than 1/3 of the total population of the countries bordering the WIO inhabit the coastal areas of the region. Although variable from place to place, a large segment of the coastal population relies on coastal and marine resources for food security and livelihoods. Due to the high dependence on natural resources and limited resilience and adaptive capacity, extreme hydro-climatic events usually have a disproportionately severe effect on the coastal communities. Further, coastal cities and settlements are growing and developing at a rapid rate leading to other impacts on the coastal and marine ecosystems.

A comprehensive cost-benefit analysis estimated that almost US$22 - 25 billion a year is derived from the coastal and marine resources of the WIO. Coastal tourism is the largest source of income that is directly linked to the coastal and marine environment, contributing over USD 11 billion a year to the GDP, equivalent to 40% of the total contribution from marine and coastal resources. 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. Coastal agriculture and forestry were next at 20% of the combined contribution to GDP, followed by mining and energy at 15% and fisheries at 11%.

Joint TDA for the WIO

This Joint TDA for the WIO is a decision-support tool that presents the results of a series of investigations and expert analyses relating to the causes of the degradation of the coastal and marine environment in the WIO. More specifically, it identifies those elements that may induce impacts beyond national boundaries or problems that are common in several countries of the region. The TDA is intended to inform countries in the region on the priority issues and problems that need to be addressed within the context of immediate and long-term sustainable management of the coastal and marine ecosystems. In this regard, the TDA forms the basis for the development of a comprehensive Strategic Action Programme (SAP) for addressing both land-based and marine-based sources of degradation of the WIO coastal and marine ecosystem including fisheries.

Need for action

The WIO coastal and marine ecosystems including fisheries are already facing a number of negative impacts and risk of further degradation and decline is real in the region. The causes and impacts of degradation of the coastal and marine ecosystem are either transboundary or are common in most of the countries of the region with the implication that regional effort is required to address the challenges.

The examination of management, policy and governance in the region, at both national and regional levels showed that the styles of marine and coastal ecosystem governance vary from country to country, reflecting their individual histories and cultural backgrounds. The styles have also been influenced by relevant regional and international agreements. The differences between countries occur in their systems of governmental organization, processes and priorities, the levels of economic development, scientific capacity and incorporation of science into policy processes, patterns of social organization, culture and values, and in their political relations. Similarly, there are differences in the governance of the major sectors related to sustainable use of marine and coastal resources. Inadequacies and gaps exist in the application of the existing legislation to ecosystem based management, also varying from country to country. A number of regional agreements and bodies are in place in the WIO including the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region), the South Western Indian Ocean Fisheries Commission (SWIOFC), the Indian Ocean Tuna Commission (IOTC) and several Regional Economic Commissions. The African Union's New Economic Partnership for African Development (NEPAD) also plays a role in the region. The WIO region countries are also parties to important international agreements such as the 1982 United Nations Convention on the Law of the Sea (UNCLOS). However, it must be noted that participation of WIO countries in these international and regional processes has not necessarily translated into specific actions on the ground to reverse the degradation of the coastal and marine ecosystems including fisheries in the WIO.

The WIO region's rapidly growing population is exerting large pressure on the coastal and 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. Several projects have been undertaken within the auspices of the UNEP-Nairobi Convention including the UNEP-GEF WIO-LaB Project (2005 - 2010); UNEP-GEF WIO-SAP Project (2017-202); UNDP-GEF SAPPHIRE Project (2018-2024) which addressed land-based sources of degradation of the coastal and marine environment including fisheries in the WIO region with funding from the Global Environment Facility (GEF). The broad visions of these projects were 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 including fisheries resources.

The initial detailed region-wide assessments of transboundary problems and issues affecting the marine environment including fisheries in the WIO region that forms the basis of the current Joint TDA were undertaken under the auspices of the UNEP/GEF WIO-LaB Project, UNDP/ASCLME project and World Bank/SWIOFP in the period 2009-2012. The UNEP/GEF WIO-LaB Project in 2009 delivered a 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). This provided the basis for the formulation of a Strategic Action Programme for addressing the land based sources and activities in the WIO region (WIO-SAP). On the other hand, the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project and the South West Indian Ocean Fisheries Project (SWIOFP) delivered in 2012 a joint TDA focussing on the current status of the Agulhas and Somali Current Large Marine Ecosystems of the WIO. This led to the formulation of the SAPPHIRE which was a joint SAP delivered by the ASCLME and SWIOF Projects. In order to promote a ecosystem approach in the management of the WIO, it was decided that the WIO-LaB and ASCLME-SWIOFP TDAs be integrated into a Joint TDA for the WIO region that presents a comprehensive analysis of the ecosystem status and threats to the long term sustainability of coastal and marine processes and resources in the region. It is expected that this joint TDA will provide the basis for formulation of a common Strategic Action Programme (SAP) for the region.

TDA process

The processes for the formulation of the WIO-LaB and ASCLME-SWIOFP TDAs were undertaken in the period between 2005- 2012 and this involved comprehensive, region-wide analysis of priority transboundary problems related to land-based activities and sources of degradation of the coastal and marine environment including the large marine ecosystems in the WIO. The development of both TDAs was led by a multi-disciplinary team of experts drawn from leading institutions in the WIO region, with specialization in various fields such as oceanography, marine pollution, coastal habitats, fisheries, river–coast interactions, governance and socio-economics. The TDA development processes undertaken under the auspices of the three projects, followed the standard five main steps, which are: 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 TDAs was derived from various thematic assessment studies undertaken under the auspices of the three GEF financed projects. In addition to a large number of national thematic assessment studies that were used, a huge body of relevant literature, including published and unpublished reports and journal papers, generated through other studies and regional processes were used in the preparation of the two TDAs. Also, a large number of 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 in the region. The review and validation of the two TDAs was undertaken by a Scientific and Technical Review Committee established within the framework of the Forum for Academic and Research Institutions in the WIO-Region (FARI).

Findings of the joint TDA

The Joint TDA identified five (5) problem areas or main areas of concern in the WIO region. These are: (1) Water and sediment quality degradation due to pollution; (2) Physical alteration, modification and destruction of habitats; (3) Alteration in freshwater flows and sediment loads from river basins; (4) Decline of living marine resources, and (5) Climate change and extreme events. In addition, a detailed analysis of coastal and marine ecosystem governance in the WIO was undertaken as part of the TDA process. The following sections present a summary of the findings of the joint TDA for each of the identified main areas of concern.

Problem Area 1: Coastal and marine water and sediment quality degradation

WIO coastal and marine ecosystem is facing an increasing threat from land-based and marine-based sources of pollution. A significant amount of the pollution load in the region emanates from land-based activities such as the discharge of municipal, agricultural and industrial wastewaters and effluents[1]. The

[1] 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.

highest pollutant loads originate from the mainland states and Madagascar, with South Africa and Tanzania contributing approximately 80% of the overall loading of nutrients and organic matter in the region. 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**Error! Bookmark not defined.**) 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. The main pollution categories that are considered important in the WIO are listed in the following table.

The joint TDA identifies the following pollution categories:

Microbial contamination	The microbial contamination is the most widespread type of pollution in the WIO region, and has most profound impacts in terms of health risk to the population through both direct contact with seawater and consumption of seafood products. Microbial contamination is associated with inappropriate disposal of municipal wastewater (including sewage effluents), 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 and turbidity	High suspended solid loads leading to high turbidity in coastal waters are due to river discharges, surface runoff and municipal and industrial wastewater discharges. Dredging activities usually associated with ports and harbours also significantly contribute to the increased turbidity of coastal waters. High levels of suspended solids and turbidity in the WIO region are particularly common in coastal waters located within the vicinity of 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 particularly in and around ports and harbours.
Marine litter/solid waste including marine plastic litter	Most of the major cities and towns found in the WIO region generate significant amounts of solid wastes including plastic litter, some of which reach the sea. Some significant load of plastic litter enters coastal waters through rivers that transports solid waste/debris from urban areas located further inland. Marine plastic litter is a common feature along the shorelines of most of the WIO countries.
Eutrophication and nutrient enrichment	Eutrophication as a result of the increased supply of nutrients is due to the disposal of municipal wastewater and effluents and discharge of irrigation return flows. In the WIO region, elevated levels of nutrients have been recorded in many hotspots, with cases of eutrophication reported in Seychelles and Mauritius.
Ground and surface water quality degradation	Groundwater aquifers along the coast are major sources of freshwater for coastal communities and these are being degraded due to seawater intrusion, discharge of municipal and industrial wastewaters and effluents. Surface freshwater resources are also being degraded due wastewater discharges.

Oil Spills	Oil spills occurs mainly in ports and harbours and in open waters of the region due to accidental spillage or during drilling and exploitation of crude oil. Oil spillage in the region has in the past impacted coastal ecosystems such as mangroves, seagrass beds and coral reefs including sandy beaches in several countries in the region.

Problem Area 2: Physical alteration, destruction of habitats and community modifications
Rapid and unmanaged transformation of the coastal land- and sea-scape and consequent loss of critical coastal and marine habitats that provide essential ecosystem goods and services is a common problem in most countries in the WIO region. This transformation of critical habitats 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 activities that lead to the alteration of shorelines and critical habitats in the 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 the impacts of climate change. Also, land reclamation for agriculture, aquaculture and coastal development, as well as extensive deforestation of watersheds, is causing changes in the flow of freshwater and sediments to the coast leading to changes in the physical set-up of beaches. 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**Error! Bookmark not defined.**. The impacts of loss, degradation and or modification of coastal habitats are presented in the following table.

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

Degradation and loss of mangrove habitats	Mangrove forest 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. The factors are closely related to land- and water-use practices in the areas adjacent to and upstream of mangrove forests. Human-induced stresses include diversion and reduction of freshwater flow, poor land use activities in and around mangrove forests and over-exploitation of mangrove forest resources. These stresses disrupt the natural equilibrium ultimately leading to the loss or degradation of the mangrove forest 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 forest cover over the past century. Most mangrove forests located around urban areas are already severely degraded.
Degradation and loss of seagrass habitats	The loss and degradation of seagrass beds in the WIO region is a result of physical actions such as dragging of fishing nets, clearance, and pollution. Climate change is also impacting seagrass beds through increased discharge of river sediment loads. Seagrass degradation has negative impacts on the coastal system’s productivity and biodiversity. This ultimately affects food security due to loss of livelihood among coastal populations.

Degradation and loss of coral reef habitats	The loss and degradation of the coral reef ecosystems in the WIO is due to global warming that has 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. Other causes of degradation include inappropriate fishing activities and discharges of wastewaters, freshwater and sediment loads. Continuous degradation of coral reef lowers fisheries productivity and leaves shorelines unprotected, impacting on livelihood and incomes of local communities, thereby increasing poverty levels.
Degradation and loss of coastal forests	Loss and 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. Other causes are increased demand for forest products such as timber and firewood. Loss and transformation of coastal forests has a significant impact on the coastal environment through reduction of floral and faunal diversity, loss of fertile soils due to increased soil erosion, and reduction in the recharge of groundwater aquifers. Ultimately, these impacts change the physical-chemical conditions and dynamics of both sediment and water exchange in the coastal zone.
Shoreline changes	Erosion and accretion of coastlines in the WIO region is leading to significant changes in shorelines of most countries. Sea level rise and episodic storm events partly driven by climate change have led to shoreline changes leading to significant impacts on critical habitats, coastal infrastructure, agricultural land and human settlements. Most of the WIO shorelines are dominated by rapidly eroding beaches. In some area, shoreline changes have been due to sediment accretion due to increased sediment loads from rivers and the re-suspension of bottom sediments during storm events. Increased turbidity due to re-suspended sediments have led to smothering of corals, seagrasses and mangroves further contributing to the degradation of the coastal and marine ecosystem in the region.

Disturbance and loss of upland watershed habitats	The degradation and loss of upland watersheds in most countries in the WIO region are leading to increased sediment and nutrient loads discharged to the coastal and marine ecosystems in the region. This is mainly due to land use change when upland forests are cleared to open land for settlements, roads, agriculture and livestock grazing. Uncontrolled clearance of forests for supply of timber and fuel wood is also another cause of loss of upland forests that are linked to the coastal-marine ecosystems through river flows.
Disturbance and loss of coastal forest habitats	The coastal forests of mainland East African extend from southern Somalia to southern Mozambique and are recognised by WWF as a Global Ecoregion and by CI as a Biodiversity Hotspot. These forests have been degraded due to clearance for timber, fuelwood and to open land for agriculture and settlements.
Disturbance and loss of coastal habitats (beaches, dunes, coastal vegetation and flood plain habitats)	Coastal habitats in the WIO region have been degraded and in some instances lost as a result of uncontrolled urban expansion, construction of roads and other infrastructure, and tourism developments. Disturbance of coastal habitats has adverse impacts on seabirds and shorebirds utilizing the coastal and marine ecosystems.
Disturbance and loss of wetland habitats	Coastal wetlands are being lost or degraded due to alteration of river flows, clearance and drainage for urban development as well as due to climate change and extreme hydrological events such as those associated with the El Nino ENSO events. Loss and degradation of wetland habitats is adversely impacting shore-birds and migratory birds utilizing this habitat as an over-wintering ground. Other important goods and services associated with these wetlands are also being lost leading to impacts on socio-economic livelihoods of the people.
Disturbance and loss of estuarine habitats	Disturbance of estuarine habitats in the WIO region is as a result of poor agricultural practices, deforestation, urban and industrial development, trawling, pollution and sand mining. The degradation of estuarine habitats threaten coastal wildlife such as hippopotamus, crocodiles, shorebirds and nursery grounds for commercially important species such as prawn, shrimp and fish and is also leading to coastal flooding in some areas.
Disturbance, damage and loss of macroalgal habitats	The degradation and loss of macroalgal habitats in the region are generally overlooked, but these are due to smothering of algal communities as a result of siltation, over-exploitation of *Euchema*, introduction of exotic algal species and the proliferation of macroalgae as a result of nutrient enrichment. This subsequently impacts coastal biodiversity and productivity.
Disturbance and loss of soft sediment habitats	Soft sediment habitats and their associated macrobenthos communities in the WIO region are vulnerable to physical disturbances as a result of fishing activities such as beach seining and trawling, sand mining, dredging, land reclamation and chemical pollution. These types of disturbances can eliminate certain species, whilst other more tolerant species may remain, resulting in a change in the community composition.

Disturbance and loss of deep water habitats	Deep water habitats in the WIO are vulnerable to impacts caused by deepwater trawling, mining, oil and gas exploration and extraction, bio-prospecting, disposal of solid and liquid wastes, disposal of animal carcasses and offal (from international shipments of livestock), dumping ballast water from ships, pharmaceuticals, disposal of greenhouse gases (sub-seabed disposal and surface seabed disposal), and mining and dredged spoils.
Disturbance and degradation of pelagic habitats	The structure and function of the pelagic habitats have significantly changed due to fishing activities and pollution. The majority of the impacts are due to land- and marine-based sources of pollution including the discharge of un- or undertreated municipal and industrial wastewaters, river discharges, surface runoff, and the accidental release of chemicals, and other liquid and solid wastes from marine sources. Additional impacts in the pelagic environment include noise pollution as a result of boat traffic, shipping and transportation, dredging and seismic surveys associated with oil and gas exploration, which are known to adversely impact marine mammals and sea turtles.
Increase in the occurrence of harmful or toxic algal blooms (HABs)	Harmful algal blooms frequently occur naturally in the WIO region response to oceanographic processes that increases the availability of nutrients in the water column. Blooms are also triggered due to the inputs of nutrient enriched waters from land-based or marine sources, with high concentrations of nitrates and phosphates. The algal blooms causes 'eutrophication' and the death of marine organisms including fish.
Introduction of exotic (non-native), invasive and nuisance species	Invasive and or nuisance species such as the corallivorous crown-of-thorns and the gastropod mollusc occur throughout the WIO causing damage to corals. The introduction of exotic non-native species has led to various impacts on local coastal - marine biodiversity. The impacts can be devastating due to potential competition with indigenous species, hybridisation causing genetic dilution, alteration of ecosystem dynamics and threat to the complexity and resilience of the local ecosystem. International shipping is the principal agent for the introduction of exotic species from ballast water or hull fouling organisms.

Problem Area 3: Alteration in river freshwater flows and sediment loads
The WIO region is endowed with a number of important rivers, including some transboundary rivers such as the Athi-Sabaki, Jubba-Shabelle, 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 riverine, estuarine and marine ecological processes and productivity. Throughout much of the region, and particularly in continental states, important transformations of the coastal and marine environment have been attributed to human activities and climatic variability occurring in the river basins. The impacts from human activities such as impeded flow of freshwater, terrigenous sediment load and increased organic load, have altered the nature of the interaction between river systems and coastal processes. Also, nutrients and pollutants from domestic sewage, industrial and agricultural chemicals have led to water quality degradation in some of the river systems that drain into the WIO. The most affected river basins are Pangani (Kenya and Tanzania); Athi-Sabaki (Kenya, Tanzania); 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, numerous small rivers that drain into WIO have not escaped human influences although the extent of their alteration is thought to be modest. The TDA distinguishes the two main categories of river–coast interactions that are presented in more detail in the following table:

Alteration of river flows and water quality	The alteration of the natural river flow is common in many of the major river systems draining into the WIO. The main causes of river flow alterations are: (i) reduction in the flow due to increased abstraction and consumptive uses of water, (ii) increased damming of the river, (iii) changes in seasonal flow patterns (e.g.due to releases for hydropower-generation during the dry season), (iv) increased floods due to loss of wetlands water retention capacity and (v) climate change which has led to either reduction or increase in rainfall and subsequently, increase or reduction in river discharges to the coast.
Alteration of sediment loads	The alteration of river sediment loads is a common problem in some countries in the WIO region. This is due to mainly due to factors that operate at river basin level such as climate change, land use/land cover change and construction of dams in major rivers. The alteration of sediment loads broadly manifests itself in three ways: • Increased sediment loads – this has a negative impact on the coastal and marine ecosystem through smothering of mangroves, coral reefs and seagrass beds, as reported in the case of Athi-Sabaki and Mwache river in Kenya, and the Betsiboka river in Madagascar. • Decreased sediment loads – this has a negative impact on the marine ecosystem through increased erosion of the delta, and through increased salt-water intrusion, leading to a reduction of mangrove habitats, 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 watershed areas, and reduced sediment transport downstream of dams due to trapping of the sediments behind the dam wall.

Problem Area 4: Decline in living marine resources

The decline of marine living resources is a growing problem in the WIO region. It is now well established that the majority of marine wild capture fisheries are fully or overexploited in the region. Fishing methods that are used in the region have impacts on other non-target species, and contribute towards the loss or disturbance of natural habitats, further threatening the long term survival of species that depend on these habitats for feeding, breeding or other critical life processes. Populations of many species, including the larger more charismatic marine mammals, seabirds, sea turtles, as well as endemic species have been affected by increased fisheries activities in the region. The issue categories related to declines in living marine resources as identified from the MEDAs are presented in the following table:

Decline in populations of marine mammals (excluding cetaceans)	There are five marine mammal species other than whales and dolphins found within the region. Dugong are potentially the most threatened and vulnerable species within the WIO and now extremely rare. The population is estimated to be less than 500 animals, the majority of which are found in Mozambique at Bazaruto Archipelago. Recent surveys have also found potentially significant populations in northwest Madagascar. Populations of dugong have declined due to hunting and incidental capture in commercial and artisanal fisheries (gillnets, trawlers and other set nets) and habitat loss particularly seagrass beds as a result of pollution and physical disturbance. In more recent years, an increase in tourism activities and boat traffic is posing a threat to these marine mammals through noise pollution and boat strikes.
Decline in populations of cetaceans	Over 32 species of whales and dolphins have been reported in the WIO. The cetacean populations in the region are declining due to hunting and incidental capture by various fisheries (commercial, artisanal and traditional). Habitat disturbance and loss, pollution, collisions and climate change are other factors contributing to the decline in local cetacean populations. Noise pollution is an increasing problem as it disrupts orientation, feeding and communication ability of cetaceans leading to strandings and physical damage to the ear of the cetaceans.
Decline in populations of seabirds	There are eleven seabird families within the WIO region. Seabird populations in the WIO are declining due to hunting and egg collection; accidental bycatch particularly in the longline fishery, but also by gillnets; and habitat destruction or loss as a result of human activities or climate change. The introduction of alien predators such as cats and rats also affect many seabird populations.
Decline in populations of turtles	There are five species of sea turtle in the WIO all of which are in the IUCN Red List and Appendix I of CITES which means international trade in live specimens or their products is prohibited. The species found include two 'Critically Endangered' species, the Hawksbill (*Eretmochelys imbricata*) and Loggerhead turtle (*Caretta caretta*), two 'Endangered' species, the Green turtle (*Chelonia mydas*) and Leatherbacks (*Dermochelys coriacea*), and one 'Vulnerable' species, the Olive Ridley turtle (*Lepidochelys olivacea*). The main threats to turtles in the region include hunting for meat, eggs and carapaces; habitat disturbance, loss and degradation of nesting beaches and foraging grounds (e.g. coral reefs and seagrass beds); pollution, marine plastic litter, oil pollution, sedimentation, light and noise pollution; accidental capture in industrial and artisanal fisheries and diseases.
Decline in populations of sharks and rays	Shark and ray fisheries and bycatch are prevalent throughout the WIO region. All elasmobranchs (sharks and rays) are highly vulnerable to overexploitation due to their slow growth, late age at maturity, low fecundity and large size at birth. There are over 200 species of sharks and rays that have been reported in catches and 15 species of sharks that are regularly caught in the WIO. Shark bycatch is commonly associated with the pelagic fisheries including the purse seine fishery and the pelagic longline fisheries targeting other species such as tuna and swordfish, and fisheries associated with FADS.

Decline in populations of large pelagics	Large pelagics such as tuna and tuna-like species including billfishes are apex marine predators. These species make up nearly 50 % of the total landed catches in the WIO. Large pelagics are heavily targeted in the WIO by a diverse range on fisheries ranging from small-scale artisanal fisheries to large commercial fishers, as well as recreational fishers in the region and beyond. Industrial fishers in the WIO tend to be distant water fishing fleets from Asia and Europe that target a wide range of migratory fish such as tuna, kingfish, bonito and mackerel, most of which are destined for export market. Because of highly migratory nature of many large pelagic species, several of the target stocks are shared between the EEZ of the WIO countries making this a transboundary issue that requires joint regional effort to manage.
Decline in populations of small pelagics	Small pelagic fisheries target small tuna-like species including horse mackerel and mackerel (Scombridae), barracuda (Sphyraeindae), Jacks (Carangidae), sardines (Clupeidae) and anchovies (Engraulidae). These are targeted mainly by the artisanal and industrial fisheries including shrimp trawlers using a variety of fishing gear (e.g. bottom-set gill nets, beach seine nets and purse seines). The purse-seine fisheries for small pelagics typically targets scads, sardines, small mackerels. The artisanal coastal net fisheries (beach seine, small purse-seines, cast nets, ring nets) target small and medium pelagic fish species for own consumption and local sale. The species targeted are variable and are important for food security among the artisanal fishers in the region.
Decline in populations of deep demersal fish species	Exploitation of deepwater species is a relatively recent development in the WIO. Deep water fisheries involve dropline/long-line fishing (200-400 m depth) targeting deepwater snappers and other associated fishes, and conventional line fishing (mainly hand-line, less than 200m depth) targeting a range of reef-associated fishes, and deepwater trawling, which could be considered the most concerning due to the associated habitat damage. Not all countries in the region have developed deepwater demersal fisheries and knowledge about these stocks is limited. However, as coastal populations expand and nearshore fisheries declines, there is growing interest in these deeper offshore fish resources within WIO countries EEZs and areas beyond national jurisdiction.
Decline in populations of reef and demersal fish	Reef and nearshore demersal fish are heavily exploited in the WIO. These are largely exploited by artisanal fisheries as they are typically open-access and are within relatively easy reach of the shore. Increased urban population and expansion of coastal tourism in some countries have also fuelled the demand for more fresh fish. Many of the preferred reef-associated fishes are becoming increasingly rare throughout the region, and some species are now recognised as being of international concern for conservation. Overfishing of reef and demersal fishes is causing an imbalance in the functioning of the wider reef ecosystem. Overfishing of herbivores can result in the smothering of corals with algae and overfishing of keystone predators can lead to outbreaks of nuisance species (e.g. sea urchins *Diadema* spp.). As resources become progressively more depleted, there has been an increase in the use of more destructive and non-selective fishing methods such as the use of dynamite, plant derived poisons or smaller mesh size nets.

Decline in populations of molluscs (bivalves, gastropods)	Fisheries for invertebrates, bivalves and gastropod mollusc resources are exploited in nearshore habitats by reef gleaning or snorkelling. Molluscs are collected opportunistically as additional catch alongside other fishing methods. The main molluscs targeted are the edible and ornamental species. Mollusc fisheries are not targeted in all countries and generally the fishery is artisanal. There is little knowledge about these fisheries as they are typically not monitored, even though several of the species are listed on Appendix II of CITES.
Decline in populations of cephalopods	There are over 16 species of cephalopods in the WIO, which are all active predators that trap prey using their tentacles. Several fisheries in the region target squid, cuttlefish and octopus, the most widespread of which is the artisanal octopus fishery. Decline in octopus fisheries landings in several WIO countries has been due to overexploitation and habitat damage. According to SWIOFC, the octopus fishery is classified as 'Overfished' in the region
Decline in populations of sea cucumbers	Sea cucumber fishing is not a traditional fishery in the WIO but it has rapidly increased in importance given the export value of the product. The fishery has spread as a result of increased foreign demand for sea cucumbers, which grew in tandem with the economic growth in China and South East Asia region**.** Sea cucumbers are typically targeted by fishers using snorkel and mask or SCUBA equipment or are collected as bycatch by spear fishermen and other gleaners. Fishers typically target the six highest value species (*Holothuria nobilis, H. fuscogilva*, *H. scabra*, *Thelenota ananas* and *Actinopyga mauritiana*) (Conand 2008). Sea cucumber resources in all countries in the WIO are presently either 'Over-exploited' (at least for the main commercial species) or 'Fully-exploited'. The fishery is characterised by a "boom and bust" nature, in that it often starts rapidly without any formal monitoring or management and then crashes just as fast.
Decline in populations of prawns and shrimp	Prawns and shrimp are targeted by both industrial and artisanal fisheries in shallow water throughout the WIO, and in shallow and deep water along the mainland coast. The status of the stocks of the main commercial species indicates that stocks are compromised due to recruitment over-fishing (due to heavy small-scale exploitation of juveniles in inshore waters before they recruit to the trawl fishery); growth over-fishing (caused by trawling of prawns too early in the season); general over-fishing (due to excessive trawling effort); habitat degradation (due to reduced river flow and destruction of mangroves); reduced profitability of the trawl sector (due to low market prices caused by foreign mariculture, and increased fuel prices). The catches are a valuable source of foreign currency in Mozambique and Madagascar and hence small-scale (traditional) prawn fisheries have expanded as a result, leading to user-conflicts with the industrial trawl fishery.

Decline in populations of lobsters	Several species of lobster are targeted within the WIO by commercial and artisanal fisheries. The commercial fisheries tend to target deepwater species using traps and trawls. These fisheries include industrial trap-fishery for spiny lobster, *Palinurus gilchristi* (South Africa, south coast); and experimental trap-fishery for spiny lobster, *P. delagoae* (South Africa, east coast); and industrial trap-fishery for spiny lobster, *P. delagoae* (Mozambique). The lobster fisheries are valuable but monitoring is limited (with the exception of South Africa) and information on stocks is insufficient. According to SWIOFC, the status of lobster stocks in the region range from over exploited (Kenya) to recovering (Seychelles).
Decline in populations of crabs	The exploitation of crabs is common but poorly researched fishery in several of the countries in the WIO region. The industrial lobster trap fishery also targets the deep water red crabs (*Chaceon macphersoni*), although other crab species are also sometimes caught and discarded. The artisanal fishery targets portunid crabs, mud or mangrove crabs and more rarely coconut crabs. The most commonly targeted species by the artisanal fishery is the mangrove crab *Scylla serrata*, which is now also being farmed. The farming of this species is further contributing to the decline of some wild populations due to the harvesting of crablets for use in mariculture. Shallow-water swimming crabs (*Portunus pelagicus*) of blue swimming crabs, also support many small-scale fisheries throughout the region, and they too are likely to be regional or sub-regional resources.
Excessive bycatch and discards	Excessive bycatch and discards is an issue of concern for both the artisanal and industrial fisheries in the WIO. Non-selective gears used by artisanal and industrial fisheries often result in by-catch of non-commercial species including vulnerable species such as marine mammals, turtles and elasmobranchs as well as juvenile fish.
Expansion of mariculture industry	Mariculture activities are expanding rapidly throughout the countries of the WIO region in response to the increased demand for seafood and other products, both nationally and internationally, and the economic development potential this sector provide. Farming of blue-green algae, seaweed, sea cucumber, clams, pearl oyster, prawn, crab and finfish are all currently active in the region. The potential for this sector to generate employment for coastal communities is seen as an opportunity to both reduce fishing pressure on wild caught stocks and reduce poverty. Mariculture can result in the loss of critical habitats (e.g. seagrass beds and mangroves). The introduction of species and pathogens could also become a biosecurity issue were the species or pathogens to escape and spread.

Problem Area 5: Climate change/variability and extreme events

Climate change is a serious issue in the WIO region due to its impacts. The issues of concern that were identified by the countries related to climate change/variability and extreme events are causes which contribute to many of the other issues including: Extreme weather events, Sea level change, Ocean acidification, Changes in seawater temperatures, Changes to hydrodynamics and ocean circulation, Changes in productivity and Geohazards (tsunamis, volcanic eruptions, earthquakes). These are presented in the following table.

Climate change and extreme events	Climate change is a matter of great concern in the WIO region. There have been several major climatic events in the WIO during the past 10-15 years that have heightened awareness about the vulnerability of the countries in this region to climate change related impacts and extreme weather events. The impacts of climate change in the region are diverse and include changes in rainfall patterns, river discharges, degradation of coastal ecosystems, among others. Shifts in the patterns of rainfall have already been reported in the WIO region leading to changes in river flows and discharge of sediment loads to nearshore marine habitats such as mangroves and coral reefs. Extreme hydroclimatic extremes such as floods and droughts have become more frequent and their intensities have increased as a result of global climate change. Many of the countries in the WIO are regularly affected by cyclones, tropical storms and El Nino ENSO events. These extreme events are often accompanied by heavy rainfall that leads to flooding of low lying areas. In the recent past, extreme waves and storm surges have increasingly occurred in the region impacting shallow nearshore habitats and lowlying areas.
Sea level change	The WIO region is characterised by both increasing and decreasing sea levels that are attributed to global warming and other oceanographic processes. The change in sea level is expected to be within the average global rate of about 1.2 mm/yr over much of the 20th century. However, significantly faster change (5.5 mm/yr) is expected to affect the region for shorter term. Madagascar has shown a sea level rise of 7.2 - 21.6 mm per year. Around Mauritius, the sea level is falling at slow rate of - 0.10 mm per year. In the last few years, an accelerated sea level rise has been observed in most countries in the WIO region. Sea level rise could cause coastal flooding leading to the degradation of corals, seagrass beds and mangroves. Sea level rise could also lead to the elimination of many intertidal areas particularly estuarine habitats and existing infrastructural developments along the coast such as roads, railways, bridges, etc. In most countries, most of the beaches are eroding at a fast pace affecting beach hotels, settlements and agricultural areas. Sea level rise is also leading to greater intrusion of seawater into coastal groundwater aquifers threatening sources of freshwater for millions of people in the region. The impacts of sea level rise have the potential to have major socio-economic consequences in most of the countries in the WIO.
Ocean acidification	Not much work has been carried out in WIO related to ocean acidification and therefore the extent of this issue is not well known in the region. Ocean acidification occurs as a result of increased dissolved CO_2 concentration in ocean water causing a decrease in the pH of sea water. Ocean acidification has a potential to cause a delay of growth rates of corals and other species by weakening their carbonate skeleton. It has been suggested that ocean acidification will also have adverse effects on plankton communities and will reduce the production and supply of white carbonate sand to lagoons and beaches. The ocean acidification will overally contribute to the decline of coral reefs and other species with carbonate skeletons or shells.
Increase in seawater temperature	The mean sea surface temperature in the WIO has increased from 27.2^{o}C to 28.2^{o}C since 1980. Increased SST is responsible for massive coral bleaching in the region. During 1997-1998 the El Nino Southern Oscillation (ENSO) caused extensive coral bleaching throughout the WIO region with coral bleaching observed in Madagascar, Mozambique, Somalia, Tanzania and South Africa. In Mauritius about 50% of the corals were bleached while in Seychelles, coral mortality was almost 100 % in some areas. It has also been suggested that high temperatures would also negatively impact highly migratory species such as cetaceans, sea turtles and tuna. Given the importance of these species in

	wildlife conservation and fishing, such impacts would be a potential concern.
Changes to hydrodynamics and ocean circulation	The Mozambique Channel is a sensitive area for air-sea interactions on inter-annual time scales. The Indian Ocean "Dipole" (IOD) impacts climate in northern Mozambique and is characterised by intensified easterlies and large changes in equatorial circulation. There has been a progressive warming of the Agulhas Retroflection area to the south of South Africa, possibly due to a poleward migration of the oceanic westerly winds, with an increase of the leakage of Indian Ocean waters into the South Atlantic and beyond. This will have potential consequences for the global thermohaline overturning circulation.
Changes in primary and secondary production	Along the equator, more stable water stratification is expected with climate change which could result in reduced advection of nutrients from the deeper water to the upper photic zone. This will affect nutrient cycling resulting in changes in the productivity which might have subsequent effects on the distribution of pelagic fishes, recruitment and fish biomass thus potentially affecting the fishing industry. Climate change is expected to lead to a shift in the timing and intensity of synoptic weather systems that affect the monsoon winds that drive large coastal upwelling system along the east coast of Somalia with potential to affect primary productivity in the region. There is a growing concern that low primary productivity will lead to a decrease in the pelagic and demersal fish catches as the absolute amount of organic matter reaching the seafloor depends on the level of primary and secondary production in the surface waters. Several fish species mackerels and some tuna-like species feed directly on zooplankton and a decrease in the zooplankton production will affect the fish production.
Geohazards (tsunamis, volcanic eruptions, earthquakes)	Countries within the WIO were exposed to the tsunami wave as a result a volcanic eruption that occurred off the coast of Indonesian in December 2006. The tsunami wave that hit most parts of the Somali coast, destroyed several coastal fishing villages, killed about 300 fishermen, and resulted in the loss of fishing gear and fishing boats. There is also the risk of volcanic eruptions in the Comoros, Mauritius and France Reunion. Piton de la Fournaise volcano on the Reunion Island has erupted every year in the last 10 years and is the most active volcano in the region. The other active volcanoes in the region include Karthala and La Grille on Grand Comoros. Volcanic eruptions when they occur adversely impacts the coastal habitats including fisheries and can lead to major damage and loss of life and properties.

Cross-cutting Problem Area: Weak 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 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 governance of the WIO coastal and marine ecosystems are as follows.

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 and 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 of transboundary problems in the WIO
The root causes of the transboundary problems related to the coastal and marine environment in the WIO region are presented in the following section:

Common Root Causes
1. Population pressure and demographics Population pressure as a result of rapid population growth over the last century exacerbated by large scale migration to the coast driven by a number of pressures; Expansion of urban areas due to population pressure and migration to the coast has increased the generation of wastes and concentration of waste streams. Also, population growth has led to increased demand for exploitation of coastal and marine natural resources.
2. Poverty and inequality The WIO region is characterized by high poverty levels, which result in increased dependency on the exploitation of natural resources and subsistence living. The consequent lack of financial resources has led to problems such as inadequate sanitation infrastructure, and institutions and regulatory bodies lacking capacity for protection and management of the coastal and marine ecosystems including fisheries.
3. Inadequate and appropriate governance In most countries in 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. Inappropriate governance also is due to inappropriate and outdated legislation, deficiencies in enforcement and compliance, and lack of management and institutional capacity.
4. Inadequate financial resources Most countries in the WIO region lack adequate financial resources, whether in absolute terms or through inadequate priority setting. Most countries have insufficient funds for effective management of the coastal and marine environment. Inadequate financial resources are due low GDPs as well as inadequate mechanisms for leveraging donor funding.

5. Inadequate knowledge and awareness
Inadequate knowledge and awareness on pertinent issues related to coastal and marine ecosystems including fisheries is evidenced by lack of interest by mainstream media on coastal –marine ecosystem issues, lack of awareness of coastal – marine issues among policy makers, lack of or inadequate regulations focussed on coastal-marine ecosystem protection, lack of research and expertise on coastal-marine ecosystems, limited or lack of integration of coastal-marine ecosystem issues in formal educational curriculum at various levels, lack of limited participation of community based organisations (CBOs) and NGOs in coastal-marine ecosystems protection and or management processes at national and regional levels, among others. 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 other major causes of management inefficiencies by coastal communities and policy makers in the WIO region.

6. Climate change and natural variability/processes
Climate change and variability in the WIO region associated with global warming is already influencing sea surface temperatures, rainfall patterns as evidenced by changes in the onset of rainy seasons, changes in the frequency of occurrence and intensity of extreme weather events, changes in the flow patterns of rivers, among others. These are causing floods that impact the floodplains, low-lying coastal areas, deltas and critical coastal ecosystems such as mangroves. Rising seawater temperature is leading to the degradation and loss of coral reef ecosystem through bleaching.

7. Economic drivers
Economic drivers include high international and local market demand for natural coastal-marine natural resources, inappropriate subsidies and incentives, and lack of alternative livelihood opportunities. The demand for ecosystem goods and services is exceeding the availability and regeneration capacity of coastal and marine ecosystems in the region.

G. Culture and traditions
Cultural traditions stem from a legacy of decades of weak or limited environmental management as well as traditional practices that hamper sustainable protection and management of the coastal and marine environment including fisheries in the region.

G. Personal attitudes
Personal attitudes such as a culture of entitlement among some fisher communities and a tendency to shift blame to other stakeholders. Bribery, greed and corruption were also identified as problems that limit protection and management of the coastal and marine ecosystems including fisheries in the WIO region.

The joint TDA has demonstrated that the coastal communities are greatly impacted, 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 in the WIO region living within the coastal zone (<100 km from the coast), as well as economies of the countries as a whole, are all affected by the negative impacts of the continuing degradation of the coastal and marine ecosystem in the WIO region. This calls for joint action in the form of a common Strategic Action Programme (SAP), to address all priority drivers of degradation of the coastal and marine ecosystem in the WIO region. Without direct and specific interventions, the coastal and marine ecosystems will continue to be degraded leading to loss of biodiversity and livelihood of people with major consequences on the economies of WIO countries. The loss of ecosystem goods and services will continue to be felt at local, sub-national, national, regional and global levels if the status quo is maintained in the WIO region.

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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 30° E to 80° E, an area of some 30 million km^2, equivalent to 8.1% of the global ocean surface (FAO, 2007). The region has distinct ocean circulation patterns with two large western boundary currents: the seasonal reversing Somali Current further 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 France Réunion (Figures 1-1 and 1-2).

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, 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 have not escaped urbanization pressures as in the case of Port Louis (Mauritius), Nosy Be (Madagascar), Moroni (Comoros) and Victoria (Seychelles).

The 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 impact 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 region 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 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 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 in the region, becoming especially more diverse towards higher latitudes (Best 2007; Berggren, 2009).

The biological richness and natural beauty of the WIO region, including its beaches, mangrove forests, lagoons, seagrass beds 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 also 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 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 underestimation 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.

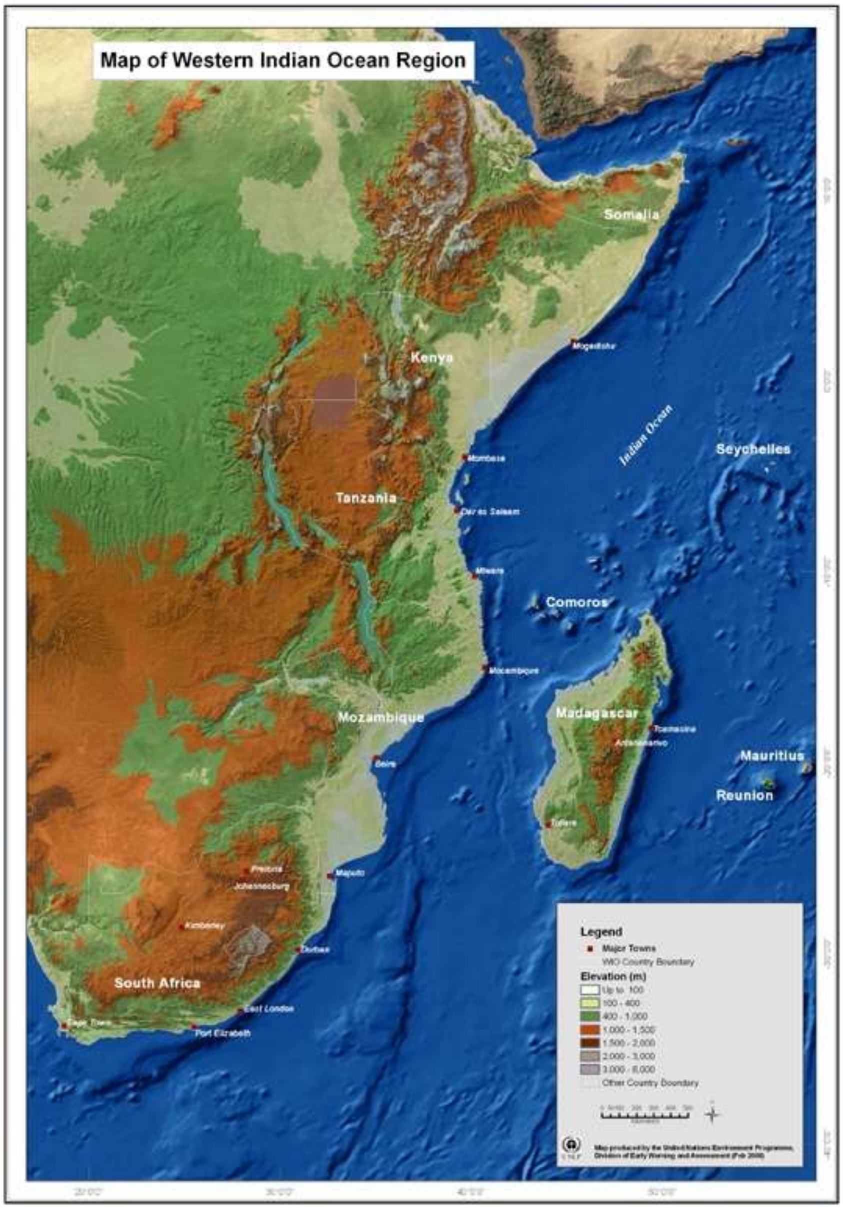


Figure 1-1: The extent of the Western Indian Ocean region

Although the WIO is still considered to be one of the least ecologically disturbed areas of global oceans, it has not escaped the impacts of global change and human development. The region is increasingly becoming threatened by natural and anthropogenic events. In the recent past, coastal and marine ecosystems 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 region is the site of major cities, harbours, industries and other socio-economic infrastructure, which affect the marine ecosystems. Pollution from domestic, industrial and agricultural sources are increasingly degrading water and sediment quality, resulting in loss of biological diversity, human health problems, reduction in fish stocks and associated threats to food security. Human activities are also causing physical alteration of the coastal zone which is inducing or accelerating coastal erosion and further leading to the destruction of vital habitats such as mangrove forests, seagrass meadows and coral reefs. Recognising the enormous development needs of WIO countries and noting the growing natural and anthropogenic pressures 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.

1.3 A call for action and GEF Funded Projects in the WIO

Most countries in the WIO 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 an integrated a regional approach, because the impacts of many sources and activities are not confined to national borders. The dynamic components of the WIO region such as winds, ocean currents, rivers and tides exist on scales larger than geopolitical entities, and over-exploitation, habitat destruction or pollution 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 the causes of degradation of the coastal and marine ecosystems in the WIO.

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) entitled "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:

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 concentrated on the issues relating to assessment and shared management of the region's continental shelf and offshore fisheries (World Bank).

The WIO-LaB project, first of the 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 was a direct follow-on to the 2002 World Summit for Sustainable Development (WSSD) and the related Johannesburg Plan of Implementation, which called 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 was a TDA focused on land-based activities and sources of degradation of the coastal and marine ecosystem in the WIO region.

The Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project and the South West Indian Ocean Fisheries Project (SWIOFP) were part of a multi-agency undertaking to institutionalize cooperative and adaptive management of the Agulhas and Somali Currents large Marine Ecosystems (LMEs) including the Mascarene Plateau LME. The ASCLME Project was implemented by the United Nations Development Programme (UNDP) with the United Nations Office for Project Services (UNOPS) serving as the executing agency. The South West Indian Ocean Fisheries Project was implemented by the World Bank. The countries of South Africa, Mozambique, Tanzania, Kenya, Comoros, Seychelles, Madagascar and Mauritius participated in the implementation of both Projects (Figure 1). Somalia had the status of an observer and was actively involved in the ASCLME Project. France participated in the implementation of the SWIOF Project through the co-financing of the *Fond Français pour l'Environnement Mondial* (FFEM), and was also an active partner in the ASCLME Project.

In addition to these three projects that were implemented in the WIO region in the period 2004-2012, the GEF also subsequently supported the implementation of the two other projects in the period 2017-2023 that were geared towards the implementation of the Strategic Action Programmes (SAPs) that were delivered by the WIO-LaB Project and ASCLME-SWIOFP projects. These two projects were: WIOSAP project addressing degradation of the coastal and marine environment in the WIO and the SAPPHIRE projects that was focussed on the fisheries and large marine ecosystems in the WIO. The two GEF funded projects were implemented within the framework of the Nairobi Convention, with the SAPPHIRE project being executed by UNDP and the WIOSAP project being executed by UNEP. A phased approach was adopted for these GEF funded projects that progressively built the knowledge base and strengthened technical and management capabilities at the regional scale to address transboundary environmental concerns within the WIO. The projects also built political will to undertake threat abatement activities and leverage finances proportionate to management needs in the participating countries.

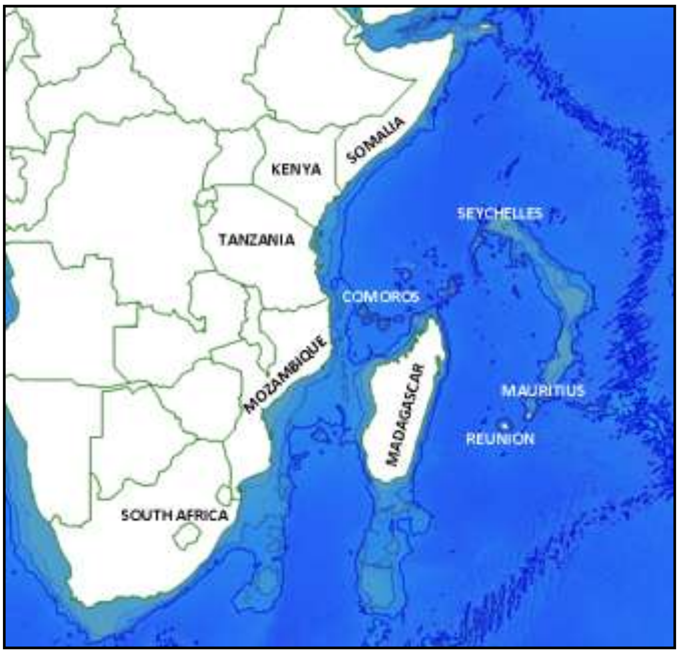


Figure 1-2: Countries that participated in the implementation of the WIO-LaB, ASCLME, SWIOFP, WIOSAP and SAPPHIRE Projects

In view of the fact that GEF and several UN Implementing agencies have adopted the Large Marine Ecosystem approach to the management of coastal and offshore waters, it became necessary to develop a Joint Transboundary Diagnostic Analysis (TDA) that takes onboard the assessment of the threats, impacts and root causes undertaken under the auspices of WIO-LaB TDA and ASCLME-SWIOFP TDA. The Joint TDA will lead to the formulation of a Joint Regional Strategic Action Programme (SAP) for the coastal and marine evosystems and LMEs that identifies an agreed set of governance reforms that the countries will jointly implement to address the priority issues identified in the Joint TDA.

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

The Transboundary Diagnostic Analysis (TDA) is the regional scientific and technical synthesis of the current status of the coastal and marine ecosystems including the large marine ecosystems of the WIO region. Providing a consolidated approach, the TDA brings together the analyses of ecosystem status and threats to the long term sustainability of coastal and marine ecosystems and LMEs as undertaken by the WIO-LaB and ASCLME-SWIOF Projects. As defined by GEF International Waters: "*The purpose of conducting a TDA is to scale the relative importance of sources and causes, both immediate and root, of transboundary 'waters' problems, and to identify potential preventive and remedial actions. The TDA provides the technical basis for development of a Strategic Action Programme (SAP) in the area of international waters of the GEF*." (IW resources guide, terms and definitions). The synthesis presented in this joint TDA will therefore be used to develop a common Strategic Action Programme (SAP) to address the problems of greatest concern facing the coastal -marine ecosystems and LMEs of the WIO region today**.**

A preliminary TDA for the WIO region was prepared under the auspices of the Nairobi Convention in 1998, prior to the formulation of the three GEF Projects. The main perceived problems or issues that were identified were (i) Shortage and contamination of fresh water, (ii) Decline in harvests of marine and coastal living resources, (iii) Degradation of coastal habitats (mangroves, seagrass beds, and coral reefs), loss of biodiversity, (iv) Overall water quality decline and (v) Contamination of coastal waters, beaches and living resources. The preliminary TDA was based on the limited data and information available in the WIO Region at that time, and mainly identified perceived problems that formed the basis for the preparation of the three GEF financed projects (WIO-LaB, ASCLME and SWIOFP). The three GEF projects that were implemented in the period 2005-2012 subsequently generated more data and information and prepared two comprehensive TDAs with the full involvement of countries and stakeholders in the WIO region.

The main purpose of this joint TDA is to provide Contracting Parties to the UNEP-Nairobi Convention with a scientific basis for the identification and prioritization of key issues concerning the degradation of the coastal and marine ecosystems including LMEs and fisheries in the WIO region. The TDA further identifies critical 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 SAP. The TDA also provides the basis for further reviewing and defining new priority areas for the Nairobi Convention's work programme in the WIO region, in addition to contributing to the visions, goals and objectives of other global and regional conventions and policy frameworks including the following:

- United Nations Sustainable 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 also complements the commitments and priorities identified within the Environmental Component of the New Partnership for Africa's Development (NEPAD).

1.5 TDA formulation process and country engagement

The process for the formulation of the joint TDA for the WIO begun during the implementation of the first three GEF financed projects in the period between 2005 and 2012 when the three projects independently delivered TDAs focussed on specific thematic areas. Subsequently, following the implementation of the WIO-SAP and SAPPHIRE projects (2017-2023) within the framework of Nairobi Convention, further process of amalgamation of the WIO-LaB TDA and ASCLME-SWIOFP TDA was undertaken to produce this comprehensive Joint TDA for the WIO region dealing with both the land-based and marine-based sources of degradation of the coastal-marine ecosystems including LMEs and fisheries.

The five main steps that were followed in the formulation of the thematic WIO-LaB and ASCLME-SWIOFP TDAs were (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 and (5) Review and validation. Each of these steps are further elaborated in the following sections:

1.5.1 ASCLME-SWIOFP TDA Process

The process for the formulation of the ASCLME-SWIOFP TDA commenced formally in 2010, and concluded with the fourth and final TDA Working Group meeting in July 2012. The ASCLME-SWIOFP TDA was an outcome of a four-year process of data collection, regional reviews and assessments, and engagement with a wide range of stakeholders in the participating WIO countries. An early decision was made through the Steering Committee to initiate the TDA process at the country level by starting with national Marine Ecosystem Diagnostic Analyses (MEDAs). The MEDAs effectively provided an up-to-date data and information on the status in each country, of the marine and coastal ecosystems, potential and actual impacts and threats, root causes of the impacts, threats, and possible mitigating actions or solutions. These MEDAs were subsequently revised in the period 2018-2022 during the implementation of the SAPPHIRE Project providing more up-to-date data and information that is critical for the joint TDA.

SWIOFP Working Groups

Each of the SWIOFP participating country were supported by a National Management Unit (NMU) lead by a National Focal Point and assisted by National Component Coordinators (NCCs) who are responsible for coordination of all the national activities. Each country had the NCCs in data and information, crustacean fisheries, demersal fisheries, pelagic fisheries, non consumptive resources and fisheries management. Both the National Component Coordinators (NCC) and Regional Component Coordinator (RCC) were hosted by the National Management Units established in all participating countries. The six RCCs were designated to the following NMUs: Component 1 (Data and Information)–Kenya; Component 2 (Crustacean resources)–South Africa; Component 3 (Demersal resources)–Tanzania; Component 4 (Pelagic resources)–Seychelles; Component 5 (Non-consumptive resources)–Mauritius; Component 6 (Strengthening management)–Kenya (Regional Management Unit). The WIO countries were also actively engaged in the review of the status of the fisheries and associated ecosystems through the South West Indian Ocean Fisheries Commission (SWIOFC) Scientific and Commission meetings as well as the relevant technical working groups. This resulted in the preparation of the Retrospective Analysis reports that provided the baseline on the status of the major fisheries in the region.

ASCLME National Technical Groups

In the case of the ASCLME Project, each participating country established a National Technical Coordination Group (COG) under the leadership of the National Focal Point. Each COG consisted of the

(1) Data and Information Coordinator, responsible for archiving of cruise data at national level, driving data policy, coordinating MEDA development and specialist input for the TDA, (2) Capacity Building and Training Coordinator, responsible for coordinating a national capacity building and training review and providing input to the development of a regional training plan, (3) Cruise Coordinator, responsible for coordinating national participation in cruises and (4) Sectoral specialists who participated in the preparation in the technical documents. Each participating country actively participated in the national review of the status of their marine and coastal ecosystems.

In preparation for ASCLME LME TDA, the ASCLME Project supported participating countries to develop national Marine Ecosystem Diagnostic Analyses (MEDAs) reports. These reports consolidated national level data and information on the status of the coastal and marine environment, socio-economics, legislation and threats to coastal and marine ecosystems in each of the participating countries. The MEDAs also captured essential information related to the dynamic biophysical processes that define the LMEs, and identified areas of concern that fed into the Transboundary Diagnostic Analyses (TDAs). The MEDA reports, together with other detailed specialist studies including those on invasive species, marine pollution, coastal livelihoods, commercial fisheries and cost benefit analyses (a total of 58 reports and studies) formed the factual basis of the ASCLME LME TDA.

Issues of concern identified by the countries in the MEDAs were taken through a prioritisation and detailed causal chain analysis process at both national and regional level. This process was used to identify transboundary issues of greatest concern to the participating countries. The process also identified proximal and root causes as well as direct and indirect consequences to coastal and marine ecosystems including human populations. These issues included those related to fisheries since both the ASCLME and SWIOFP representatives were involved in the process of formulating the ASCLME LME TDA.

1.5.2 WIO-LaB LBSA TDA Process

The following section provides details on the process that was adopted in the preparation of the TDA.

Establishment of the TDA Task Team

The WIO-LaB LBSA TDA development process was essentially similar to that which was adopted by ASCLME and SWIOFP. The WIO-LaB LBSA TDA process was led by a regional TDA Task Team consisting of scientific and institutional experts from the WIO region, covering diverse fields such: (1) Marine Pollution, (2) Coastal Habitats (including some aspects of fisheries), (3) River-coast Interactions, (4) Governance and (5) Socio-economics. Details on the members of the Task Team are presented in Annex 1. In order to facilitate integration with the project's workplan, the coordination of the TDA Task Team was undertaken by the WIO-LaB Project Management Unit (PMU) based at the Nairobi Convention Secretariat in Nairobi, Kenya.

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 task team embarked on an initial review of transboundary problems within the WIO region. The findings of this exercise enabled the team to establish a clear work plan 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. The Task Team also facilitated a regional TDA workshop 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

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

The first regional TDA workshop gathered over 40 experts who were grouped into following four Regional Technical Task Forces established under the auspices of the Nairobi Convention:

- 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 including NGOs that are active in coastal and marine ecosystem conservation in the WIO region also participated in the first regional TDA workshop.

Fact finding, data collection and analysis

Following on the outcomes of the first regional TDA workshop, the Task Team embarked on a process of detailed analysis of documented and perceived priority transboundary problems based on available scientific data and technical information. Much of the data and information that were used in this process were gathered during the implementation of the WIO-LaB project as thematic assessment studies or through other initiatives[2]. The following detailed studies formed the main technical documents that supported the formulation of the WIO-LaB LBSA 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 on the detailed studies and in consultation with other specific experts, the TDA Task Team 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 Nairobi Convention/WIO-LaB Technical Task Forces, specifically at a series of meetings held throughout the region[3]. The final step in

[2] 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).

[3] The 2nd meeting of the Regional MWW Task Force (Toliara, Madagascar, 3-5 June 2007);
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 Task Force (Stone Town, Zanzibar, 31 January – 2 February 2007);

the preparation of the WIO-LaB LBSA TDA involved a detailed governance analysis which was undertaken by the Legal and Technical Review Task Force.

Review and validation of LBSA TDA

An important step in the development of the WIO-LaB LBSA TDA involved validation of the outputs of the TDA Task Team by experts and institutions in the region to provide credibility to the process. The principal mechanism for validation of the WIO-LaB LBSA TDA 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 other independent experts. As part of the review process, the draft LBSA TDA was presented to a FARI[4] workshop. Subsequently, FARI nominated experts to participate in the process of reviewing the LBSA TDA. A total of 12 STAC members selected on the basis of their expertise were involved in the review of the TDA. The results of this review process were presented and agreed upon in a regional meeting of STAC in which members of TDA Task Team[5] also participated. The STAC feedbacks were subsequently used by the TDA Task Team to finalize the LBSA TDA that was subsequently circulated for endorsement by STAC. The final version of the LBSA TDA was subsequently presented for endorsement to the WIO-LaB Project Steering Committee in May 2009.

The final version of the WIO-LaB TDA together with the LME TDA delivered under the ASCLME-SWIOFP process were subsequently integrated in 2022 to form the current Joint TDA for the WIO region that comprehensively addresses land- and marine–based sources and activities responsible for the degradation of the coastal and marine ecosystems including large marine ecosystems and fisheries of the WIO. In view of the fact that the WIO-LaB LBSA TDA and ASCLME LME TDAs were delivered a decade ago (2009-2012), a comprehensive process of updating data and information for the joint TDA was undertaken partly through the use of new data and information presented in the national MEDAs but also through the use of most current information presented in various thematic reports delivered in the period 2017-2022 under the auspices of the SAPPHIRE and WIO-SAP projects. Therefore, this joint TDA presents the most current situation in the WIO region in as far as sources, causes and impacts of transboundary problems driving the degradation of coastal and marine ecosystems (including fisheries and LMEs) in the WIO are concerned.

2 Defining the Management Boundary of WIO Ecosystem

For the purposes of effective ecosystem management and governance of any natural system, certain management boundaries must be agreed upon. The objective of the definition of a boundary is to motivate for the management of a whole system using a large marine ecosystem approach. In the case of a relatively open ocean system, these boundaries can be defined on the basis of bathymetric features, patterns of biodiversity, patterns of ocean currents and productivity, temperature of chlorophyll fronts, movement and dependencies of migratory species, or socio-economic, governance or cultural features of the human population.

The three LMEs in the WIO are the Somali Current LME, Agulhas Current LME and the Mascarene Plateau LME (Figure 1-3). The original definition of the Agulhas and Somali Current LMEs only considered coastal currents and areas within Exclusive Economic Zones (EEZs). However, it has long been recognised that the Mascarene plateau region must be included in the LME approach for the WIO region due to the connectivity of the WIO islands and the mainland countries, driven largely by the South Equatorial Current and connected by sub-regional eddy, coastal current, counter-current and upwelling systems. The region also has a shared historical, cultural, political and biological (indo-pacific) history as the WIO which extends from the South-East of South Africa up to the horn of Africa and includes the WIO island states.

Since at least 2008, the source region of the Agulhas current, including the islands of Mauritius, La Reunion (France), Seychelles and Comoros, has been included in the greater Agulhas Current LME (Heileman *et al.* 2008). Even so, this boundary is not discrete, with the seasonal South Equatorial Counter

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

Current introducing connectivity from mainland East Africa and the Somali Current LME to the Seychelles Islands.

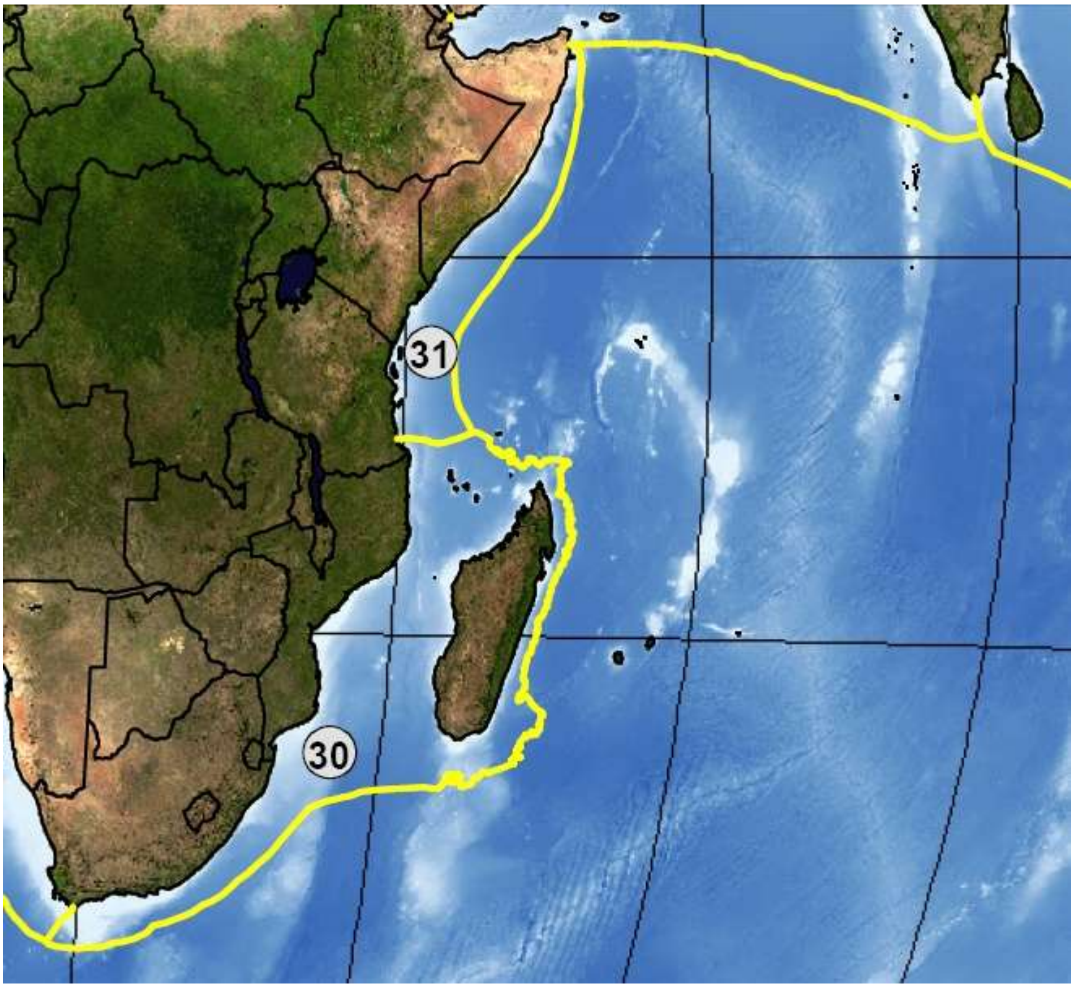


Figure 1-3: Large Marine Ecosystems of the World; 30–Agulhas Current; 31- Somali Current (http://www.lme.noaa.gov accessed 01-2011).

In this joint TDA, the area that is considered to be the Western Indian Ocean region is shown in Figure 1-4. This region includes the following:

1) The major surface currents directly associated with the Agulhas and Somali Currents,

2) The defining bathymetric features (ocean basins) of the region, bounded by the Carlsberg Ridge, Central Indian Ridge and Southwest Indian Ridge, and

3) The culturally diverse yet historically connected peoples of southern and East Africa as well as the Indian Ocean Islands.

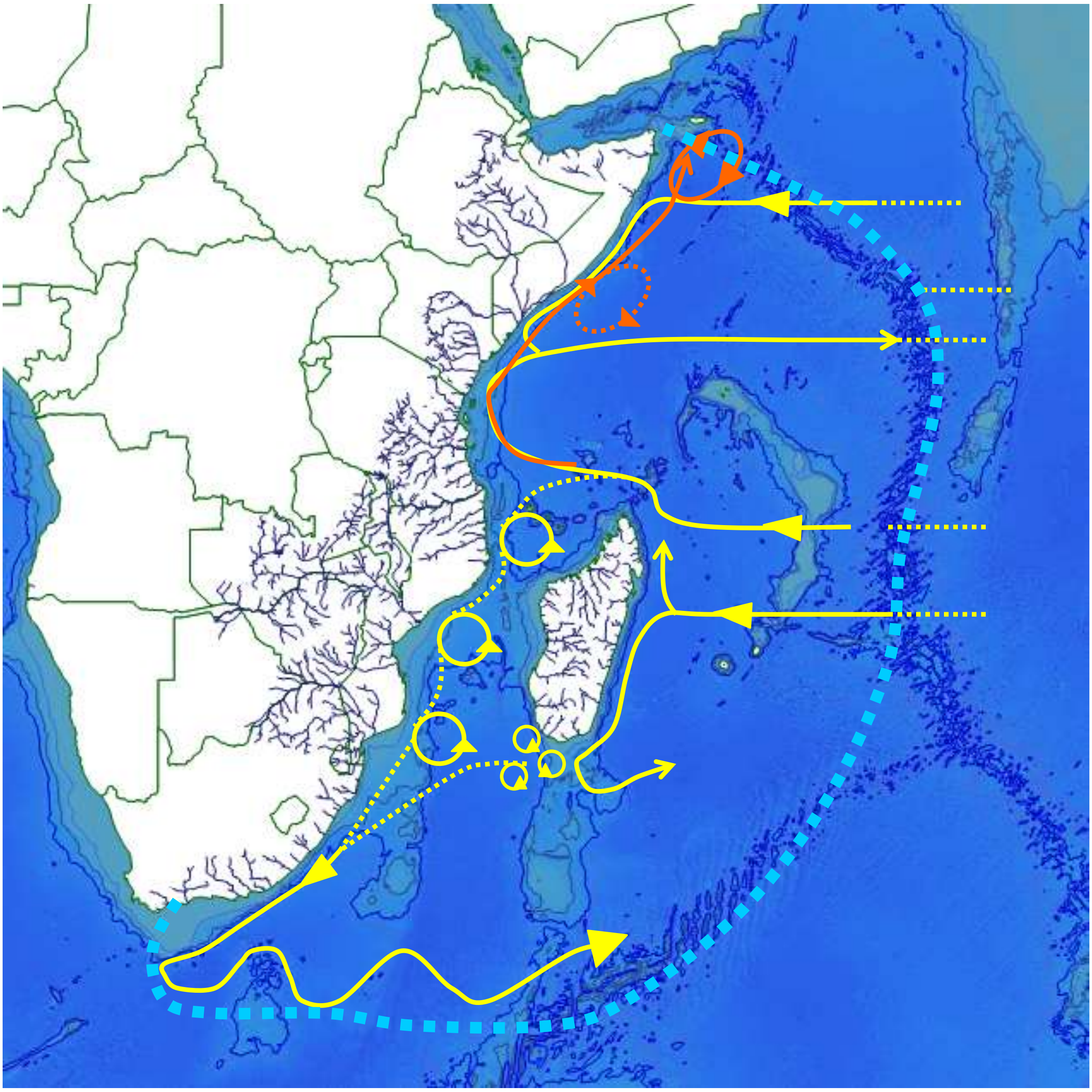


Figure 1-4: The provisional management boundary for the WIO region.

In defining the landward (western) boundary of the WIO region, it is important to note that discharges from major rivers have an impact on the coastal and marine ecosystems in the region. Also, major towns and cities, especially those located on continental mainland Africa have a significant polluting effect in the coastal and marine ecosystems. With this in mind, landward extent of the WIO region should extent into the river basins draining into the WIO as this is important for ensuring a comprehensive ecosystem approach to problem analysis. The eastern boundary lies approximately 67 degrees East to include the EEZs of all the major WIO island states, the South Equatorial Current and the Central Indian Ridge. The southern boundary lies approximately 42 degrees South and approximately 20 degrees East to include the Agulhas Current region, as well as the Agulhas Return Current. The important seamounts of the SWIO are included, but not the EEZs of South Africa and France in the Southern Ocean. The northern Boundary lies 10 degrees North, to include the Somali current, offshore upwelling and great whirl, but excludes the EEZ of Yemen. The southern boundary is dynamic, changing with the Agulhas retroflection and leakage of Indian Ocean water into the South Atlantic. 27 degrees East was taken as the Benguela Current LME boundary, and although there is an overlap with the stated WIO LME boundary here, this is to be expected given the exchange of water and biota between the systems. Although these boundaries are chosen to facilitate a pragmatic ecosystem approach to management in the region, connections in surface and deep ocean circulation exist to the East, with the eastern Indian Ocean, to the southwest with the Atlantic Ocean (BCLME), to the North with the Arabian Sea and to the north-east with the Bay of Bengal (BOBLME).

3. Baseline Environmental Status and Physical Setting

3.1 Location and Geographical setting

The WIO region has a combined coastline exceeding 16,400 km and a total continental shelf area of about 475,000 km^2 (Table 1-1)[6]. The region is characterized by a wide diversity of habitats including sandy beaches, rocky shores, 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 1-1: Key geographical characteristics of the WIO region Countries

Countries	Land area (km^2)	Coastline (km)	Territorial waters (km^2)	Continental Shelf (km^2)	EEZ (million km^2)
Comoros	2,230	427	12,684	900	0.160
Madagascar	581,540	4,828	124,938	96,653	1.079
Mauritius	1,865	372	16,840	27,373	1.900
Seychelles	455	491	45,411	50,000	1.374
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	**4,100,114**	**16,454**	**463,725**	**475,919**	**7.53**

Note: Data extracted from the GEO Data Portal, 2003[7]

3.2 Coastal zone, continental shelf and the deep ocean

The Western Indian Ocean (WIO) is one of the most geologically diverse of the world's oceans, containing active and fossil plate boundaries, fracture zones, complex mid-ocean ridge configurations and some of the thickest known sedimentary sequences (Parson and Evans 2005). The topography of the sea floor has a significant influence on the oceanographic environment, water flow and marine biophysical processes.

The WIO covers approximately 22.3 million km^2, is floored by deep abyssal plains and bounded to the west by non-volcanic continental shelves (Parson and Evans 2005). This ocean was formed by the break-up of Gondwanaland over 160 million years ago (Ma), which saw India, Madagascar and Antarctica break away from the African continent. India and Madagascar separated from Antarctica approximately 120-130Ma, and subsequently from each other ca. 85Ma, with India continuing to move northwards. The movement of plates northward over the stationary La Reunion hotspot formed the Maldive and Laccadive islands, Chagos bank, and the volcanic ridge underlying much of the Mascarene Plateau, as well as the Mauritius-Reunion island chain (Duncan and Hargreaves 1990, Muller *et al.* 1993, Parson and Evans 2005).

Three major features dominate the seafloor topography of the WIO; the Chagos-Laccadive Ridge, the Indian Ocean mid-ocean ridge, and the most prominent bathymetric feature of the Indian Ocean, the Mascarene Plateau, which extends as a vast submerged part-continental and part-volcanic plateau for over 1500 km (Figure 1-5). The Mascarene plateau is made up of the Seychelles Plateau, the Ritchie Bank, the Saya de Malha Bank, the Nazareth Bank and the St Brandon shoals to the south (Parson and Evans 2005). Between these features, islands and continental shelves, four basins formed by complex spreading

[6] Based on data in the National MEDAs (2022)

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

patterns make up the deepest parts of the WIO; the Central Indian Basin, the Madagascar Basin, the Somali Basin, the Mozambique Basin, and the Mascarene Basin (Mart 1988, Parson and Evans 2005).

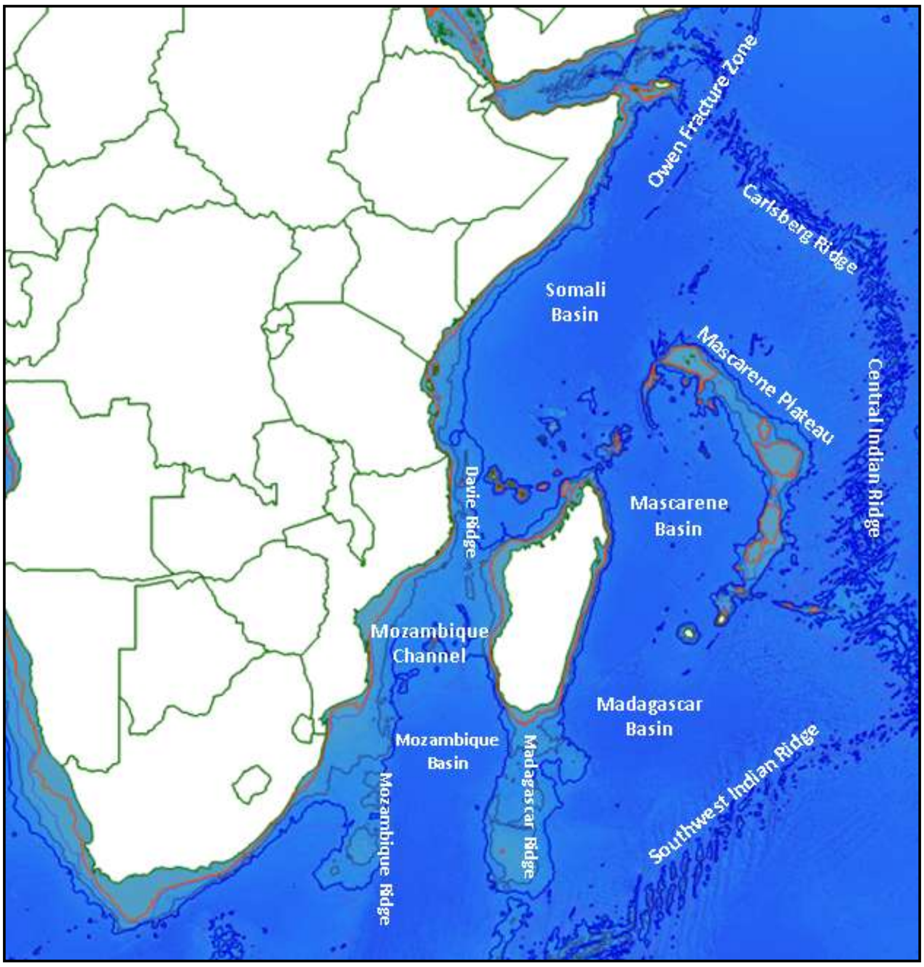


Figure 1-5: Bathymetry and geological features of the Western Indian Ocean, the 200m isobath is shown in red (Parson and Evans 2005)

The continental shelf is the flooded margin of a continent, extending from the shoreline to a point of increasing slope; the shelf break. The continental shelf of the WIO region tends to be narrow in the North, off the Somali coast, gradually widening to the South, and extending to 150m depth on average. Features of the offshore coastal zone and continental shelves have a significant effect on ocean current flow, and thus on the biophysical characteristics of the region. The widening of the continental shelf in the vicinity of St Lucia and the Agulhas Banks, for example, has been shown to drive local upwelling (Lutjeharms *et al.* 1999).

The mainland WIO continental shelf, particularly in northern South Africa and northern Mozambique, is incised by canyons up to 1.5 km long and 750 m deep, extending from the continental shelf to the abyssal plain (Figure 1-5) (Harris and Whiteway 2011, Ramsay 1994). Modification of ocean currents, local upwelling and mixing in the vicinity of canyons can have extremely important effects on local oceanography and physical processes (Harris 2011). Aggregations of commercially important pelagic and demersal fish species have been associated with canyons, as have species of conservation importance such as the coelacanth, *Latimeria chalumnae* (Nulens *et al.* 2011). Canyons may also act as conduits for the transport of sediments and nutrients from the continental shelf to the deep sea.

Approximately 700 seamounts have been identified in the WIO region from global studies of bathymetry). Being raised from the ocean floor, and often with exposure to more light because of their lesser depths, seamounts are well known to be hotspots of biodiversity and marine biomass in the pelagic ecosystem. As such, they are often targeted by fishing vessels. Closed circulation cells may form around seamounts, trapping nutrients, inducing upwelling and enhancing primary productivity (Harris 2011, Keating *et al.* 1987). Enhanced primary productivity attracts seabirds, marine predators and attracts a range of pelagic species, and makes them favoured breeding and feeding grounds for demersal species (some of commercial importance e.g. the orange roughy). Being isolated habitats, seamounts are characterized by a high degree of endemism (Rogers *et al.* 2009).

3.3 Climatic conditions

The climate in the WIO region ranges from sub-tropical to tropical (FAO, 2005). Mean daily temperatures in the northern parts range from 25^{o}C-29^{o}C, while the hottest summers reach 35^{o}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 is the smallest, ranging from 26^{o}C to 32^{o}C (Hughes *et al.*., 1992; Kenya MEDA, 2022). Mombasa has an annual mean temperature of 26°C, with minimum temperature of 24^{o}C and mean maximum temperature of 32^{o}C (Kenya MEDA, 2022). In Tanzania and northern Mozambique, mean maximum temperature ranges between 31^{o}C and 32^{o}C and the minimum temperatures range 21^{o}C - 23 ^{o}C (Tanzania MEDA, 2022; Mozambique MEDA, 2022), while average annual temperature on the east coast of South Africa are 21^{o}C, reaching an annual maximum mean of 29^{o}C (AFRISCO, 1994; IUCN 2003; FAO, 2005; Preston-Whyte, 1980). Lower temperatures, between 8-10^{o}C, can occur from June to August in the southern extreme of the region.

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) (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 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) (Ngusaru, 1997; Slingo *et al.,* 2005).

The rainfall in the WIO 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 2,000 mm and in most cases is in the range of 500 to 1,000 mm (FAO, 2005a; Kenya MEDA 2022; Tanzania MEDA, 2022).

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; Kenya MESA, 2022; Tanzania MEDA, 2022; Kenya MEDA, 2022). 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 rainfall 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 WIO 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).

3.4 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 Western 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). In the coastal fringes of Kenya, Tanzania and Mozambique, the sedimentary rocks are boarded by metamorphic crystalline rocks of the Mozambique belt formed during the Precambrian, about 550 ±100 millions years ago (Windley, 1986; Kent *et al*, 1971; Shaghude, 2012). Some of the detached continental fragments comprise the granitic islands of the main Seychelles group and the island of Madagascar. The more recent outer islands of the Seychelles 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 m 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 wave-cut 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 m. 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 km from the Equator southward, with water depths ranging mostly from 8-150 m. 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.

3.5 Hydrology, River Basins and Estuaries

There are twelve main river basins within the WIO region (Figure 1-6). Table 1-2 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.

Table 1-2: Overview of the main rivers in the WIO region

River	**Area (km^2)**	**Length (km)**	**MAP[8] (mm)**	**MAR[9] (mm)**	**Average flow (mm^3/yr)**	**Highest flow month**	**Lowest flow Month**	**Sediment Load (Mt/yr)**
Tana	126,828[a]	1,102[b]	566[a,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]	Sept[i,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]	Nov[p,o]	16.5[n]; 15-25[o]; 17[q]
Ruvumaz	155,400[p,r]	800[p,s]	1,160[s]	96[t]	28,000[t, 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]	395[w]	1,100[w]	115[t]	6,600[t]	Feb[w]	Oct[w]	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]	Sep[v]	7[ii]
Maputo	28,500[t]	380[t]	630[t]	102[t]	2,900[t]	Feb[t]	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; Kitheka 2004; Kitheka et al., 2022).

The zone of interaction between the freshwater and the saltwater ecosystems- the estuaries - is of significance to this study. 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 (Kitheka 2002; Kitheka et al., 2004). 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 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. Tables 1-2 and 1-3 provide 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 river basins that eventually impacts estuaries in

[8] MAP: Mean Annual Precipitation
[9] MAR: Mean annual Runoff

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.

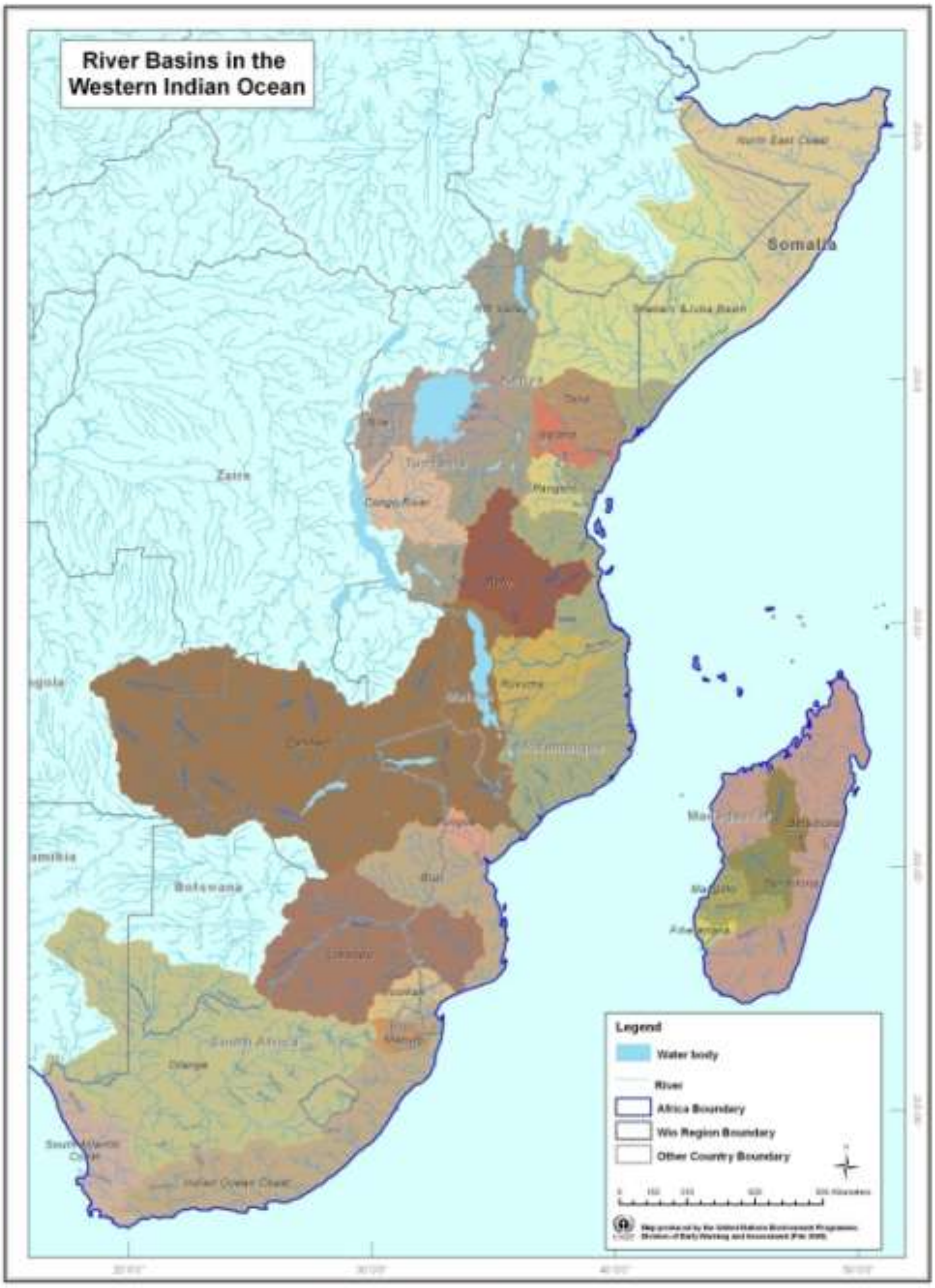


Figure 1-6: The main river basins in the WIO

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; Kitheka, 2019, Kitheka *et al*., 2022; 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 1-3: 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 Malindi-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,	Sustains rich offshore Sofala Bank with its fisheries, key nursery ground for fish and offshore shrimp resources (ZRA, 1998;

River	Key facts	Key ecological functions
	2006).	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).

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 the city of Nairobi (UNEP, 1998; Kitheka *et al*., 2004; Kitheka *et al*., 2022). The Athi-Sabaki is a transboundsary river as part of its catchment is found in northern Tanzania. 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 river extents into northern Tanzania to receive 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). A large dam-Thwake Multi-purpose dam is under construction in the middle upper part of the basin and is expected to be commissioned in 2023. Thwake dam is expected to have major impacts in terms of river flow and sediment load reduction downstream with potential disastrous consequences in Malindi bay (Snoussi *et al*., 2004; Kitheka, 2018; Kitheka *et al*., 2022). 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 five major rivers in the Tanzania mainland which contributes 50% of total freshwater discharge into WIO are Rufiji, Pangani, Wami, Ruvu and Ruvuma, while the minor rivers such as Mbwemkuru, Lukuledi and Matandu are seasonal rivers and are less important in terms of freshwater discharge to the WIO (Francis *et al*, 2001; Tanzania MEDA, 2022). The longest river is Ruvuma whose main tributary extends into Mozambique and drains into the WIO through Cabo Delgado Nappe, Unango and Marrupa complexes (MoW 2019; Fossum *et al*. 2020). The total annual water discharge of Ruvuma river is 9,240 million cubic meters per year (MCM/year). There is no water abstraction for hydropower, industrial or mining in the Ruvuma river basin. Wami/Ruvu is the 3rd largest basin covering about 7% of the total area of the country. Wami river has discharge approximately to 3,280 MCM/year while Ruvu river has a discharge of 1,370 MCM/year (MoW, 2019; Tanzania MEDA, 2022). Wami/Ruvu basin has the limited water resources and the consumption of water is relatively high. The main consumption of water includes domestic uses (345 MCM/year), irrigation (682 MCM/year), livestock and aquaculture (34

MCM/year), hydropower (2 MCM/year) and ecosystem and wildlife (298 MCM/year). Large amount of water in Ruvu/Wami is also used for irrigation and domestic uses and water resources vulnerability is increasing in the basin (Tanzania MEDA, 2022). The Pangani River is a transboundary river basin shared by Kenya and Tanzania with much of its headwaters in the Kilimanjaro and Meru mountains (PBWO/IUCN, 2007; Hamerlynck *et al*., 2008.). The Pangani River flows into the WIO through Pangani Estuary (PBWO/IUCN, 2007). Pangani river basin is the smallest basin as it covers less than 6% of the total area of the country (MoW, 2019). The basin includes some of the most biodiverse areas in Eastern Africa such as the endemic-rich flora and fauna of Mt Kilimanjaro and Mt Meru, the famous plant and animal diversity of the East Usambara Mountains, Jipe lake and wetland systems, dry Maasai Steppe, Pangani Falls system and estuary and mangrove swamps (MoW, 2020). In 2019, water availability approximated 7,970 MCM of which 7,383 MCM was surface water and 58 MCM was groundwater (MoW, 2019). The abstraction of water in the Pangani river is very high. In 2019, water utilized for hydropower and irrigation was approximately 6,439 MCM out of 7,970 MCM of water available and 157 MCM was used for the domestic purpose (MoW, 2020; Tanzania MEDA, 2022).

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-fringed Funzi Bay near 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. Rufiji river has the highest flow estimated to be 22,250 MCM/year. At present, the river is an important resource for water abstraction and fishing (Shaghude, 2004). The river discharges into the WIO through a delta situated 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). A large dam namely Julius Nyerere HEP Dam is being constructed in the upper parts of the Rufiji river and it is expected to be commissioned in 2023. 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 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).

Mozambique -The Rovuma river is a transboundary river forming the boundary between Tanzania and Mozambique for the final 650 km of its journey to the Western Indian Ocean (Pallet, 1997). The total basin area is 155,000 km^2 with 65.39% occurring in Mozambique, 34.30% in Tanzania and 0.31% in Malawi (Mozambique MEDA, 2022). With an average discharge of 356 m^3/s, the Rovuma river is considered the second largest in Mozambique after the Zambezi basin which has a discharge of 3,558 m^3/s. The Rovuma basin is an important water catchment area for the conservation of biodiversity. The river rises from the Matogoro Mountains in southeast Tanzania and flows across the Makonde Plateau before flowing into 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 and is a dominant feature in the region with 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).

The Zambezi River basin (1.4 million km^2) is the fourth largest in Africa after the Congo, Nile and the Niger. The River originates from the Kalene Hills in the North Western Province of Zambia and flows south and then eastwards for some 2,650 km to the Indian Ocean. The mean river discharge is 3,558 m^3/s. The Zambezi River is a transboundary river system since it flows through nine riparian states, namely Angola, Botswana, Democratic Republic of Congo (DRC), Malawi, Namibia, Tanzania, Zambia, Zimbabwe and Mozambique (Mozambique MEDA, 2022). The exploitation of waters of the Zambezi river 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 major environmental impacts downstream (Beilfuss, 1999). Proposals for the development of these dams did not seriously consider downstream environmental impacts (Brown and King, 2002) and, as a result, adverse impacts of the dams were not effectively mitigated against. The major impacts observed at the coast include reduction in terrigenous sediment loads which has increased downstream scouring and erosion of the delta, 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 WIO directly off its delta, through the transport of vital nutrients downstream which are discharged into the sea (ZRA, 1998; Brown and King, 2002). 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 major flood events (Brown and King, 2002). This has had a negative impact on fisheries, prawn catches and mangrove forests in Mozambique (ZRA, 1998; Hirji *et al*., 2002). The floodplains of the delta have also 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 m, then travels 395 km eastwards into the Western 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 Western Indian Ocean through Mozambique at an estuary located some 20 km northeast of the city of Beira, at Bué Maria. Although there is no dam upstream of the river, a water pipeline transferring 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) has been constructed 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 is critical for restricting seawater intrusion upstream of the main source of Beira's freshwater supply. A flow of $10m^3/s$ is considered minimal to safeguard the intake of freshwater for Beira (Van der Zaag, 2000). The 10% baseflow (i.e. the flow with a 10 % chance of occurring; with a return period of 10 years) at Bué Maria has been set 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 is another transboundary river that drains parts of Botswana, South Africa and Zimbabwe, some of the most economically developed areas in the WIO region. The river flows into the Western 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). Although there are no large dams on the main stem of the Limpopo 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 extents up to 55-80km upstream 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 a transboundary river 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 in the recent past (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 is also a transboundary river with 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. Although the Maputo River basin is small in terms of size as well as discharge, it, along with the Incomati in River, is one of the two largest rivers that sustains ecological systems in 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 and the Incomati rivers (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 over-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). Other river systems in Mozambique are Montepuez river, Messalo river and several small coastal basins to the northeast such as Muagamula, Sicoro-Lingula, Messingue and Necumbi, Lúrio, Megaruma, Muaguide and coastal basins to the south such as Tara-Quilite, Meapia and Ridi. The Messalo River basin has a total area of 24,437 km^2 (Mozambique MEDA, 2022).

South Africa - South Africa forms part of the transboundary water resources under the Southern African Development Community (SADC) (Kistin and Ashton 2008). There are six major transboundary river basins in South Africa namely Incomati basin, Umbeluzi basin, Maputo-Usutu-Pongola basin, Limpopo basin and Orange-Senqu basin that are shared with five southern African states of eSwatini, Mozambique, Namibia, Zimbabwe, Botswana and Lesotho (Ashton et al. 2008; Kistin and Ashton 2008; Turton and Ashton 2008a; Ashton and Turton 2009). The Thukela river is one of the most important in South Africa as it flows into the WIO. The river catchment has a notably steep gradient, extending from sea-level to the Drakensberg Plateau with peaks of over 3,000 m within a distance of 180 km from the coast (Forbes *et al*., 2002). Rainfall in the catchment is erratic and years of prolonged drought in the central and lower Thukela river basin alternate with very wet periods. 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 river discharge and 25-30% of the total river 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 m altitude (Shahin, 2003). The river is navigable for about 140 km 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 found in the lower course of the river has 150 small lakes that include Amparihibe-South (12.5 km^2), Ambania (9.1 km^2), Amboromalandy (6.6 km^2) and Bondrony and Matsiabe (5.0 km^2) (IWMI, 2006). 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 high sediment load emanating from highly eroded catchments experiencing high rates of soil erosion, reaching up to 250 tonnes per hectare (IWMI, 2006). The heavy sedimentation problem in the river has also been exacerbated by gold mining activities upstream of the river. The river is therefore turbid throughout the year due to discharges from mining fields and highly degraded catchment areas situated upstream.

Mauritius- The Island of Mauritius is divided into 25 major river basins and 21 minor ones (Mauritius MEDA, 2022). The catchment areas vary from 3.9 km^2 to 172.7 km^2 and almost all the major rivers are perennial (Ministry of Energy and Public Utilities, Hydrology data book 2000-2005). Most of the rivers have their source in the central plateau and flow radially to the sea. The relief of the country, size and shape of the watersheds are such that heavy rainfall results in flash floods with very sharp peaks. Flows in streams and rivers vary from a few litres per second to more than 500 m^3/s during floods (Sharma, 2000). The Island of Rodrigues has been divided into 20 major river basins and 10 minor ones. The catchment areas vary between1.08 Km^2 and 6.73 Km^2. The deep valleys with steep gradients and the absence of impounding reservoirs in Rodrigues result in most of the rainfall over the island being lost to the sea as high velocity runoff. Due to negligible infiltration to groundwater, base flow of Rodrigues rivers is very low. The flows range from 1.4 l/s in River Grenade to 56.9 l/s in River Baie aux Huitres (Ministry of Energy and Public Utilities, Hydrology data Book 2000-2005).

Seychelles- There are 146 water courses on the three main islands of Mahe, Praslin and La Digue listed for protection under the State Lands and River Reserves Act (1976) (GoS, 2020). The lower reaches of watercourses have been affected by human activities including nutrient enrichment and chemical pollution, canalization and reclamation of flood plains. There are 38 catchment areas on Mahé Island covering a total surface area of 56 km^2, 11 on Praslin with an area of 8.6 km^2 and 8 smaller catchments totalling 1.2 km^2 on La Digue. The major catchments on the main island of Mahé are the Mare Cochons, Le Niol, Grand St Louis, Rochon, Mamelles, Cascade and Baie Lazare; on Praslin, the major catchments are Nouvelle Decouverte Salazie, Anse Kerlan and Fond Boffay catchments whilst Maurice Payet is the biggest catchment on La Digue. The principal freshwater sources are found on Mahé, Praslin and La Digue where several river catchments interconnect with numerous rivers and streams. Many of the rivers are ephemeral with very few perennial ones (Seychelles MEDA, 2022).

Somalia: Somalia is a dry and arid nation with annual rainfall averaging just 100 mm in the north-east and 200-300 mm in the central plateaus. The country has nine significant water basins namely the Gulf of Aden, Darror, Tug Der/Nugal, Ogaden,Shebelle, Juba, Lag Dera, Lag Badana, and the Central Coastal Basin (Jama and Mourad, 2019). The Juba-Shebelle river complex provides water to the south-western region, which is also the country’s grain breadbasket. Somalia’s total accessible water is estimated to be around 14.7 km^3, with the Juba-Shebelle river complex accounting for the lion’s share (FAO SWALIM, 2022; Somalia MEDA, 2022). Both Juba and Shebelle rivers are transboundary rivers with catchment areas extending into Ethiopia and Kenya. Although the two river systems discharges a large volume of sediments, nutrients and freshwater to the coast, little is known about their hydrological characteristics and level of utilization.

3.6 Oceanography and Productivity

The general oceanography of the WIO is driven by the various influences of the seafloor bathymetry, configuration of continental masses, input of water from surrounding oceans, and interaction with the atmosphere (Figure 1-5). WIO characteristics are also 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).

3.6.1 Tidal Regime

The WIO region experiences predominantly semi-diurnal tidal regime and the tidal ranges during spring and neap tides vary tremendously across the region. The northern parts of the WIO experiences mixed tides along the coast of Somalia where the tidal range is around 3.5 m in the south and is less than 1.5 m in the north coast. Tides in the Gulf of Aden are relatively small ranging from 0.20 to 0.30 m (Somali MEDA, 2022). Tides along the Kenyan and Tanzanian coast (including the main islands, Pemba, Unguja and Mafia) are predominantly semi-diurnal with a Form Factor of about 0.16 (Ngusaru 1997; Mahongo and Francis, 2010; ASCLME, 2012; Shaghude *et al*, 2012). In Kenya, the spring tidal range varies from 3.2 to 3.5m and neap tidal range varies from 0.9m to 1.4 m (Kitheka *et al.*, 2004; Nguli *et al.*, 2004, Brakel 1982, Tychsen, 2006). Along the coast of Tanzania, the mean neap tidal ranges varies from 0.9 to 1.2 m, while the mean spring tidal ranges varies from 3.0 to 3.6 m (Ngusaru, 2002; ASCLME, 2012). Mozambique coast also experiences semi-diurnal tides with the mean spring tidal range varying from 1.4 m to 3.7 m above mean sea level (Theron *et al*., 2012). In general, lower tides of about 1.4 m above the mean sea level are observed in the southern Mozambique and in the northern region, the mean high water spring tidal level increases to 2.9 m above MSL at Beira, 3 m at Nacala and 3.7 m above MSL at Mocimboa da Praia (Theron et al., 2012). The mean spring tidal ranges along the Mozambican channel reach 6 m (3 m above MSL) and are the maximum ranges observed along the entire African coast (Orme, 2005).

Tides around South Africa are also dominated by the semi-diurnal tides with a period of 12.42 hours. However, the diurnal tide of approximately 24 hours is also significant. Tidal ranges in spring tide are 1.8 m, which categorizes these tides as micro-tidal (Meyer *et al.*, 2005). However, tidal ranges at times can be over 2 m, which would classify them as meso-tidal (Searson and Brundrit, 1995; Meyer *et al.*, 2015). The neap tidal range along the coast of South Africa varies between 0.4 and 0.5 m (South Africa MEDA, 2022). In the Mascarene Island of Mauritius, the tides are also semi-diurnal with a tidal range of 0.50 m during spring tides and much smaller range 0.20m during neap tides. However, during annual king spring tides (March and September), the tidal range increases to as high as 0.85 m (Mauritius MEDA, 2022). In the Comoros, the spring tidal ranges vary from 3 to 4.9 m and during neap tide the tidal range is of the order 1m (Comoros MEDA, 2022).

3.6.2 Sea Level Changes

The WIO is experiencing significant interannual variation in sea level due to thermal expansion of the ocean attributed the global warming and steric effects that are attributed to salinity variations (Figures 1-7-2-0). There are however significant differences in the rates of sea level rise in the region. For instance, along the coast of Tanzania, the highest sea level occurs during March–May and the lowest occur during July–September (Mahongo and Julius, 2010). This pattern is also observed at Dar es Salaam Harbour and Kilindini Harbour in Mombasa, Kenya, but considerably different patterns occur at Tanga in northern Tanzania, where the highest and lowest sea levels occur during July to September and February to May, respectively (Ragoonaden, 1988). Sea level variability is characterized by both annual and decadal variability with an overall decreasing trend before the year 2000, followed by an increasing sea level trend after the year 2000 (Makame, 2012; Mahongo, 2014; Salum, 2021; Figure 1.9). The decadal variabilies are influenced by sun spot activities which have a cyclicity of about years. The Zanzibar tide gauge sea level records are therefore characterized by two high peaks in June 1988 and December 2009, and a low peak in April 1999 (Figure 1-9). The average sea level anomaly in the first phase (1984-1994) was about 21.37 mm above the long term mean. This phase was followed by a second phase (1994-2004) of low sea levels with mean anomaly of -20.08 mm, and later high sea levels that had mean anomaly of

25.08 mm the third phase (2004-2011) to slightly above the original level (Tanzania MEDA, 2022). Along the Kenya coast, data from KMFRI GLOSS Mombasa tide station shows that sea level is increasing at a rate of about 2mm/year which is consistent with the global trends, according to the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC, 2014). The sea-level rise for the southern Africa region has been estimated to range between 1.0 to 2.5 mm/year (Church et al., 2004; Mozambique MEDA, 2022). This estimate is based on sea-level data covering the period from 1950 to 2000. The global trends of sea-level rise for the southern Africa region are consistent with more refined global trends, which present sea-level rise values between 1.3 and 2.3 mm/year (INGC 2009). For the past decade, global sea level has increased at a rate of 3.3±0.4 mm/year (Rahmstorf *et al.*, 2007; Stocker *et al.*, 2013; Davis-Reddy and Vincent, 2017). Along the South African east coast, sea level is rising at a rate of 2.74 mm/year (Mather *et al*., 2009, Davis-Reddy and Vincent, 2017; Wepener and Degger, 2019). In the Mascarene Island of Mauritius, relative sea-level rise of approximately 3 mm/yr (Emery and Aubrey, 1989; Ragoonaden 1997). Sea level rise has been accelerating with a marked upward trend in Mauritius especially since 1996 (Figures 1-8a-b and 1-10). In the Seychelles, the annual long term trend shows a rate of rise in sea level of approximately +0.5cm/year (1993 to 2020), but this value has increased to +0.61cm/year. This is a clear indication of a higher sea level rise over the Seychelles compared to the projected global mean sea level rise +0.31mm per year (Figure 1-10) (Seychelles MEDA, 2022).

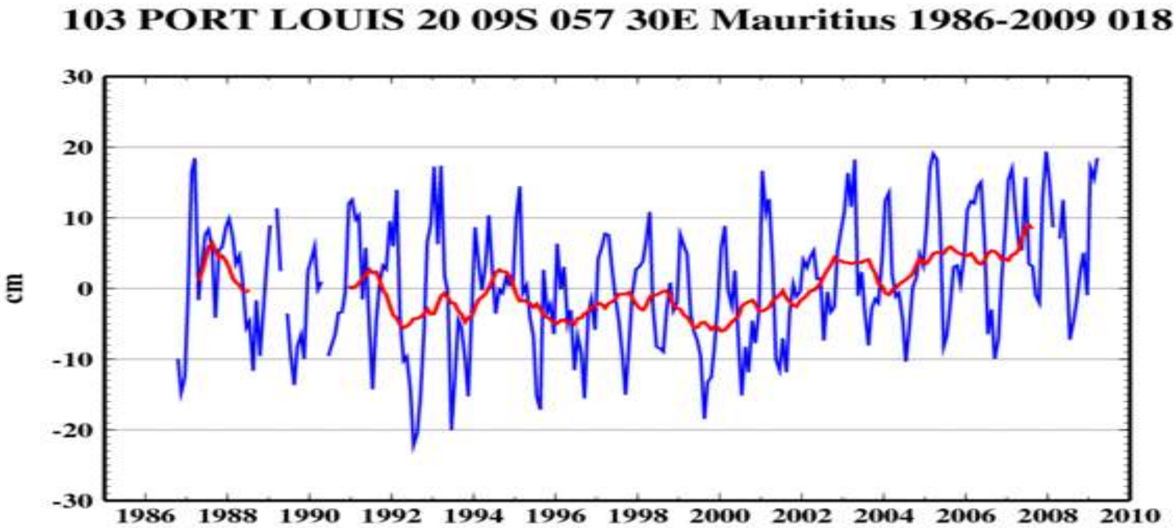


Figure 1-8a: Variability of sea level (1986-2010) at Port Louis, Mauritius.

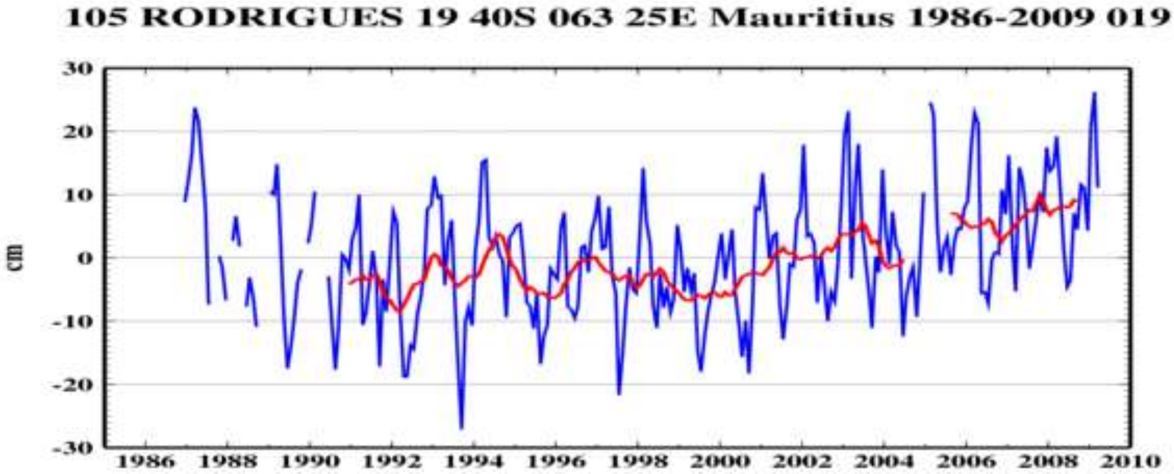


Figure 1-8b: Variability of sea level (1986-2010) at Port Mathurin, Rodrigues.

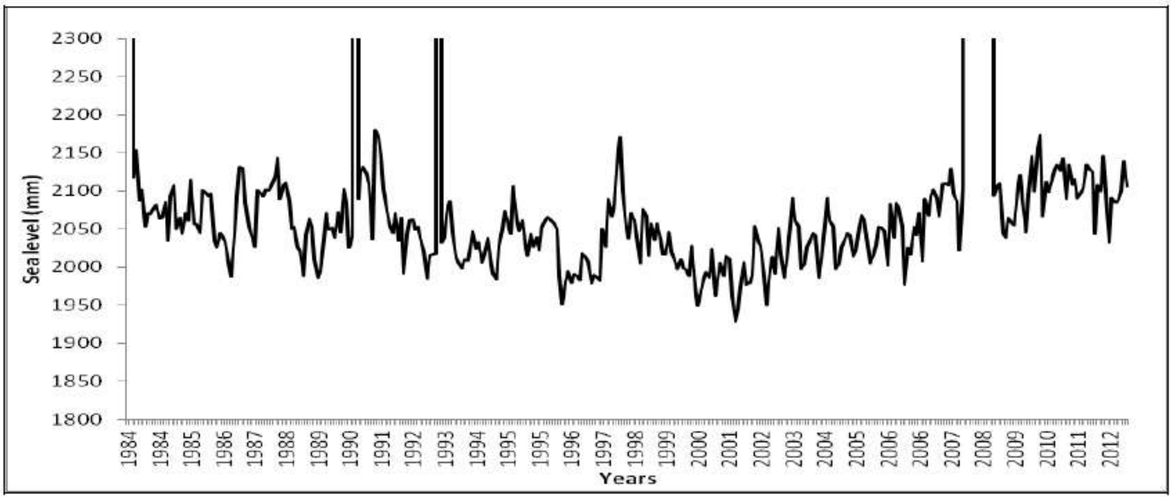


Figure 1.9: Variability of sea level (1984 – 2013) in Zanzibar, Tanzania (Source: Makame (2014).

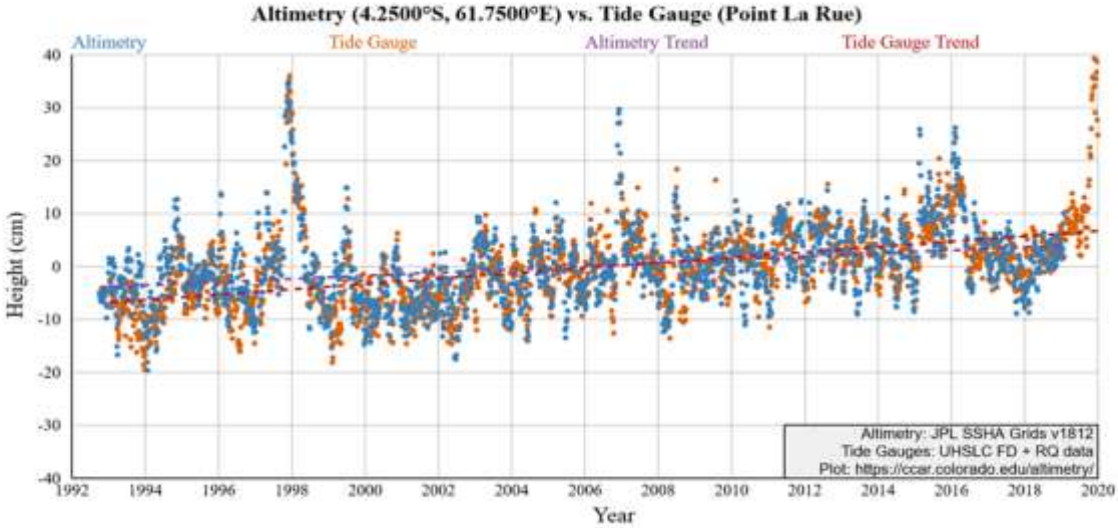


Figure 1-10: Variability of sea level (1993 - 2020) at the Pointe La Rue, Seychelles (Source: University of Hawaii Sea Level Center)

3.6.3 Ocean Temperature

Sea Surface Temperature is an essential climate variable which provides insight into the flow of heat into and out of the ocean. It is a fundamental variable for ocean and weather prediction, as well as for climate variability and climate change. Ocean Heat Content represents the heat energy stored in the ocean and is a key factor in the Earth's energy budget, ocean-atmosphere interactions, marine ecosystems, and sea level change. Using satellite and in-situ measurements, the ocean surface within Kenyan territorial waters have warmed over recent decades by around 0.1±0.002 °C per year since 1985 while the mean SST has increased from 27.0 °C to 27.1 °C with eight of the ten warmest years on record occurring since 2010 ((Kenya MEDA, 2022).

The sea surface temperatures along the coast of Tanzania are characterized by a progressive seasonal change (Mahongo and Shaghude, 2014; Shaghude *et al*, submitted/under review), with minimum temperatures during July to September (25.2-26.6°C), slightly higher temperatures in October/November (26.5 – 28.5°C) and December to February (26.0-29.2°C) and highest temperatures in March/April (28.0-30.2°C). Generally, relatively higher sea surface temperatures are observed during the NE monsoon season than during the SE monsoon season (Sekadende *et al*, 2020; Fig. 2.22). Furthermore, during the NE monsoon season, considerable variation of sea surface temperatures is observed between the coastal waters and offshore waters, with the offshore waters being relatively warmer (27-28°C) than the coastal waters (<27°C). During the SE monsoon season, there are was no considerable cross-shore variation of sea surface temperatures along the Tanzanian ocean waters.

Vertical variation of sea water temperatures along the Tanzanian ocean waters are also reported to vary on seasonal basis. A recent study conducted along the north-western coast of the Pemba Channel revealed that during the NE monsoon season the seawater temperature ranged from a maximum temperature of about 29^oC at the surface to about 27^oC at the 150 m depth, while during the SE monsoon season, the seawater temperature ranged from maximum temperatures of about 26^oC at the surface waters to about 24^oC at the depth of 150 m (Shaghude *et al*, 2020).

Observations obtained in Nansen cruises, revealed that Sea Surface Temperature (SST) decreases gradually from north to south along the coast of Mozambique, reaching a minimum near Maputo (IMR, 1977, 1978a, b, c; Johnsen et al., 2007). In the South of Sofala Bank (>16°S) water temperature decreased at a rate of 0.5°C per 1° latitude (IMR, 1978b; Johnsen et al., 2007; Krakstad el al., 2015). A difference of 4 °C was measured between winter and summer temperatures (IMR, 1977c, 1978b). Cells of cool water with a temperature below 16°C at a water depth of 150 m were observed near Angoche and the Delagoa Bight (IMR 1977c, 1978a, b, c, 1990a). The cool Delagoa Bight cell has been associated with upwelling of water from around 1000 m deep, at the core of a quasi-permanent cyclonic lee-eddy (Lutjeharms and da Silva, 1988).

The northern parts of the Agulhas Current system stretches from approximately the southern mouth of the Mozambique Channel (~ 28°S) to the eastern edge of the Agulhas Bank at Port Alfred in South Africa. Ocean surface temperatures at the northern end range between 28°C in February and 23°C in July (Lamont *et al.*, 2016). At the southern end, they range between 25°C in January and 21°C in August (Christensen, 1980; Lutjeharms, 2006a).

In the Mascarene Island of Mauritius, there are no large upwelling areas and the warmest period experienced in March has temperature of around 29^0C and the coldest period in September has mean sea surface temperatures of 23^0C. However, during the summer months, temperature can rise up to 31^0C causing fish mortality and coral bleaching. The isothermal layer is 50m thick and the thermocline located at about 100 m below the surface of the ocean. The thermocline is much deeper during the winter months (Mauritius MEDA, 2022). Analysis of the SST dataset for the Seychelles indicates that the spatially annual mean of 28.58°C with warming trend of +0.02°C yr^{-1} within the period 1990–2019 (Seychelles MEDA, 2022). This rate of warming can be said to be typical of other Mascarene Islands in the WIO.

3.6.4 Ocean Salinity

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 rainfall falling on the ocean and 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). Overall, the salinity of WIO surface waters varies between 32 and 37 practical salinity units (PSU) with large local differences. The northern parts of the Western Indian Ocean, especially the area bordering the Arabian Sea, has a dense, high-salinity layer (36-37 PSU) to a depth of about 120 m because of high evaporation rates at subtropical temperatures, with moderate seasonal variations. The salinity in the Gulf of Aden between Ras Fartak and Socotra usually exceed 36 PSU (Carvalho-Junior, 2022). However, salinity in the eastern part of the WIO, particularly towards the Bay of Bengal is considerably lower, often less than 35 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. During the inter-monsoon periods (May-April), the offshore waters along the Kenya coast are usually characterized by relatively low surface salinity ranging between 34.74 and 35.08 PSU. This is attributed to rainfall as well as flow of relatively low salinity water from the Bay of Bengal and Indonesia (Newell, 1957). The high salinity water originates from the Arabian Sea and Red Sea. Low salinity less than 34 PSU occurs in the bays and creeks where the influence of river runoff is greatest (Kitheka, 1997; Kitheka et al., 2002, 2004). Along the northern Mozambique Channel, the salinity is of about 34.7–34.8 PSU (DiMarco et al., 2002), and may exceed 34.8 PSU (de Ruijter et al., 2002). In northern parts of the Agulhas Current, salinities at the surface are on average 35.3 PSU along and over the continental shelf and up to 35.5 PSU in the northern part of the current itself. Surface waters of the northern Agulhas Current consist of a mixture of Tropical and Subtropical surface waters (salinities <35.0 and >35.5 PSU). The purer Subtropical Surface Water is responsible for a salinity maximum at 200 m depth (Lutjeharms, 2006a). Subsurface water masses consists of South Indian Intermediate Water (4-6°C, salinity <35.6 PSU), Red Sea Water (salinity >34.7 PSU and very low dissolved oxygen values), North Atlantic Deep Water and Antarctic bottom Water. In general temperature-salinity of subsurface waters in the northern Agulhas Current changes little from north to south (South Africa MEDA, 2022). Open ocean surface salinity in the Mascarene Island of Mauritius range between 32 and 37 PSU. Near shore, salinity is generally reduced by inflow of fresh water from rivers and via runoff from land (Mauritius MEDA, 2022).

3.6.5 Ocean Currents and Surface Circulation

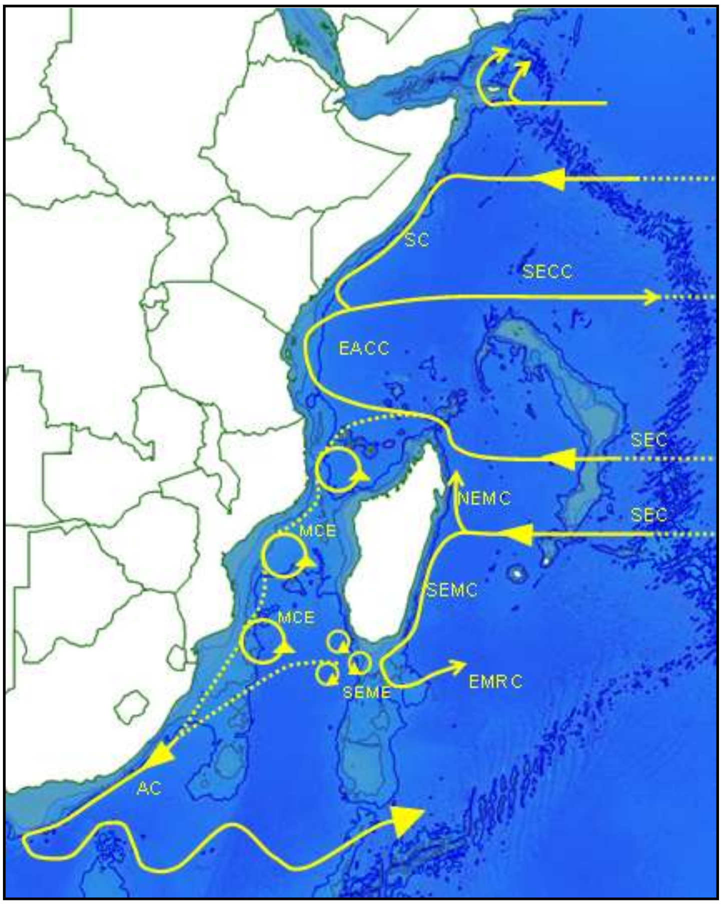
Ocean surface circulation in the WIO is wind-driven. In the northern monsoon zone, surface circulation reverses every half year and features two opposing gyres that are separated by the Indian subcontinent (see Figures 1-11 and 1.12). During the Northeast Monsoon, a weak counter-clockwise gyre develops 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 m 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 a short period of one-month (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 m/s (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 eddies drift southward along the shelf edge at speeds of about 0.5 m/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 WIO 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 m and the Somali Current to about 800 m; the other currents do not penetrate farther than 300 m.

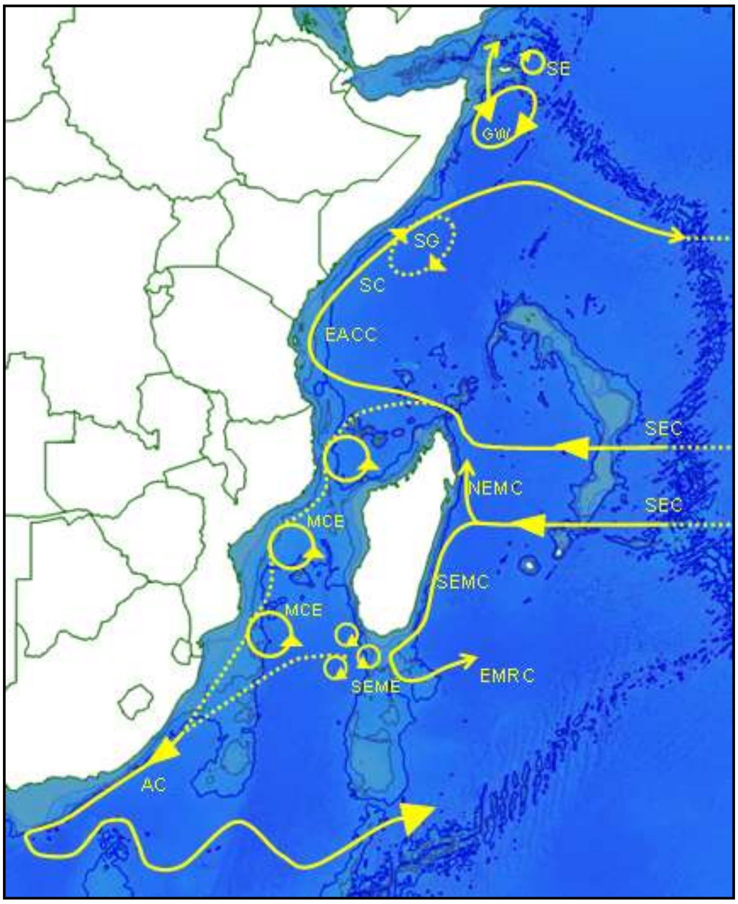
The South Equatorial Current (SEC) strongly influences the near-surface circulation of the Western Indian Ocean. The SEC flows westward across the Mascarene Plateau, after which it divides north and south to form components of the Somali and Agulhas currents, respectively. To the south, it flows down the east coast of Madagascar as the South East Madagascar Current (SEMC). To the north it forms the North East Madagascar Current (NEMC) and across the northern tip of Madagascar to contribute to the southward transport and circulation of the Mozambique Channel, as well as feeding into the northward-flowing East Africa Coastal Current (Schott and McCreary 2001). Low-salinity Indonesian Throughflow (ITF) thermocline water forms a component of the SEC, and has a significant influence on the heat and freshwater budgets of the Western Indian Ocean (Song *et al.* 2004, Song and Gordon 2004).



Indicated are the:
South Equatorial Current (SEC),
South Equatorial counter current (SECC),
Northeast Madagascar Current (NEMC),
Southeast Madagascar Current (SEMC),
East African Coastal Current (EACC),
Somali Current (SC),
Agulhas Current (AC),
Mesoscale Eddies (ME) and
South east Madagascar dipole eddies (SEME).

Dotted lines indicate direction of transport, not boundary currents. Adapted from Schott and McCreary (2001), Schouten *et al.* (2003), De Ruijter *et al.* (2005), Lutjeharms (2004), and Tew-Kai and Marsac (2009).

Figure 1-11: Near-surface ocean currents of the western Indian Ocean during the North-east monsoon (January/February).



Indicated are the:
South Equatorial Current (SEC),
South Equatorial counter current (SECC),
Northeast Madagascar Current (NEMC),
Southeast Madagascar Current (SEMC),
East African Coastal Current (EACC),
Somali Current (SC),
Southern Gyre (SG),
Great Whirl (GW),
Agulhas Current (AC),
Socotra Eddy (SE),
Mesoscale Eddies (ME) and
South east Madagascar dipole eddies (SEME).

Dotted lines indicate direction of transport, not boundary currents. Adapted from Schott and McCreary (2001), De Ruijter *et al.* (2005), Schouten *et al.* (2003), Lutjeharms (2004), and Tew-Kai and Marsac (2009).

Figure 1.12: Near-surface ocean currents of the western Indian Ocean during the South-west monsoon (July/August).

3.7 Large Marine Ecosystems of the WIO

3.7.1 The Mascarene plateau

As the South Equatorial Current (SEC) flows over the Mascarene plateau, its waters are channelled by the shallow banks which have an influence on water transport and productivity (Figure 1-14). It has been estimated that 23Sv of the total 56Sv of the SEC is channelled between the Saya de Malha and Nazareth banks (New *et al.* 2005). The remainder is diverted around the north of the Saya de Malha bank and southwestwards, between the Cargados Carajos Bank and Mauritius. Preliminary in-situ ADCP data from the ASCLME research cruise confirmed this finding (Stromme *et al.* 2008) and are shown in Figures 11 and 12. Upwelling in the open ocean between 5 and 10 ° South in the Central and Western Indian Ocean is indicated by mesozooplanton and biochemistry. Although there is some evidence of topographically induced upwelling on the lee side of the Mascarene Plateau, this is highly variable and has not been consistently or conclusively established (Gallienne and Smythe-Wright 2005).

3.7.2 The Agulhas Current LME

The Agulhas Current LME is considered to be a Class II, moderately productive ecosystem, with an average productivity of 150-300gCm^{-2}.year (Heileman *et al.* 2008). It is a relatively oligotrophic system with localized upwelling driven by eddies, or nearshore currents influenced by seafloor topography. The Agulhas current is the largest western boundary current in all the world's oceans (Bryden *et al.* 2005). Source water for the current derives from the East Madagascar current and the Mozambique Channel eddies (Biastoch and Krauss 1999, De Ruijter *et al.* 2005, Heileman *et al.* 2008). The current flows southwards along the East coast of South Africa, following the shelf edge closely; usually within 31 km of the coast and no more than 203 km offshore. Total transport is always poleward, varying from -121 Sv to -9 Sv, with an average of -69.7 Sv (Bryden *et al.* 2005). Triggered by eddies and interaction with the Natal Bight, large solitary cyclonic meanders (Natal pulses) intermittently interrupt the stability of the current, and their passing causes a reversal of shelf currents – possibly leading to upstream transport of biota for short periods of time (Lutjeharms *et al.* 2000, 2003, De Ruijter *et al.* 2005). South of the Agulhas Bank, meanders in the current increase, producing shear eddies and warm plumes on the shoreward side. At approximately 40°S, the Agulhas current retroflects and Agulhas rings are shed, to spin off to the west into the Atlantic Ocean. The majority of the Agulhas current volume travels eastwards in the Agulhas Return Current which is also the region of highest variability in the southwest Indian Ocean (De Ruijter *et al.* 2005)

An important feature of Agulhas Current LME within the Mozambique Channel is the high level of mesoscale variability dominated by large anticyclonic eddies (Figure 1-13). In the North, Rossby forcing drives the generation of approximately seven eddies per year which are formed at the narrows of the Mozambique channel at 16-17°S. Eddies move steadily southward and the frequency slows to five eddies per year. In the South, Mozambique Channel eddies merge with cyclonic and anti-cyclonic contra-rotating eddy pairs or dipole eddies formed to the south of Madagascar which move south-west to feed into the Agulhas Current (Ridderinkhof and De Ruitjer 2003, Schouten *et al.* 2003, Quartly and Srotskz 2004, Tew-Kai and Marsac 2009). Cyclonic eddies are characterized by divergent flow at their centre, upwelling of cold nutrient-rich water, and thus by higher primary production (McGillicuddy and Robinson 1997, Tew-Kai and Marsac 2009). Anticyclones tend to have low-nutrient water at their centre due to convergent flow and downwelling, which also promotes retention of passive organisms, but enrichment has been noted at their periphery (Mizobata *et al.* 2002). At a depth of 100m, distinct hydrographic differences have been noted between these mesoscale features, with cyclonic eddies characterized by Subtropical Surface Water, and anti-cyclonic eddies containing Tropical Surface Water (Lamont *et al.* 2012).

Chlorophyll variability in the Agulhas Current LME is mostly driven by seasonal wind-induced turbulence, coastal upwelling and river runoff in the North (10-16°S) and South (24-30°S) of the Mozambique Channel. In the centre (16-24°S), seasonality has less of an influence, and chlorophyll distribution is more dependent on mesoscale dynamics (eddies and filaments). In this part of the channel, interaction between cyclonic and anticyclonic eddies generates complex multiple fronts which can lead to entrainment of chlorophyll from the coast to the open ocean. This enrichment process, if persistent, leads to favourable foraging areas for top predators (Quartly and Srokosz 2004, Tew-Kai and Marsac 2009).

Frequent upwelling on the Mozambican continental shelf between Praia do Tofo and Bazaruto appears to be driven by the interaction of poleward moving mesoscale eddies and the narrow continental shelf, together with divergent upwelling driven by water flow following its path along the shelf edge as it diverges from the coastline, drives high productivity). This region supports one of the highest, non-migrating hotspots of whale sharks (*Rhincodon typus)* in the WIO at Praia do Tofo (Rohner *et al.* 2012). Ecologically, other species are also associated with this highly productive region and economically, this has important consequences for tourism in the area. Figure 13 illustrates geostrophic currents derived from satellite altimetry data together with ADCP data collected on the ASCLME Mozambique channel survey (Kaehler *et al.* 2008).

In contrast to the circulation patterns near the surface of the ocean, deep ocean transport in the Agulhas Current LME demonstrates quite different patterns. For example, a deep water Agulhas Undercurrent flows northwards up the East Coast of southern Africa below the Agulhas Current (Beal and Bryden 1997). Deep water current patterns are illustrated in Figure 14.

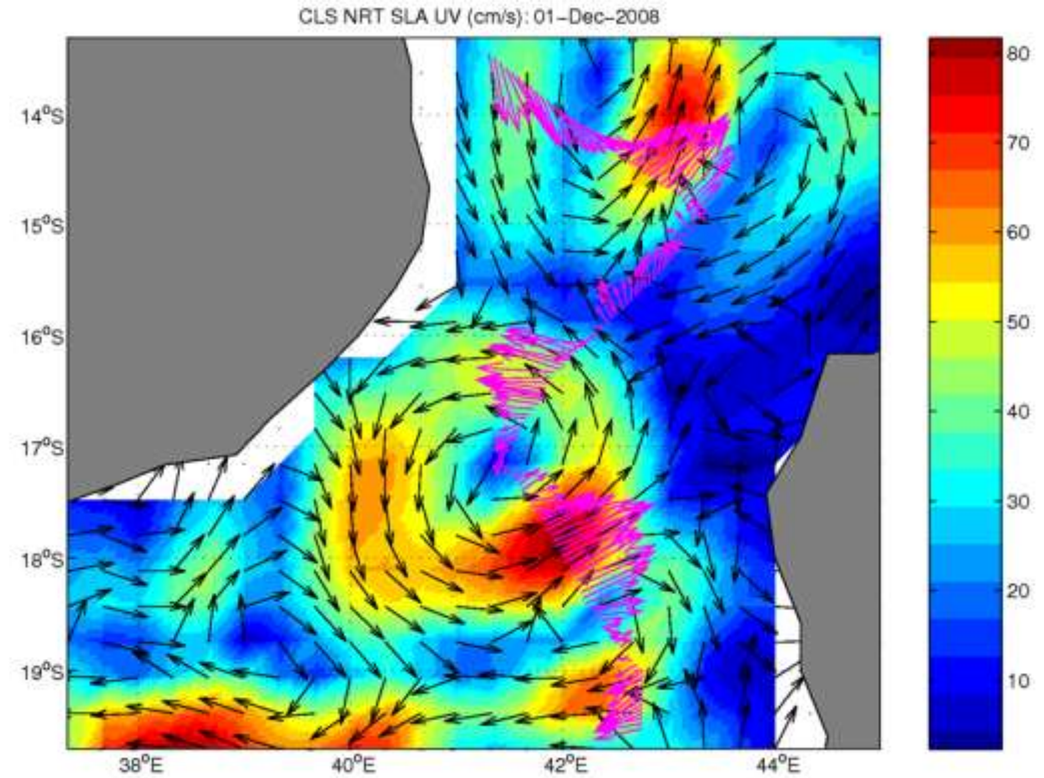


Figure 1-13: Geostrophic currents derived from satellite altimetry data together with ADCP data collected on the ASCLME Mozambique Channel survey (Kaehler *et al.* 2008).

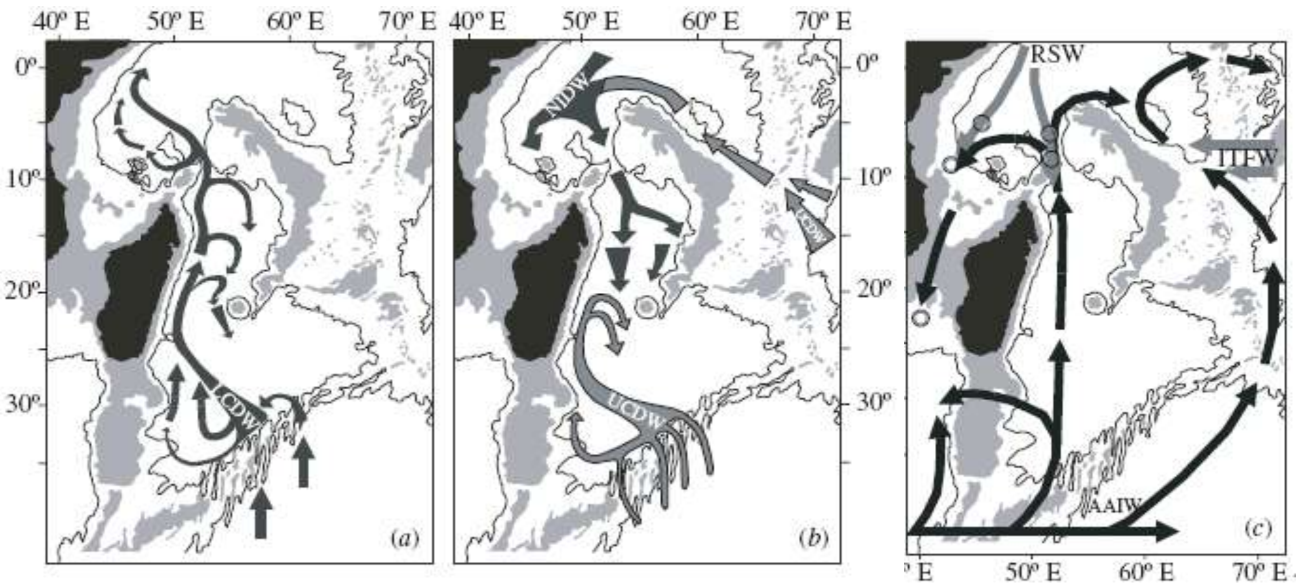


Figure 1-14: General circulation patterns at a) -3800m, b) -3700 to -2000m, and c) -1500m to -500m, (McCave *et al.* 2005)

Mozambique Channel circulation is also affected by the monsoon regime, with the southwest monsoon associated with strong winds and high volume transport through the Mozambique Channel, while the northeast monsoon is associated with low winds and very low levels of transport through the channel (Biastoch and Krauss 1999). North-East monsoon winds have also been correlated with upwelling off the coast of Mozambique, particularly in the vicinity of Angoche, which has important consequences for local productivity and nutrient availability to the economically important prawn stocks of the Sofala Bank (Maluaene *et al.* 2012).

3.7.3 The Somali Current LME

The Somali Current LME is also considered to be a Class II, moderately productive ecosystem, with an average of 150-300gCm^{-2}.year (Heileman and Scott 2008). The primary productivity of the Somali current is strongly influenced by persistent monsoon-driven upwelling. Productivity is highest during the south-west monsoon which drives an upwelling cell off the continental shelf (Okemwa 1998). The Somali Current is the western boundary current of the north-western Indian Ocean. It is strongly influenced by the two monsoon seasons of East Africa. During the north-east monsoon, the Somali current flows towards the south-west to meet the northward-flowing East African Coastal Current, and then flows eastward at 0-2°N in the South Equatorial Counter Current (SECC). As the season changes and the south-west monsoon strengthens, the EACC strengthens and the Somali current changes direction to flow towards the north-east. At this transition, an intense jet (the Indian Equatorial Jet) develops that may reach speeds of 3.5 m.s^{-1}. The jet, appearing between April and June for short, one-month periods, is not well understood, but it has been shown to drive a strong offshore upwelling cell known as the Great Whirl (Schott and McCreary 2001). By August, the East African Coastal Current and the Somali Current form a continuous north-eastward flowing current to the East Arabian Current (Heileman and Scott 2008).

3.8 Fronts and temperature

Oceanic fronts in the WIO are either seasonal or persistent and occur at a variety of scales from < 1km to thousands of kilometres. They indicate the boundary between two water masses, and are often associated with zones of increased productivity. A study of oceanic fronts in the World's LMEs by Belkin and Cornillon (2007) shows the Agulhas Current Front (ACF), the clearly distinguishable inshore boundary of the Agulhas current. Other more ephemeral currents that have been mapped include the East Madagascar Current Front (EMCF), and Glorioso Islands front (GIF). During the south-west monsoon, a sharp front separates the warm salty Somali Current water from the offshore upwelling.

Steady warming has been observed in both the WIO LMEs. In the Agulhas Current region, warming of 0.68°C has been recorded since 1957 (Heileman *et al.* 2008). Post 1982, the warming of the Agulhas current has been non-uniform, with warming of up to 1°C recorded for the Agulhas Current Retroflection. The all-time warmest year was in 1998 for both LMEs, as it was for much of the Indian Ocean (Annamalai and Murtugudde 2004, Reynolds and Smith 1994).

3.9 Primary productivity

The primary productivity in the WIO is highly variable in both time and space and there are large differences in primary productivity between the eastern and western zones of the WIO and also between northern and southern zones. The northern part of WIO in the Gulf of Aden along Somali coast experiences the highest cholorophyll-a biomass concentration reaching 3.50 mg/m^3 while the central and southern regions have chlorophyll-a biomass concentrations that are of the order 0.12 mg/m^3 or less. The mean chlorophyll-a biomass across the Mascarene Plateau is of the order 0.476 ± 1.562 µg/l (Stromme 2008). While the South Equatorial Current dominates the general circulation in the Mascarene Plateau, the higher chlorophyll-a biomass over the Seychelles Bank and Amirante Shelf is associated with Arabian Sea High Salinity Water under the influence of the warmer eastward flowing South Equatorial Counter Current. Except for the Amirante basin where chlorophyll-a biomass exceeded 30 µg/l, the highest phytoplankton biomass between Mauritius and Seychelles occurs on the Saya da Malha Bank (Figure 1-15). Except in the vicinity of Agalega Island where the enhancement of phytoplankton biomass is associated with an upwelling process, most of the EEZ of Mauritius is characterised by generally low productivity of the order 5 tc/Km^2/year, which is low compared to the waters surrounding the Seychelles group of islands where productivity range 200-300 tc/km^2/year (SOE, 1991).

Along the Kenya coast, divergent flow leads to the upwelling of cold, nutrient-rich deeper waters to the surface around the Northern Kenyan Banks where chlorophyll-a biomass reach maximum concentrations of up to 1 mg m^{-3} during the NEM (February) indicative of upwelling in the 200 m depths compared to the SEM when chlorophyll-a biomass is of the order 0.1 gC m^{-2}day^{-1} (Kenya MEDA, 2022). The water column primary productivity along the Tanzania coast ranges from 0.204 to 4.142 gC m^{-2}day^{-1} (Lugomela *et al*., 2001; Tanzania MEDA, 2022). Studies of primary production conducted in the 1960s reported zones of elevated productivity (>1.0 gC m^{-2} day^{-1}) along the east coast of South Africa and a range of 0.1-3.1 gC m^{-2} day^{-1} on the South Africa's Natal shelf (Ryther *et al.*, 1966). In the Natal Bight, relatively higher chlorophyll-a biomass of 0.2-2.2 gC m^{-2} day^{-1} have been reported (Burchall 1968a,b). A review of data up to 1988 for the Natal Bight indicated that the range in chlorophyll *a* biomass range

0.03-3.9 mg m^{-3} (Carter and Schleyer, 1988). Chlorophyll *a* levels in the euphotic zone range 20-70 mg m^{-3} on the Natal Bight during spring (Barlow *et al.*, 2008). On the Agulhas Bank, a chlorophyll-rich zone is usually present in the inshore zone of the eastern Agulhas Bank, with concentrations of 2-5 mg m^{-3} in the maximum layer, but levels of >1 mg m^{-3} can extend across the entire shelf with a high degree of spatial heterogeneity (Probyn *et al.*, 1994). The maximum chlorophyll a concentration is usually located subsurface from 10-30 m. The eastern Bank is characterized by primary production rates of 1.2-2.8 gC m^{-2} day^{-1} in the continental shelf break, and relatively higher levels of 5.3 gC m^{-2} day^{-1} in the coastal and mid-shelf areas in summer. Recent studies along the South Africa's east coast and Natal Bight showed that primary production ranged 0.27-3.58 gC m^{-2} day^{-1} in November 2006 and 0.63-3.69 gC m^{-2} day^{-1} on September 2007 (Barlow *et al.*, 2009), suggesting no significant differences in productivity between spring and summer. However, a recent study by Robert *et al*. (2016) show that chlorophyll concentration levels varied seasonally and spatially, given that the Agulhas current ecosystem is low in nutrients (oligotrophic). The high level chlorophyll waters are found offshore from the St Lucia upwelling cell in winter and poor chlorophyll waters are found in the central bight in summer (South Africa MEDA, 2022).

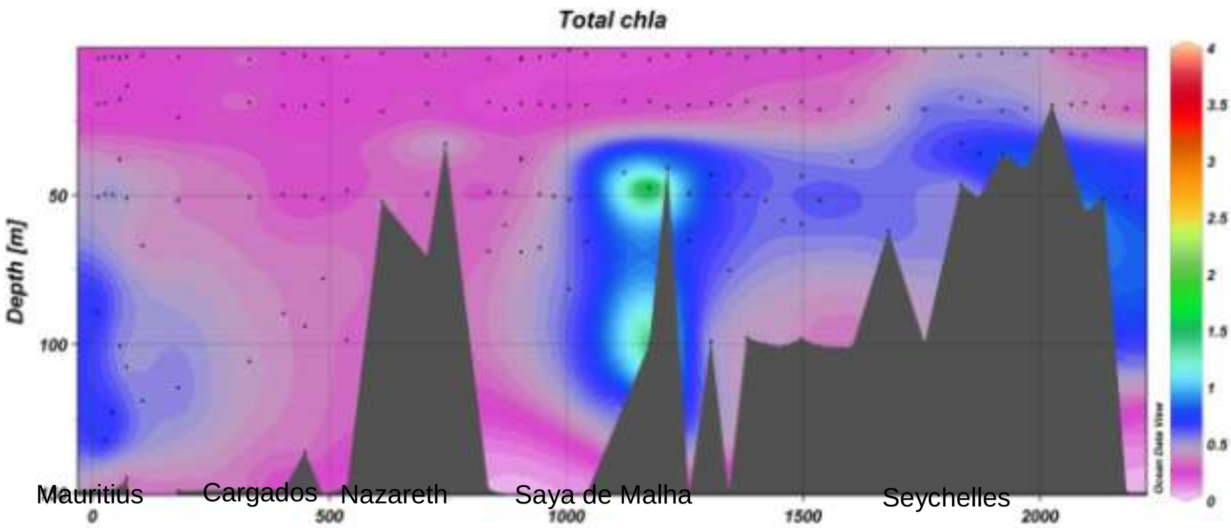


Figure 1-15. The vertical distribution of phytoplankton biomass in the Mascarene plateau between Seychelles and Mauritius.

3.10 Secondary productivity

As with primary productivity, there are large spatial differences in secondary productivity in the WIO. In the Somali Current LME, Euphausiids make upto 25% of total zooplankton biomass and copepods the remainder. Within the upwelling zone, copepods *Calanoides carinatus* and *Eucalanus elongatus* dominated the upwelling zone (Okemwa 1998). Along the Tanzanian coastal waters, the taxa of zooplankton that have been identified are Calanoida, Larvacea, *Corycaeus* spp., *Cypridina sinuosa*, *Oithona* spp., caridean larvae, *Sagitta* spp., *Euterpina spp*, *Lucifer* spp, *Oncea* spp, *Hydromedusae spp*, *Euconchoecia chierchiae*, *Creseis acicula*, Brachyuran zoeae, Ctenophora, Mysidacea and other minor species (Okera, 1974). All major groups of the zooplankton have an annual cycle of abundance, with relatively high numbers being recorded during the southeast monsoon period between February and August because during this season, there is also high abundance of phytoplankton. During the northeast monsoon the situation is reversed, such that low abundance of zooplankton is associated with low abundance of phytoplankton (Tanzania MEDA, 2022).

Mesoscale eddies in the Mozambique Channel play a very important role in the distribution of zooplankton communities. In situ studies over four years (2007-2010 inclusive) demonstrated that cyclonic eddies (with characteristic cool water 20°C at 100m, negative sea level anomalies) exhibited moderate to high levels of zooplankton (0.3-0.7ml.m^{-3}) and anticyclonic eddies (with characteristically warm temperatures –23°C at 100m, and positive sea level anomalies) exhibited low concentrations (<0.2 m^{-3}) of zooplankton (Huggett 2012). Taken together, divergences and fronts tend to reflect more species than cyclonic and anticyclonic eddies (Potier *et al.* 2012).

Extensive zooplankton sampling undertaken since 1988 on the Agulhas Bank revealed large populations of the copepod *Calanus agulhensis* that provide an important food source for spawning anchovy (Huggett and Richardson, 2000). The greatest copepod diversity is associated with the Agulhas Current. Between the KZN border and St Lucia, neritic, oceanic and mixed copepod communities have been identified including large populations of *Calanoides carinatus*, an upwelling species associated with eddy centre upwelling off Durban. The hydromedusae and siphonophore assemblages have also been documented (Buecher *et al*., 2005, Thibault-Botha *et al*., 2004, Thibault-Botha and Gibbons, 2005). At the KwaZulu-Natal Bright, the mmean zooplankton biomass is significantly higher in winter (17.1 mg DW m^{-3}) than in summer (9.5 mg DW m^{-3}). The total biomass in summer is evenly distributed within the central bight, low off the Thukela River mouth and maximum occurs near Durban (Pretorious *et al*., 2016). In winter, the highest zooplankton biomass is found offshore between Richards Bay and Cape St Lucia. There is a significant relationship between zooplankton biomass and bottom depth with greatest total biomass located inshore (<50 m) (Pretorious *et al*., 2016). There are seasonal differences in copepod size composition suggesting that a smaller, younger community occupied the cool, chlorophyll-rich waters offshore from the St Lucia upwelling cell in winter, and a larger, older community occurred within the relatively warm and chlorophyll-poor central bight in summer. Nutrient enrichment from quasi-permanent upwelling off Durban and Richards Bay appears to have a greater influence on zooplankton biomass and distribution in the KwaZulu Natal Bight than the strongly seasonal nutrient input from the Thukela River (South Africa MEDA, 2022). In the Mascarene islands, the level of secondary productivity is low. For instance, ddue to the low primary productivity of the oceanic water around Mauritius (5 tic/Km^2/year), the secondary production is also low, except in some areas on the shallow water banks found within the Mascarene Plateau. Protozoan zooplankton group identified in the waters of Mauritius include the foraminiferas and the dinoflagellates while the metazoans zooplankton group comprise *inter-alia* the copepods, chaetognaths (arrow worms) and cnidarians such as jellyfish (Mauritius MEDA, 2022).

3.11 Ocean-atmosphere interactions

The prevailing wind regimes that dominate the Somali and Agulhas Current LMEs are the monsoon regime in the north and the sub-tropical high pressure system in the South (Schott and McCreary 2001, UNDP 2005). The monsoon regime is characterized by north-easterly winds from December to April (moderate winds, dry terrestrially derived air), and stronger south-easterly winds from June to October. Rainfall over much of East Africa is bimodal, with rainy seasons in March to May and October to December (Kenya MEDA, 2022; Tanzania MEDA, 2022). This regime changes to a single season rainfall regime with increasing distance from the equator (Conway *et al.* 2005, Schott and McCreary 2001). Between November and April, wind movement and air pressure disturbance cause cyclones, which tend to originate between 10 and 20°S over the Central Indian Ocean, and move westwards affecting Mauritius, Madagascar and Mozambique, sometimes with devastating consequences.

The El Nino Southern Oscillation (ENSO) forms an important component of the forecasting of the rainfall over southern Africa. ENSO controls approximately 25% of wet season (January – March) rainfall variability. In ENSO-neutral seasons, rainfall anomalies have been positively correlated with Sea Surface Temperature (SST) anomalies at 80°E and 25°S in the Indian Ocean. Wet rainfall anomalies are enhanced by warm SST anomalies (Lizcano and Todd 2005). Also, the dry rainfall anomalies are enhanced by cold SST anomalies (Lizcano and Todd 2005). ENSO has also been shown to correlate with drought events in Madagascar. Over inter-annual time scales (1982-1999), the normalized difference vegetation index (NDVI) has a strong negative correlation with El Nino events, which is attributed to drought events and wild fires. Long term environmental change is predicted to increase the frequency of these events, with severe consequences for Madagascar (Ingram and Dawson 2005). El Nino events been shown to bring drought to South Africa, but more rain to equatorial East Africa.

The Indian Ocean Dipole is an inter-annual mode of variability in Indian Ocean SST (Saji *et al.* 1999). The strength of the dipole is measured by the Dipole Mode Index (DMI) defined as the difference in SST anomaly between the Eastern and Western Indian Ocean. The DMI varies from -1 to 1.5°C with both a mean and standard deviation of 0.3. It has been shown that East African inter-annual rainfall variability is not directly linked to SST anomalies in the Indian or Pacific Oceans, but rather to a positive dipole event (Saji *et al.* 1999; Black 2005). In fact, the observed link between East African rainfall and ENSO is likely a manifestation of the link between ENSO and the IOD. However, strong El Nino forcing in boreal autumn may cause cooling in the WIO, trigger an IOD and thus cause rainfall in coastal equatorial East Africa (Black 2005).

3.12 Ecological setting and Biodiversity

3.12.1 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 1-16 shows the key habitats in the WIO region. A further description of each of the types of ecosystems is presented in the following sections.

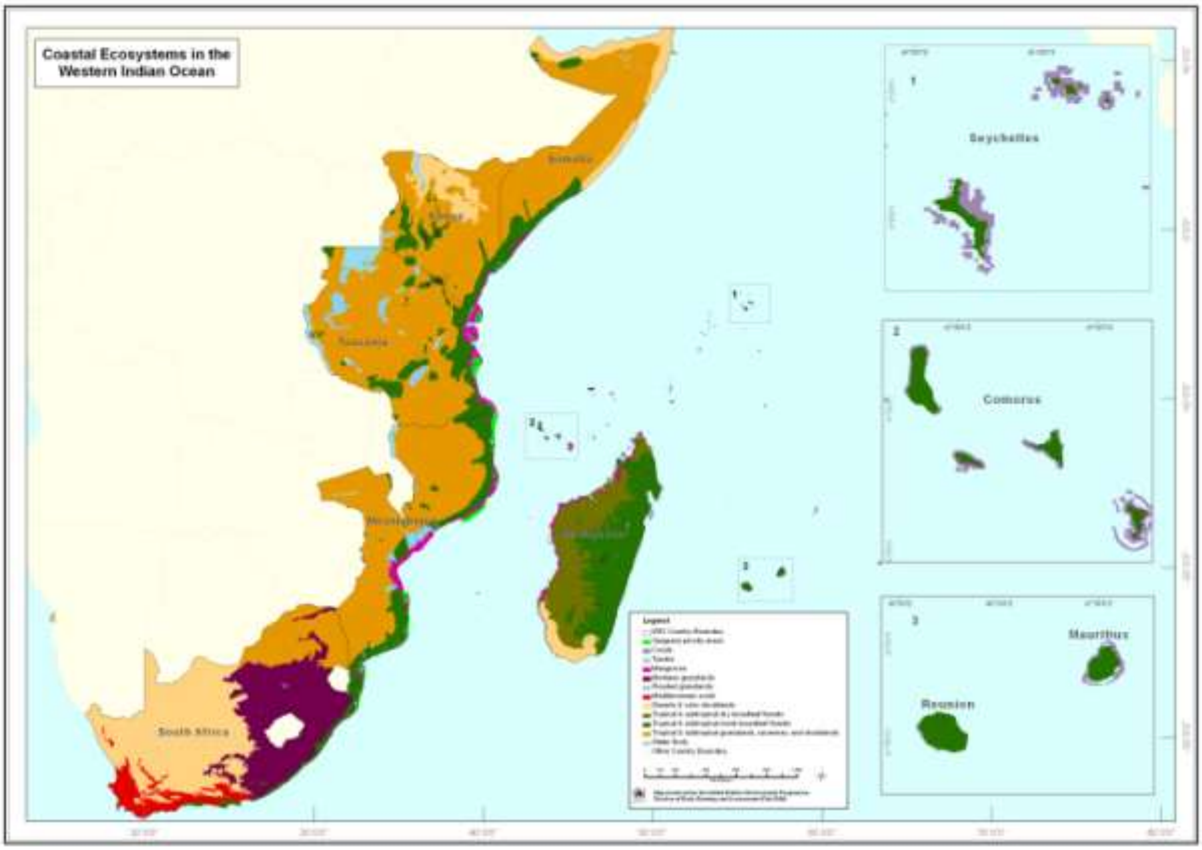


Figure 1-16: The key ecosystems and habitats in the WIO region

3.12.2 Mangrove forests

The latitudinal limits of mangroves in the WIO are about 31°22'N and 38°20'S (Tomlinson, 1986; Spalding *et al*., 1997). 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 1-4).

Table 1-4: Distribution of mangroves in the WIO

Country	Area (ha) [1]	Species	Main mangrove areas
Somalia	1,000	8	Juba/Shebele Estuary, Istambul, Kudha, and Burgavo creeks
Tanzania	158,100	9	Rufiji Delta, Tanga, Kilwa , Pangani.
Kenya	61,271	9	Lamu Archipelago, Tana Delta
Mozambique	318,851	9	Zambezi Delta

South Africa	1,672	6	St Lucia
Madagascar	314,000	9	West coast at Mahajanga bay, Nosy Be, and Hahavavy
Comoros	184	5	Grande Comoro, Moheli
Seychelles	2,900	7	Aldabra Atoll
Mauritius	180	2	Mathurin Bay, Rodrigues

Data source: [1]FAO, 2005c, Beentje and Bandeira 2007; Spalding *et al*., 1997; Ministry of Environment and NDU, 2006; National MEDA Reports, 2022

In the WIO region, nine species of mangroves are commonly encountered, with the most common species being *Rhizophora mucronata* and *Ceriops tagal* (Table 1-5). The most common mangrove-associated tree species occurring within the mangrove ecosystem are *Barringtonia asiatica*, *Barringtonia racemosa* and *Pemphis acidula* (Beentje and Bandeira, 2007). The following section provides brief description of status of the mangrove forests in each of the WIO Countries. The root causes of degradation are discussed in the later part of the TDA.

Somalia- The majority of Somalia's mangrove forests are found in the country's southwest coast. However, small pockets of *Avicennia marina* are found on the country's northern coast, behind sand spits and along the Gulf of Aden coastline (Somali MEDA, 2022). The eight mangrove species that are found in Somalia are *Avicennia marina, Bruguiera gymnorrhiza, Ceriops somalensis, Ceriops tagal, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum*. Approximately 1,000 ha of mangroves are found in Somalia, with the majority of them located in the Juba/Shebelle estuary and along Istambul, Kudha, and Burgavo creeks and on the sheltered sides of the barrier islands (FAO, 2007; Gedow Amir et al., 2017).

Kenya-Mangroves are a common feature in deltas, lagoons, protected bays and creeks distributed all along the Kenyan coastline. There are about 61,271ha of mangroves in Kenya with over 60% (37,350 ha) occurring in Lamu County (GOK, 2017). Other mangrove areas are in Kilifi County (Ungwana Bay, Ngomeni, Malindi, Mida), Mombasa County (Port Reitz and Tudor creeks), Kwale County (Mwache, Gazi, Funzi and Shimoni creeks) and Tana Delta (Kenya MEDA, 2022). The nine mangrove species in Kenya are *Rhizophora mucronata*, *Avicennia marina* and *Ceriops tagal*, *Lumnitzera racemosa, Bruguiera gymnorrhiza, Sonneratia alba, Xylocarpus granatum, Xylocarpus moluccensis and Heritiera littoralis* ((Bosire et al., 2014; GOK., 2017; Kenya MEDA, 2022). Mangrove forest supports approximately 3 million Kenyans livelihood. Mangrove resources are being used by coastal communities to supply local needs for fuel wood, fences, house construction, boat building, fish traps and medicine (Kairo et al., 2010). At a commercial level, mangroves are an important item of trade and a source of employment and income for the coastal communities. Mangrove forests in Kenya also face several threats arising from both anthropogenic and natural factors. Between 1985 and 2009, the country lost about 20% of its mangrove cover, translating to about 450 ha of mangrove cover loss and degradation per year. The loss was exceptionally high in the peri-urban mangroves of Mombasa county where more than 70% cover loss was recorded, mostly due to human factors (GOK, 2017). Currently, the area of degraded mangroves in Kenya stands at 24,585 ha (Kenya MEDA, 2022). Considerable effort has been made on the restoration of mangrove forests along the Kenya coast with several successful projects in Sabaki estuary, Gazi bay, Mwache and Tudor creeks. Kenya's *Mikoko Pamoja* project has been successful in creating awareness on the need to enhance protection of mangrove forests in the country.

Tanzania-Mangroves in Mainland Tanzania occur along the entire coastline in continuous and fragmented stands covering approximately 158,100 ha (MNRT, 2015; Mangora *et al*., 2016). On Zanzibar islands, the mangrove coverage is 16,488 ha (Mchenga and Ali, 2015). There are ten mangrove tree species in Tanzania, the most common and dominant mangrove formations are those of the family Rhizophoraceae (*Rhizophora mucronata*, *Ceriops tagal* and *Bruguiera gymnorhiza*). The other main species of mangroves are *Avicennia marina*, *Sonneratia alba*, *Xylocarpus granatum* and *Heritiera littoralis*. Less common mangroves are *Lumnitzera racemosa*, *Pemphis acidula* and *Xylocarpus molluccensis* (Mangora *et al*., 2015). The largest mangrove forest in Tanzania is found in the Rufiji delta, where over 150,000 people in the delta make their living directly from mangrove resources. The mangrove ecosystem is experiencing rapid rates of deforestation and is also threatened due to sea level rise (Kauffman *et al*., 2011). Areas that experience highest rates of degradation are those that are easily accessible especially near major urban centres such as Dar es Salaam, Tanga, Mtwara and Zanzibar (Tanzania MEDA, 2022). Uncontrolled harvesting for both domestic and commercial use and illegal clearance and conversion of mangrove areas to rice farms in the Rufiji delta, saltpans in Tanga, Bagamoyo and Mtwara are common threats (Mangora *et al*., 2015). There has also been a decline in mangroves forests due to natural factors. For instance, in the Rufiji delta, the mangrove forests have declined from a total area of 51,941 ha in 1991 to 45,519 ha in 2015 due to flooding of Rufiji River (Monga *et al*., 2018). The mangrove area in Zanzibar is 16,488 ha of with 5,274 ha are found in Unguja and 11,214 ha are found in Pemba (Mchenga and Ali, 2015). The estimated loss of mangrove forests is about 1,000ha per annum. About 950ha are lost due to clearance for agriculture, firewood and building poles. Initiatives have been made by government, non-government and international actors to save existing deforested mangrove forest from further destruction. For example, some conservation projects aimed at restoration of mangroves have been initiated in the Rufiji delta in late 1990s and were implemented by WWF-Tanzania, TFS Agency and the Rufiji District Authority. Community awareness to mangrove forest restoration led to a significant increase in mangrove forest cover in mainland Tanzania and Zanzibar in the period between 2009 and 2015 (Monga *et al*., 2018; Tanzania MEDA, 2022).

Mozambique-Mozambique has extensive mangrove areas, particularly along the central coast which is one of the largest in the WIO region (Spalding et al. 2010). The mangroves forests cover 2.3% of the total land area IN Mozambique which is equivalent to 318,851 hectares (Giri *et al*., 2011). The extent of mangrove coverage various across the country with 890 km^2 in Sofala, 645 km^2 in Maputo, 412 km^2 in Inhambane and 413 km^2 in Zambezia. According to Simard et al. (2019), mangrove forests occupy a total surface of 3,054 km^2 in Mozambique. The greatest abundance of mangrove forests occurs in central deltaic and estuarine areas of Mozambique (Mozambique MEDA, 2022). The most dominant mangrove species are *Avicennia marina* and *Rhizophora mucronata*. Mangrove cover in Mozambique has reduced at a rate of 18.2 km^2/year over the past few decades largely due to urbanisation, tourism and industrial development (Taylor et al. 2003). Mangrove related fisheries, namely shrimp fisheries, have in the past been estimated to contribute 40% to the country's GNP (Fatoyinbo et al. 2008).

South Africa-In South Africa mangrove forests are limited to the eastern coastal region and are located in estuaries from Kosi Bay in KwaZulu-Natal (KZN) in the north to Tyolomnqa Estuary (Chalumna River) near East London in the south (Ward and Steinke, 1982; Bolosha 2017; Peer et al. 2018). Currently, total mangrove area in South Africa is 1,672 ha spread over 32 estuaries which represents 0.05 % of Africa's total (Rajkaran 2011; Hoppe-Speer 2012; Adams and Hoppe-Speer et al. 2015; Adams and Rajkaran 2020). The largest mangrove forests are found in the subtropical areas (28° to 29°S) at St. Lucia and Richards Bay. The Kosi, St. Lucia, Mfolozi and Mhlathuze estuaries account for about 75% of mangroves while the Mngazana Estuary has the third largest area (Naidoo 2016). Six mangrove species that have been identified in South Africa are *Avicennia marina, Bruguiera gymnorrhiza*, *Rhizophora mucronata, Ceriops tagal*, *Lumnitzera racemosa and Xylocarpus granatu,* with the first three being the most abundant species while the last three are only restricted to the Kosi estuary (Ward and Steinke, 1982; Hoppe-Speer 2012; Adams et al. 2016; Adams and Rajkaran 2020). *Avicennia marina* is the widest spread in South Africa compared to the other six species (Steinke et al. 1995; Adams et al. 2016).

Madagascar-Mangroes are widespread along the entire west coast of Madagascar with the largest formations found along the north-west coast (Spalding et al. 2010). Small dense mangrove stands exist on the east coast along the Masoala Peninsula (Taylor et al. 2003). Mangroves in Madagascar are known to functions as important nursery grounds for 60 species of juvenile fish, including 44 commercial species (Taylor et al. 2003) as well as crustaceans.

Comoros- In the Comoros, mangrove forests are not well developed and occupy about 184.23 ha, the majority in Moheli with 100 ha, Anjouan with 9 ha and Grande Comoros with 75.23 ha (Ambadi, 2004). The nine species of the mangrove found in the Comoros are *Avicennia marina*, *Xylocarpus granatum*, *Xylocarpus moluccensis*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata, Lumnitzera racemosa, Sonneratia alba* and *Heritiera littoralis* (Comoros MEDA, 2022).

Seychelles-In the Seychelles, mangrove forest are found within the inner granitic and outer islands and these occupy a total surface area of 29 km^2. There are eight mangrove species in the Seychelles namely, *Rhizophora mucronata, Bruiguiera gymnorhiza, Ceriops tagal, Sonneratia alba, Lumnitzera racemosa,* *Avecenia marina*, *Xylocarpus granatum* and *Xylocarpus mulocuensis* (GoS, 2014). The mangrove faunal assemblage in the inner islands is characterized by low species diversity and high abundance dominated by herbivorous gastropods and suspension feeding bivalves (GoS, 2020). Mangroves are rather restricted in the Seychelles with the last continuous belt existing between Port Launay and Port Glaud on the west coast of Mahé. In recent years there has been some notable secondary expansion along the east coast of Mahé where successive land reclamation programmes have created inshore lagoons (GoS, 2011). The various phases of land reclamation on the east coast of Mahé created lagoons where a limited mangrove flora (dominated by *Avicennia marina* and *Rhizophora mucronata)* and fauna has re-colonised (GoS, 2020). Curieuse supports a diverse mangrove area on its west coast and Praslin retains a few isolated mangrove areas while other very small areas occur on other islands such as Cousin. The most extensive forests are found in Aldabra, Cosmoledo and Astove. The mangrove forests found on Aldabra are the largest area of mangroves in Seychelles and are 16 times larger than the mangroves at Port Launay on Mahé (SIF, 2016).

Mauritius-Mauritius has two species of mangrove namely *Rhizophora mucronata* and *Bruguiera gymnorhiza* that are estimated to cover a surface area of about 1.8 km^2 (Third National Communication Report, 2016). Mangroves bear significant ecological importance to marine ecosystems and therefore they have been legally protected through the Fisheries and Marine Resources Act of 2007. The Ministry of Blue Economy, Marine Resources, Fisheries and Shipping) has implemented a mangrove propagation programme from 1995 to 2008 with the goal of rehabilitating degraded mangrove forests. It is estimated that since the start of the mangrove propagation programme in June 1995, at least 400,000 seedlings have been planted over an area of approximately 200,000 m^2, which is about a three-fold increase in mangroves from their initial extent (Mauritius MEDA, 2022).

Table 1-5: The main mangrove species in the Western Indian Ocean region

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	

3.12.3 Coral reef Ecosystem

The coral reefs in the WIO cover a surface area of approximately 12,913 km^2. Coral reefs extend through most of the region from Bajuni coast in southern Somalia to the coast of KwaZulu-Natal in South Africa. The most common coral reefs in the WIO are the fringing reefs, but barrier reefs (Madagascar, Mayotte), atolls (Seychelles) and patch reefs (South Africa) are also found 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. Coral reefs provide important habitat for many tropical species, including fishes of commercial and subsistence importance, they are a major drawcard for tourism, and they provide many materials for commercial and non-commercial value such as shells for sale and coral rock for building. In the WIO region, coral reefs also 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). The coral triangle between East Africa, the northern tip of Madagascar and the associated islands constitutes a high biodiversity region which merits greater conservation and resource-use management, especially as it has proven vulnerable to elevated SST-related coral bleaching due to climate change (Sheppard 2003, Obura 2005). The following section provides brief description of status of the coral reefs in each of the WIO Countries. The root causes of degradation are discussed in the later part of the TDA.

Table 1-6: 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). Fringing coral reefs occur along much of the 500 km Kenyan coastline, except in areas under influence of rivers such as the Tana and Athi Sabaki rivers (Obura *et al*. 2000, Spalding 2001, WWF-EAME 2004). 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. During the 1997-1998 El Nino (ENSO) event, the most significant bleaching of corals ever recorded in the WIO resulted in reduced coral cover from initial 40% to 14.5% along the Kenya coast (Kenya MEDA, 2022). In 2003, coral reefs showed signs of recovery and had returned back to 27% coral cover in 2009. Coral bleaching occurred during the north east monsoon season when sea surface temperature (SST) maxima were elevated by 1-2^{0}C above normal for over 2 months, causing extensive bleaching and the subsequent mortality of corals. Since 1998, several minor bleaching events have occurred in 2005, 2010 and 2016 and these have made it difficult for the coral reefs to recovery, while chronic local stressors such as overfishing of herbivores, land-based nutrients and habitat damaging activities such as destructive fishing practices, have aggravated the degradation further reducing coral resilience. During 2016 bleaching event, coral cover declined by 25% and algal cover increased 2.5 times. On average, the decline in the absolute cover of live hard coral between 2010 to 2016 was 1.4%, which represents a loss of 6.2 %. The bleaching and mortality varied across the reefs, with the most affected sites being Mombasa Marine Park and Kisite Marine National Park and Reserve in the south, whilst Shimo La Tewa, Mkokoni and Bomani areas recorded less than 15% mortality (Mwaura et al., 2017; Kenya MEDA, 2022).

Tanzania – Coral reef communities in Tanzania comprise at least 273 species from 63 genera and 15 families (Obura, 2004), covering about two thirds of Tanzania's continental shelf. Fringing reefs forming margins along the edge of the mainland or islands and patchy reefs dominate the coastal waters of

Tanzania. Coral reefs are one of the most productive and diverse marine ecosystems in Tanzania waters and, with their associated habitats support a variety of marine species. Levels of coral cover in Tanzania are considered high for East Africa, with 30-40% live coral cover for healthy reefs (Figure 1-17; Yahya *et al*., 2017). Over 500 species of commercially important fish and other invertebrates are commonly found in coral reefs. Fishing on shallow coral reef areas (where 70% of the fishery is artisanal) employs 53,035 fishers in Mainland Tanzania (Marine Fisheries Frame Survey 2018) and 49,332 in Zanzibar (Fisheries Frame Survey 2016). Additionally, coral reefs are one of Tanzania's major tourist attractions, bringing foreign currency into the country and providing a livelihood for coastal people. For example around 20% of the GDP in Zanzibar is directly related to the coral reefs and the tourism industry (Yahya *et al*., 2017; www.zanzibar-ecotourism.org)

Figure 1.17: A typical healthy coral reef in Zanzibar, Tanzania (*Photo credit: B. Yahya)*

Over the past few decades, a number of factors have contributed to the degradation of coral reefs in Tanzania. These factors include seine netting, over-fishing, shell collection, wave action, boat anchoring, crown-of-thorns starfish (COTS) and coral bleaching. The closeness of the reefs to land makes them particularly prone to human impact, either from exploitation or from indirect terrestrial influence such as sedimentation and pollution. For example, sediments from the Ruvuma river occasionally affect coral reefs of Mafia Island Marine Park (Machano, 2012). Repeated cycles of coral bleaching, and partial mortality and recovery occur in many sites (Figure 1-18). Many of the Tanzania reefs were severely affected by the coral bleaching event of 1997-1998 which reduced the average live coral cover from 52% before bleaching to about 27% after the event (Wells *et al*., 2004). Another coral bleaching started in February 2016 and increased through June with peak bleaching occurring during late March and April (Ussi *et al* 2019). Bleaching of 80–90% was observed on some reefs, such as Sinda reef off Dar es Salaam and northern Chumbe reef, Zanzibar (Yahya *et al*., 2017). Following the bleaching event, coral reefs in Zanzibar were the worst affected, with a 52% decrease in live coral cover compared to other areas in Mainland Tanzania (Gudka *et al*., 2018). Generally, coral reefs recovery has been very slow in Tanzanian waters. Reef restoration has been done at small scale in some parts of Tanzania like Fumba (Zanzibar) and Dar es Salaam. Reef translocation has been done at Fumba and closures mostly in Marine protected areas (Tanzania MEDA, 2022).

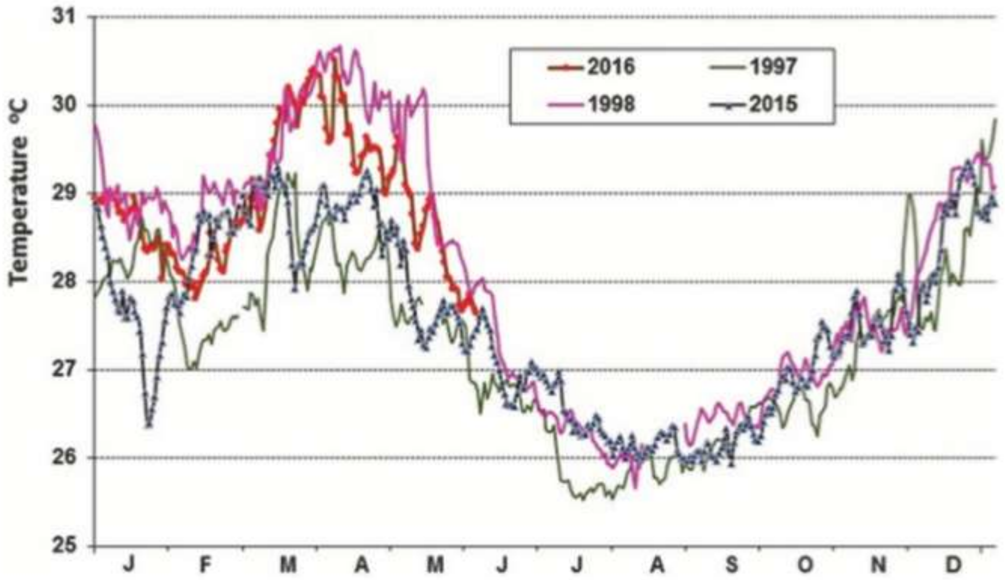


Figure 1-18: Seawater temperature at Chumbe coral reef, Zanzibar for 1997, 1998, 2015, and 2016. Elevated seawater temperatures (higher than 30 °C) are associated with coral bleaching (Source: *Ussi et al., 2019)*

Mozambique - Coral reefs cover an area of about 1,860 km^2, 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). Fringing reefs are extensive along the northern coastline except in proximity to rivers which have deposited deltaic sediments. There are several offshore island groups which sustain coral reefs including the Quirimba Archipelago near the Tanzanian border, the Primeiro and Secundo island chain near Angoche, the Bazaruto Archipelago in the central coast and Inhaca Island in the south. 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 – Coral reefs of South Africa are the southernmost coral communities in the world located on the northern region of the Kwazulu Natal, along the Maputaland coastline between Lake St Lucia to the Mozambican border at a latitude of 27◦54 S, stretching approximately 150 km and mostly dominated by alcynacea and small Scleractinia (Riegl et al., 1995; Riegl, 1996; Riegl 2003; Schleyer et al., 2018). The reefs are situated within the Maputaland Marine Reserve and St Lucia Marine Reserve (Floros 2010). All South African reefs are within protected areas and fall within the iSimangaliso Wetland Park, a World Heritage Site (Schleyer et al., 2018; Ramsay and Mason, 1990). However, at Aliwal Shoal, located 3km off Umkomaas on the KZN south coast, some do occur, but with lower diversity. These are covered by soft coral fauna over much of their surface with relatively fewer species not the hard corals common on most true coral reef (Jordan and Samways, 2001). Soft corals are also located within the Agulhas region-these Agulhas reefs are dominated by sponges, ascidians, bryozoans and octorals (Driver et al. 2012). Coral reefs of South African are delicate ecosystems and over the years have been affected by various factors however to a lesser extent from climate related bleaching (Celliers and Schleyer, 2002; Morris, 2009), oceanography-movement of the Agulhas current along the east coast (Morris, 2009), sedimentation (Schleyer and Celliers, 2003), invasive species-crown-of-thorns starfish predation (Celliers and Schleyer, 2006), human activity-increase recreational fishing, particulate, chemical pollution and high diving intensity (Floros et al., 2013). Corals are largely protected from sea level rise and bleaching by the small scale upwelling events and swell generated inshore counterflows off the coast of South Africa caused by the Agulhas current (Riegl 2003).

Seychelles - Coral reefs are critically important to Seychelles, which is highly dependent on these ecosystems for food security, local livelihoods and economic growth (USAID, 2017; Seychelles MEDA, 2022). They are critically important in fisheries through the provision of employment and an estimated 4000 metric tonnes of reef associated fishes (SFA, 2016). Seychelles has 1,700 km^2 of coral reef, the vast majority of which occurs around the south eastern islands which is about 13.1% of the total coral reef area of the Eastern Africa and the South West Indian Ocean islands (Nevill et al., 2015; Ahamada et al, 2008; GoS, 2011). Two different eco-regions are recognized in terms of the composition of hard coral biodiversity-the northern eco region has lower species richness compared to the southern eco region (Bijoux, nd). Of the 200 species of Scleratinian corals identified in Seychelles, 34 are classified as threatened under IUCN criteria, 2 species as endangered and 32 as Vulnerable (GoS, 2014). The coral reefs of the Seychelles inner islands are the most extensively used and are in areas where the coral reef ecosystems face the greatest threat (JICA, 2014). The reefs can be classified into two main types: (i) granitic reefs, which consist of corals growing over large granite boulders, and (ii) carbonate reefs, which are further divided into fringing reefs, atolls, and platform reefs (Stoddart 1984). The back reef environment is mostly covered by macro-algae of the genus *Sargassum* and *Turbinaria* or seagrass comprising mostly of *Thalassodendron ciliatum* and *Thalassia hemprichii*. Reef associated animal groups include corals, crustaceans, echinoderms, fish, macroalgae, mollusk and sponges (World Bank, 2017). Despite positive trends observed between 1998 and 2015, recovery of coral reefs in the Seychelles was abruptly terminated in the first half of 2016 by another large-scale mass coral bleaching event that led to 90% mortality at some sites (Bijoux et al., 2017; Gudka et al, 2018). During coral bleaching events, the coral reefs in the Inner Islands are more severely impacted than the coral reefs in the Outer Islands (Gudka et al, 2018). The Curieuse Marine National Park has been heavily impacted as bleaching occurs across all sites (Mcgavin et al., 2017). North Island is the most affected with an 81% decline in living hard coral cover (Gudka et al, 2018). Since the bleaching event, the coral reef systems of the inner islands have undergone a widespread phase shift from a coral-dominated state to a rubble and algal-dominated state (World Bank, 2017). There are ongoing efforts to mitigate existing anthropogenic impacts on coral reefs and associated shallow marine habitats. Some projects are focusing on restoring damaged coral reefs to increase their resilience through Ecosystem Based Approaches (EBAs).

Comoros -The three islands that make up the Comoros are volcanic with steep slopes and as such have little shelf region and thus not much coral reef. However, the islands are edged by a narrow fringe of coral while Moheli has more extensive coral reefs, making a total area of 430 km^2 (Spalding 2001). The fringing reefs are restricted to 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).

Madagascar - The coral reefs of Madagascar covers approximately 2,200 km^2 which is equivalent to 17.3 % of the total reef area in the WIO region (Spalding 2001). The most extensive reefs are found along the north-east, north-west, and south-west coasts, and have the highest richness of coral species in the Western Indian Ocean (Ahamada *et al*. 2008). Coral reefs are widely distributed along the west coast. 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 m and a few kilometres offshore and are 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 km. 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.

Seychelles

The Seychelles Archipelago, which consists of 115 islands and atolls, has a coral reef of (1,690 km^2 which is equivalent to about 13 % of the total coral reef area in the WIO (Spalding 2001). Most of the population lives on the three inner islands, which have only 40 km^2 of coral reef and where both industrial and artisanal fishing are important economic activities. Primary threats to coral reefs include dredging and reclamation, sedimentation, excessive fishing pressure, coral diseases, invasive species and climate change associated with global warming (Ahamada *et al*. 2008).

Mauritius
The island of Mauritius is almost completely encircled by fringing coral reefs, with substantial lagoon and reef development on the east and southwest coasts (Spalding 2001). Rodrigues, on the other hand has a highly developed coral 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 surrounded by large expanses of coral reefs (Spalding *et al.*, 2001). Most coral reefs around Mauritius have been degraded by human activities (Spalding 2001), although the island of Rodrigues remains relatively less impacted (Turner and Klaus 2005).

Reunion (France)
Being a volcanic island with steep slopes and great depths, Reunion has only a few fringing reefs covering an area less than 50 km^2 on the leeward western shores (Spalding 2001). Reunion has a large coastal population and overexploitation of coastal fishes based on coral reefs has been occurring for a long time (Spalding 2001). On outer islands and coral reefs within the large EEZ of Reunion, larger mother ships with attendant dories harvest reef fish using handlines to catch mainly Lethrinidae, especially *Lethrinus mahsena* and *L. variegatus* (van der Elst 2012).

3.12.4 Seagrass beds

Twelve seagrass species comprising about a fifth of the world's total, occur in the WIO region (Table 1-7; Bandeira and Bjork, 2001; Gulström *et al*., 2002). Seagrasses, which are one of the most productive aquatic ecosystems on earth, extend from southern Somalia to the north coast of South Africa, and are widely distributed throughout the WIO region mainland and island states. The 12 Species are distributed from the intertidal zone down to about 40m. The 12 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 1-7). *Ruppia maritima*, recently defined as a seagrass (Short *et al*., 2001), is also a dominant species in the south-eastern Africa (Colloty, 2000). Seagrass beds are often found in close proximity to coral reefs and mangrove forests, are characterized by very high productivity, and support a wide variety of species. Molluscs and fish of commercial importance (including fishes of the families Apogonidae, Blenniidae, Centriscidae, Gerreidae, Gobiidae, Labridae, Lethrinidae Lutjanidae, Monacanthidae, Scaridae, Scorpaenidae, Siganidae, Syngnathidae and Teraponidae) use seagrass beds to forage and for shelter during their juvenile stages (Gullstrom *et al.* 2002). Seagrass beds are extremely important nationally, regionally and globally, for the health and sustainability of marine living resources of the WIO region, but also for the global sequestration of carbon.

Table 1-7: 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		√			√				√

Species	Comoros	Kenya	Madagascar	Mauritius	Mozambique	Seychelles	Somalia	South Africa	Tanzania
Halophila ovalis	√	√	√	√	√		√	√	√
Enhalus acoroides		√			√	√			√
Cymodocea serrulata	√	√	√	√	√	√	√	√	√
Cymodocea rotundata	√	√	√		√	√	√	√	√
Ruppia maritime								√	

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 following section provides brief description of status of the seagrass beds in each of the WIO Countries. The root causes of degradation are discussed in the later part of the TDA.

Kenya - Seagrass beds are one of the most conspicuous ecosystems types along the Kenyan coast, especially located inside the coral fringed coastal lagoons (Wakibya 1995). The most important sites are located in Lamu and Kiunga, Malindi, Mombasa, Gazi Bay, and Mida Creek and Diane-Chale lagoon (Dahdouh-Guebas *et al*., 1999; Ochieng and Erftemeijer, 2003). Twelve species of seagrass that are found in Kenya include *Thalassodendron ciliatum, Thalassia hemprichii*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Syringodium isoetifolium*, *Halodule uninervis, Halophila minor, Halophila stipulacae, Halophila ovalis* and *Zostera capensis* (Dahdouh-Guebas *et al*., 1999; Obura, 2001; Gulstrom *et al*., 2002; Ochieng and Erftemeijer, 2003; Kenya MEDA, 2022). These seagrass species are widely distributed along the Kenyan coastline and most of them occur in mixed meadows with *Thalassodendron cilatum* forming large monospecific meadows in several areas. The seagrasses occur in a succession regime with small species such as *Halodule* spp. and *Halophila* spp. being pioneer species and the larger seagrasses such as *Thalassia hemprichii*, *Thalassodendronciliatum*, and *Enhalus acoroides* forming the more dominant climax communities. Although the species diversity is known, the acreage of seagrasses along the Kenyan coastline is yet to be established. Seagrasses form breeding and feeding grounds for several fish species as well as dugongs and turtles (Björk et al. 2008). They also support a diverse assemblage of plant and animal species which include macroalgae that grow as epiphytes on the stems and leaves of the seagrasses (Uku 2005), invertebrates that include sea cucumbers, sea urchins, shrimps and lobsters (Ochieng and Erftemeijer 2003). Seagrasses also perform important functions in the ecosystem such as sediment stabilization, nutrient cycling, shoreline protection, enhancement of water transparency, biological system support and carbon sequestration. (Muthama and Uku 2003; Orth et al., 2006).

Tanzania - In Tanzania seagrass beds are widespread and are found in all bays in most inshore areas and on the west side of most islands. The most extensive seagrass beds are found in Tanga coast, deltas of Ruvu, Wami and Rufiji rivers, Mafia and Songo songo archipelago, Kilwa and in Zanzibar archipelago (Aller *et al*., 2019; Khamis *et al*., 2017). There are 12 species of seagrass off the coast of Tanzania which are *Halodule uninervis, Halodule wrightii, Syringodium isoetifolium, Cymodocea rotundata, Cymodocea serrulata, Thalassodendron ciliatum, Zostera capensis, Enhalus acoroides, Halophila minor, Halophila ovalis, Halophila stipulacea and Thalassia hemprichii*. They primarily grow between the intertidal and subtidal zones, typically near coral reefs and mangrove forests, and they provide extensive ecosystem services in tropical and temperate regions around the world (Nordlund *et al*., 2016; Staehr *et al*., 2018). Studies of dugong distribution and migration along the Tanzania coast show that they are associated with areas of extensive seagrass beds particularly in the Rufiji delta and Mafia-Kilwa area which has a viable dugong population. Seagrass meadows and proximate coral reefs support 70% of small-scale fishing. Seagrass beds in Tanzania are threatened by natural and human activities that include anchoring of fishing and tourist boats, excessive sedimentation increasing turbidity and reducing light penetration. In Zanzibar, eutrophication due to increased levels of dissolved organic matter and nutrients from untreated sewage in intertidal and subtidal zones related to population and tourism increases is a threat to seagrasses (Staehr *et al*., 2018). Shoreline dynamics including sand deposition and removal, illegal fishing practices such as beach seining and shallow water trawling also threatens seagrasses. Natural grazers such as sea urchins and dugongs have also in some places reduced the cover of seagrass beds (Tanzania MEDA, 2022).

Mozambique - In Mozambique, seagrass beds are most extensive in the sandy (south) and limestone (north) areas of the coastline (Green and Short 2003). Extensive seagrass beds are found in the Bazaruto Archipelago and around Inhaca Island. 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 - Little is known about the seagrass beds of South Africa but eelgrass *Zostera capensis* dominates the muddy bottom of the east coast estuaries and *T. ciliatum* is dominant on the rocky shorelines. It is estimated that they cover a surface area estimated at 700 (Bandeira and Gell 2003). Seagrass beds are confined to estuarine waters from KwaZulu-Natal to the Western Cape region (Green and Short 2003). Seagrass beds along the east coast of South Africa cover about 7 km^2, with the highest concentration in the St. Lucia and Richards Bay estuaries (Colloty, 2000). However, periodic droughts have severely impacted 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).

Seychelles - Seagrass beds in the Seychelles are extensive in Platte, Coetivy, Amirante Banks and Aldabra. 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 m depth (Titlyanov, 1995). Four seagrass species (*T. ciliatum*, *T. hemprichii*, *H. uninervis* and *S. isoetifolium*) and 119 algal species occur both on the Aldabra Atoll 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 - Comoros has eight seagrass species namely *Thalassia hemprichii*, *Thalassodendron ciliatum, Syringodium isoetifolium, Halodule wrightii, Halodule uninervis, Cymodocea rotundata, Cymodocea serrulata*, *Halophila ovalis, Zostera capensis* and *Enhalus acoroïdes.* Other species include *Gracilaria, Jania, Lithotamnium, Ulva, Codium, Halimeda, Porolithon* and *Pandina*. Seagrass habitats support a wealth of marine fauna such as gastropods, crustaceans, sea turtles, dugongs, fish as well as algae. Seagrass beds are well developed in the northern and southern ends of Grande Comore

Island and around the Bimbini peninsula on the western part of Anjouan Island, but are distributed in shallow waters surrounding Moheli Island. In Ngazidja, the sea grass beds cover are very small area of about 3.3 km^2 and in Ndzuani they cover an area of 14.2 km^2, particularly in the Bimbini region, where they form dense and continuous beds. Sedimentation due to soil erosion, various forms of pollution, overexploitation and destructive activities such as fishing methods and urbanisation are the cause of degradation of seagrass meadows in the Comoros (Comoros MEDA, 2022).

Madagascar - Seagrass species diversity, distribution, abundance and status in Madagascar are largely unknown. Few studies conducted in Madagascar showed that seagrass beds are generally well developed in reef lagoons (Cooke *et al*. 2000). Most meadows are 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).

Mauritius – 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). Extensive seagrass beds occurring in lagoons surrounding Mauritius were reported prior to 1980 (Montaggioni and Faure 1980. However, current data on the status of seagrass habitats is lacking and their status is assumed to be declining (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.

3.12.5 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 1-8 lists some WIO locations with their main shoreline substratum type.

Table 1-8: 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 WIO countries are thus strongly influenced by the nature of the substrate, as the sections that follow demonstrate.

The following section provides brief description of status of the sand beaches in each of the WIO Countries. The root causes of degradation are discussed in the later part of the TDA.

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 km 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 - Tanzania is endowed with sturning white beaches and turquoise waters (Figure 1-19; Tanzania MEDA, 2022). There are several sand beaches along the coast and small islands of Tanzania for example Zanzibar. Some stunning beaches are found around islands such as Mafia, Pemba, Fanjove, Kilwa which have the potential to serve as world-class tourist attractions (Anderson, 2011b). Tanzania has risen to become African haven for beach lovers. Beach sand is supplied from several sources including rivers and sea. Sand beaches act as a protective buffer against wave and tidal currents (Shaghude *et al*., 2015). Several beaches and adjacent coastal areas in Tanzania are under increasing pressure from natural and human threats. Factors threatening beaches in Tanzania include wind, wind-generated waves, storm surges and land sourced floods, expanding tourism development, inappropriate coastal protection structures and erosion due to increased severity of stormy conditions (Shaghude *et al*., 2015). At Kunduchi, the NNW of the coast favours forcing by the SE monsoon, resulting in long-term coastal erosion and the “loss” of sand beaches around Ras Kiromoni and its accretion on the adjoining shore at Ununio. Extraction of sand from the rivers has also led to reduced riverine input to the beaches (Shaghude *et al*., 2015).

Figure 1-19: A typical sandy beach at Pongwe in Zanzibar, Tanzania (*Photo credit: B. Yahya)*

Some parts of Tanzania coast have widespread rocky shores such as Kunduchi and Bahari beach (Shaghude *et al*., 2012). About 49% of the beaches in Zanzibar are delineated by rock islands where they form natural coastal defense (Mchenga and Ali, 2015). Moreover, the low tide pools created on the rocky shores sustain a number of small anemones, starfish, minnows and others. These tidal pools give life to some of the world most interesting species that could not survive in large open ocean environment. The intertidal rocky outcrops are relatively resistant to erosion and contribute to coastal defense. However, relatively little is known about the rocky shores of Tanzania (Tanzania MEDA, 2022).

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). There is lack of information on the seaweed and macro algal species that might be occurring on the barren basalt rocky shores of the Comoros.

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.

3.12.6 Coastal forests

Coastal forests in the WIO region include terrestrial vegetation with a continuous stand of trees found adjacent to the coastal areas but excluding mangroves (White, 1983). The range inland can be up to 200 km (*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. These regions are 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 1-8 summarizes the phytochoria, their 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 1-8: Phytogeographic regions on the WIO mainland

Phytogeographic region	Area (km^2)	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 (1° N) to the mouth of the Limpopo River (25° 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 (Kitheka *et al*., 1998). Arabuko-Sokoke Forest in Kenya, covering a surface area of 410 km^2 is one of the better-protected coastal forests in the region (Burgess and Clarke, 2000). Most coastal forest sites occur as clusters that are isolated from each other, over distances varying from one to several tens of kilometres. The vegetation between the coastal forest clusters is usually a mixture of farmland, savannah-woodland and thicket (Burgess and Clarke, 2000). The savannah-woodland is usually dominated by mixtures of miombo woodland vegetation and coastal mosaics (see *Flora Zambesiaca* maps in Wild and Grandvoux Barbosa, 1967). The following section provides a description of coastal forests in each of the WIO Countries. The pressures leading to their loss and degradation are described in the later sections of the TDA.

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 has reduced from 93.5 km^2 to 9.0 km^2 (Burgess and Clarke, 2000).

Kenya - Coastal forests in Kenya covers a surface area of about 660 km^2. However, the majority of Kenya's coastal forests 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 ms (Burgess and Clarke, 2000). Notable coastal forests in Tanzania include the Jozane forest on the Unguja Island (Zanzibar), Mlola forest on Mafia Island and Ngezi Forest 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 km north of the border between Mozambique and Tanzania, in the Matumbi and Kichi Hills, with at least three species 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 –The dominant vegetation associations in the Seychelles 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). There are 250 species of indigenous plant species of which 75 are 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 are known to occur in these two centres. Some endemic families and genera, respectively, include 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.

3.13 Fisheries and fisheries ecology

The central coast of Tanzania including the islands of Mafia and Zanzibar, south-central coastal section of Mozambique including the Sofala Bank, parts of the west coast of Madagascar and the Seychelles Plateau that surround Mahe, Praslin and La Digue islands, are the only areas where there is considerable expanse of continental shelf (Spalding *et al.*, 2001). The remaining 95% of the WIO is deep, mostly between 500 and 4,000 m. 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.

Despite this relatively narrow 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 in the estuaries of most rivers and seagrass beds flourish in shallow, soft bottom lagoonal environments where the sun's rays are able to penetrate into the water column (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 conducted in the region, estimate that the overall fish diversity in the WIO region includes some 2,200 species which is equivalent to about 15% of the global total of marine fishes. Few oceans share similar ichthyofaunal richness as the Western Indian Ocean (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 WIO region, plus the countless crustaceans, molluscs and echinoderms, several hundred species 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.

Fisheries in the WIO region range from traditional subsistence and artisanal activities to large-scale industrial operations. Artisanal fisheries use a wide variety of different gears including hand-lines, traps, nets (seine, cast, gill nets), small trawls and harpoons. These target demersal and small pelagic fish species as well as sea cucumbers, lobsters, crabs, prawns, bivalves and octopus. Industrial fishing consists mainly of longlining and purse seining for tuna and large pelagics as well as trawling for prawns, langoustines, lobsters and crabs. It has been estimated that 65 million people live within 10 km of the coast in the wider Indian Ocean region (Burke *et al*. 2011) and for many of these people seafood represents an important source of food and employment. While large industrial fisheries, such as those targeting tuna and crustaceans, supply the world's markets, most developing countries of the WIO have important artisanal fisheries that contribute towards local food security and the local economy (van der Elst 2012). The Western Indian Ocean (WIO) generates about 5% of the global industrialised fish catch, equivalent to more than 4 million tonnes of fish per year (FAO 2012a).

3.13.1 History of Fisheries in the Western Indian Ocean

In the last half century, the production of fish and fish products in the wider Indian Ocean region increased significantly, from 0.861 million tonnes in 1950 to 11.2 million tonnes in 2010, as a result of improvements in fish capture technology and in response to a rising demand both from within the region and globally. Although total catches have increased since 1999, annual catches have remained stable at around 4 million tonnes (FAO 2012a, van der Elst *et al.* 2005). The coastal regions of the WIO have a long tradition of exploiting their coastal marine resources. The fisheries that developed historically are in principle, the same as the "artisanal" or "traditional" coastal fisheries of the present day. These fisheries provide a livelihood for several million people and characteristically employ a diverse range of fishing gear types and target many different species (Samoilys *et al*. 2011, WIOFish 2011). They are often important for food security. A number of different factors have constrained the further development of the artisanal fisheries in the WIO (e.g. lack of infrastructure and access to finance to upgrade boats and equipment). Despite this there has been a significant increase in fishing effort in the last few decades as coastal populations have continued to expand and demands for fish and fish products have increased within the region and internationally. The industrialisation of the offshore fisheries is perhaps the most significant recent development in the WIO (Cochrane and Japp 2012), particularly the targeting of tuna and other large pelagic resources by Distant Water Fleets (DWF) from the European Union, Japan, South Korea and Taiwan. DWF nations began longlining for tuna in the WIO in the early 1950s, initiated by the Japanese and soon followed by the Taiwanese (1954) and South Koreans (1960). Since then, the presence of Asiatic longliners in the WIO increased significantly, until recently when the numbers of active Japanese and Korean longliners diminished because of declining profitability. Large-scale purse seine fishing for tuna began in 1983, when French and Spanish fleets moved into the WIO, fishing under access right agreements (Kimani *et al*. 2009). Catches of tuna and tuna-like species in the WIO increased from 0.5 million tonnes in 1987 to 1.1 million tonnes in 2003 (Anon 1998, 2006).

The fisheries sector in the WIO currently employs 2.7 million people, full and part time, generating wages of about US$366 million per year. The fisheries have also diversified and the number of species recorded in landings has increased from 85 species in 1971 to 152 species in 2000 (van der Elst *et al*. 2005). According to the Southwest Indian Ocean Fisheries Committee (SWIOFC), one third of stocks in the region are now considered to be either 'Overfished' or 'Depleted' (FAO-SWIOFC 2011) (Figure 1-20). Although there is some contention about the reliability of these estimates, the general overarching impression is one of overexploitation. There is now a growing demand for new resources that is leading to increased exploration and exploitation of deepwater fisheries. Due to the overfishing of coastal stocks, many countries are now planning to expand their semi-industrial and industrial national fleets to new fishing grounds in their EEZs (Michel *et al*. 2012). Some countries have even developed their own semi-industrial fishery, but in most countries there is still a huge disparity between the capacities of the artisanal fisheries and the industrial offshore fisheries that has yet to be resolved.

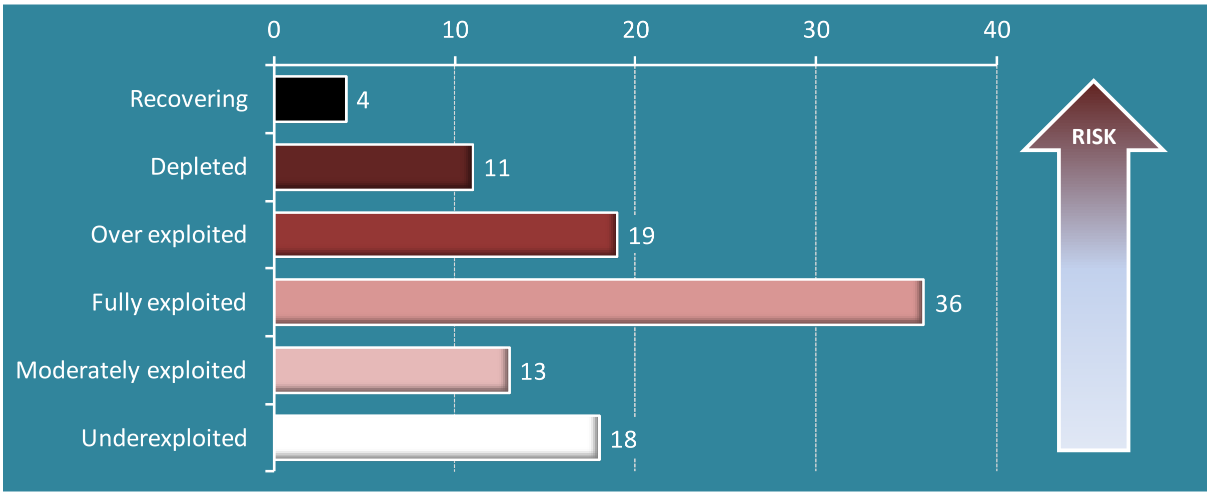


Figure 1-20: Status of stocks in the WIO in 2009 (SWIOFC 2011)

Due to limitations of traditional boats, equipment and safety concerns, the majority of artisanal fishers in the WIO concentrates their fishing activities on the near-shore coral reefs and drop-offs on the edge of the continental shelf. Although some will migrate, the majority of artisanal fishers are not equipped to be able to venture into deep offshore waters. Rapidly increasing coastal populations, coupled with high levels of unemployment and poverty, has thus resulted in overcapacity within artisanal sector in most countries in the WIO. As the resources are often open access, and many of the coastal fisheries require minimal skills and investment, there has been increasing pressure on near-shore waters and resources. Environmental conditions, especially the monsoon winds (either south east or north east) and tidal ranges also further limit effort.

Lack of infrastructure and inadequate post-harvest storage and processing facilities have prevented most fishers in the WIO from accessing larger more lucrative international markets to obtain the maximum value from the catches. Although some countries have adequate storage facilities, many do not and this continues to result in extensive post-harvest losses. Limited access to finance has also prevented many fishers within the region from upgrading their equipment and increasing production. Some countries are now trying to address these issues and have implemented microfinance and duty concessions to give the sector the opportunity to become more competitive internationally. Other countries have also implemented schemes where the local fisheries benefit from the money raised through providing licences to international vessels.

3.13.2 Overview of Fisheries in the Western Indian Ocean

Under the auspices of the SWIOFP, each participating country in the WIO undertook its own national data inventory and gap-analysis focussing crustaceans, demersal fishes, pelagic fishes and biodiversity issues. This gap analyses and retrospective analyses together with the information presented in the national MEDA reports prepared under the auspices of the ASCLME project provided the basis for the following description of the status of fisheries in the WIO.

3.12.2.1 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 hundreds 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 foreign-owned 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).

3.12.2.2 Crustacean Fisheries

Fisheries for prawns (shrimps), lobsters and crabs are very common along the coastal edges of the WIO region, and are exploited at both the artisanal and industrial scale. Reported landings for nine (of the ten) countries in the WIO are approximately 35,000 tonnes per year (van der Elst *et al*. 2009), and the largest contributors are the shallow-water penaeid prawn fisheries of Mozambique and Madagascar. Several species of tropical spiny lobsters and crabs (e.g. mangrove- and swimming crabs) are targeted in shallow waters by artisanal and recreational fishers, and caught by simple gears operated from the shore or from small boats. According to the Scientific Committee of the South West Indian Ocean Fisheries Commission (SWIOFC), most of the crustacean stocks in the region are fully or overexploited (Table 1-9) although there is some disagreement about the status of shallow water prawns in South Africa and deepwater prawns (and langoustines) in Mozambique and South Africa. The deep-water crustaceans in the WIO region (i.e. deep-water prawns, langoustines, several deep-water spiny lobster species and deep-sea crabs) are only accessible to industrialised trap and trawl fisheries and therefore the extent and fisheries potential of deep-water stocks are not as well known as for shallower-water species (Groeneveld *et al*. 2009).

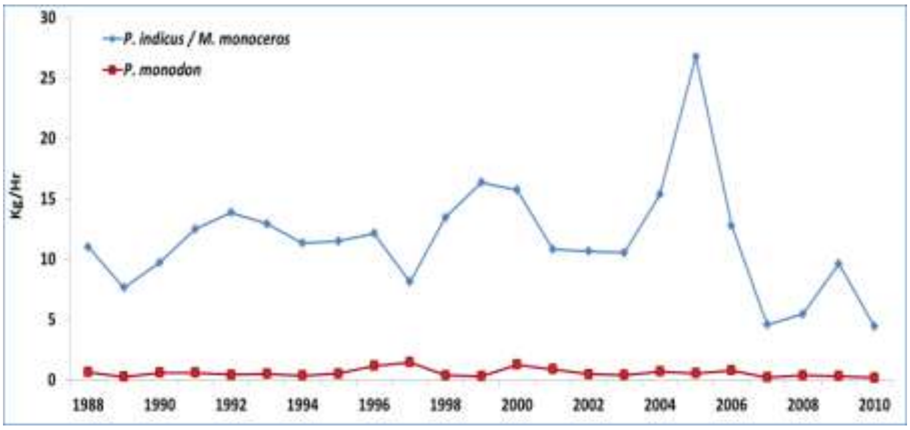
Table 1-9: The status of crustacean stocks in the 9 ASCLME countries as agreed during the 5th session of the Scientific Committee of the SWIOFC (FAO-SWIOFC 2012)

Country	Species/Complexes/Groups	Stock Status
Comoros	Crustaceans (prawns, langoustines, crabs)	Under Exploited
Kenya	Spiny and rock lobster	Overexploited
	Shallow-water prawns (commercial)	Fully Exploited
	Shallow-water prawns (artisanal)	Unknown
	Crabs	Fully Exploited
Madagascar	Langoustines	Fully Exploited
	Prawns	Fully Exploited
	Crabs	Fully Exploited
Mauritius	Deep-water prawns (*Heterocarpus laevigatus*)	Under Exploited
Mozambique	Spiny and rock lobster (*Palinurus delagoae*)	Depleted
	Shallow-water prawns (*P. indicus* & *M. monoceros*) (industrial)	Fully Exploited
	Shallow-water prawns (semi-industrial & artisanal)	Fully Exploited
	Deep-water prawns (*Haliporoides triarthus* & *Aristeomorpha foliacea*)	Moderately Exploited
Seychelles	Spiny and rock lobster (*P. longipes, P. versicolor, P. penicillatus, P. ornatus*)	Recovering
	Spanner crab (*Ranina ranina*)	Under Exploited
Somalia	Spiny and rock lobster	Overexploited
South Africa	Spiny and rock lobster (*P. gilchristi, P. delagoae* & *P. homarus*)	Fully Exploited
	Crustaceans (deep & shallow-water prawns, langoustines, scyllarids)	Overexploited
Tanzania	Spiny and rock lobster	Fully Exploited
	Shallow-water prawns	Depleted

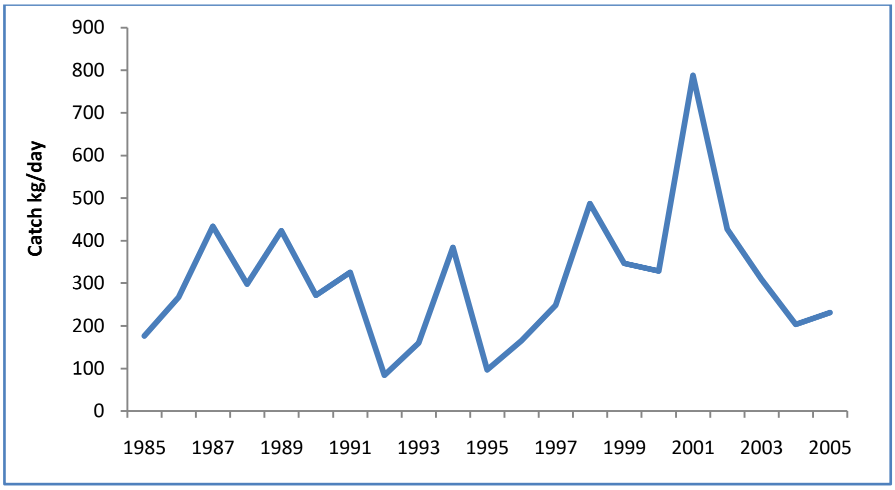
3.12.2.3 *Industrial Trawl Fisheries (Shallow)*

Apart from the tuna fisheries, trawling for shallow water penaeid prawns is the most prevalent, coastal, industrial fishery in the WIO region. All of the east African mainland countries (South Africa, Mozambique, Tanzania, Kenya and Somalia) as well as Madagascar use this fishery method. The main target species are *Fenneropenaeus indicus* (*Penaeus indicus)* and *Metapenaeus monoceros* which together contribute around 90% of landed shallow water trawled prawn catches. Other commercially-valuable shallow prawn species (*Penaeus monodon*, *P. semisulcatus*, *P. latisulcatus* and *P. japonicus*) are also caught, but in a much lower abundances. The vessels and gear used for trawling are broadly similar in all of the WIO countries, with increased levels of sophistication in parts of the fleets in Mozambique and Madagascar. Steel, motorised vessels of up to 40 m in length are equipped with refrigerators to preserve the catch, allowing them to stay at sea for up to 1 month. Demersal otter trawls are used with up to 4 trawls on outrigger booms. With the exception of South Africa, trawled catches of prawns are exported and represent a valuable source of foreign currency, particularly in Mozambique and Madagascar. Mozambique, Tanzania, Kenya, Somalia and Madagascar have substantial small-scale (traditional/artisanal) fisheries which appear to be growing and increasingly targeting prawns, leading to user-conflicts with the trawl sector. In Kenya, the trawl fishery was intermittently closed in 2000 and 2001, and again in 2006 due to clashes with artisanal fishers (Ochiewo 2004, Munga *et al*. 2012). After re-opening in 2007, it was closed again in 2008-2010. In 2011, only 3 vessels were licensed of which 2 fished in 2011 and 2012 (Fennessy 2012).

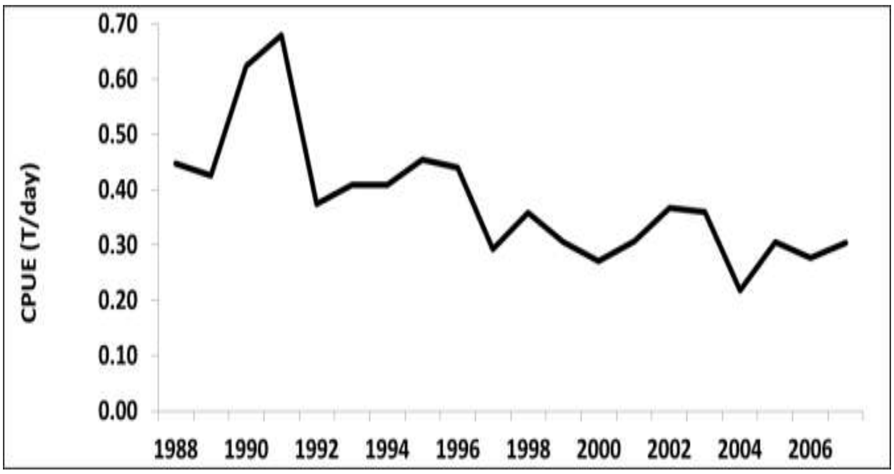
According to the Scientific Committee of the SWIOFC, penaeid prawns in the WIO region are fully exploited (FAO-SWIOFC 2011). For instance, in Kenya, catch per unit effort (CPUE) declined from 2001 onwards; in Mozambique CPUE declined sharply from the late 1970s to the late 1980s, then declined more slowly to 2004, after which it remained steady; and in Tanzania, catches declined sharply from the mid- 2000's. The Tanzanian prawn fishery was closed in 2008 in order to allow stock to recover (Figure 1-21a-d) (Fennessy 2012). In Madagascar artisanal catches have declined from 750 tonnes in 2003 to just over 100 tonnes in 2009. In South Africa declines in prawn catches occurred following the closure of the large St Lucia estuary in 2001 from which about half of the prawns recruit (Fennessy 2012).



(a)



(b)



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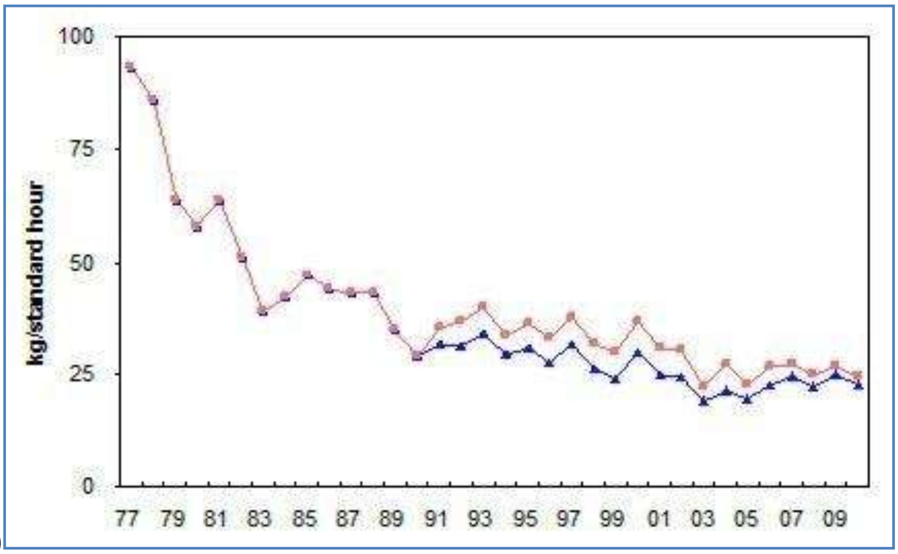
(d) 

Figure 1-21: Trends in CPUE for the shallow water prawn trawl fisheries in (a) South Africa, (b) Ungwana Bay, Kenya, (c) Tanzania and (d) Sofala Bank, Mozambique by day (blue) and day and night combined (red) (Fennessy 2012).

While there are management measures in place for the shallow water prawn trawl fishery sector in each country, these measures usually lack clearly quantified objectives, and ensuring compliance with some measures is usually difficult in most countries. There is currently no Ecosystem Approach to Fisheries (EAF) management plans that have been developed for the crustacean fisheries in the WIO, although these have been proposed for the artisanal and commercial fisheries in Kenya, Tanzania and Madagascar (FAO-SWIOFC 2012). The small-scale fisheries sector in the WIO is usually characterised by lack of effort limitation, lack of effective management measures and low compliance. The fisheries are all managed at a national level, with no regional management strategy. There is however no genetic evidence at this stage to indicate that the priority shallow water prawn species are shared and thus it is appropriate that the stocks in each country continue to be managed separately for the time being (Fennessy 2012).

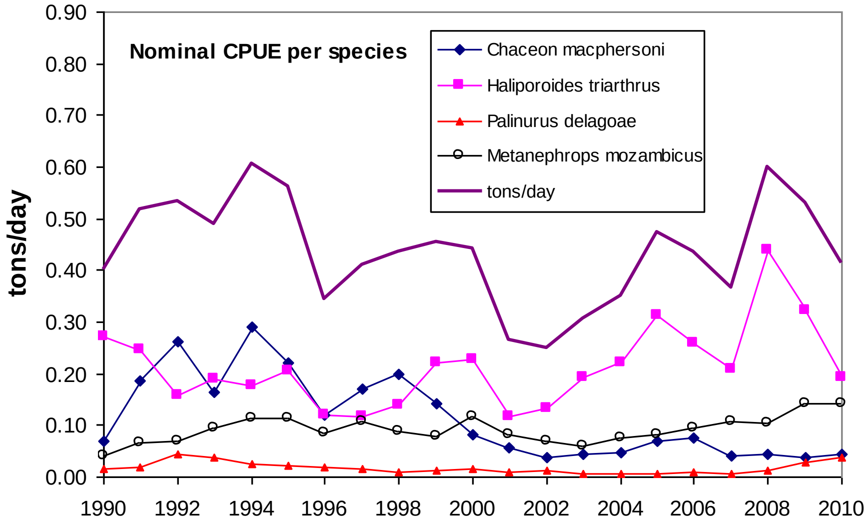
3.12.2.4 Industrial Trawl Fisheries (Deep)

Industrial deep-water bottom trawl fisheries for crustaceans in the SWIO operate at depths of 100 – (600)800 m and catch a mixture of high value crustacean species. Deep-water crustacean trawl fisheries in the WIO are far less common than shallow-water prawn trawl fisheries, and known fishing grounds are restricted to eastern South Africa, Mozambique, Madagascar, Tanzania and Kenya. Long term deep-water trawl fisheries exist only in Mozambique and South Africa. In Madagascar, Kenya and Tanzania trawling appears to be occasional and is limited to a few vessels that operates for short period of time (Groeneveld 2012a).

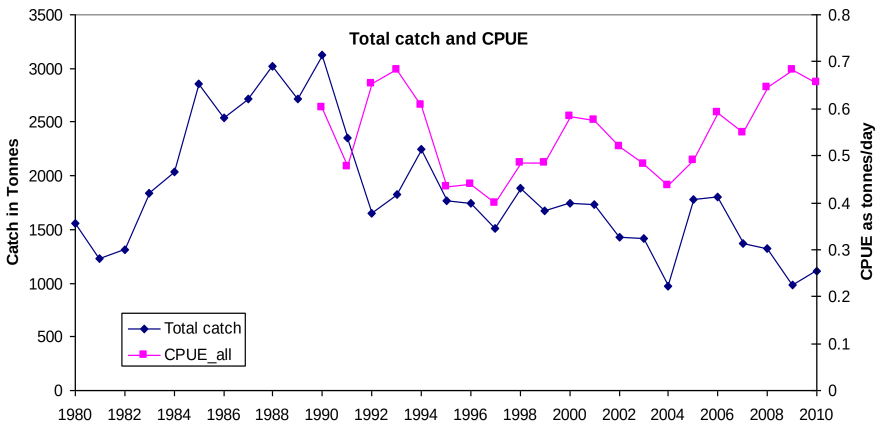
The fisheries target a variety of crustacean species depending on the depth and area being trawled, but catches are generally composed of deep-water knife (or pink) prawns (*Haliporoides triarthrus*), several other deep-water prawns (*Aristeus virilis*, *Aristeus antennatus*, *Aristaeomorpha foliacea*, *Plesiopenaeus* and *Heterocarpus* spp.), langoustines (*Metanephrops mozambicus*), deep-water lobsters (*Palinurus delagoae*) and red crabs (*Chaceon macphersoni*). Other species of crustaceans are caught in smaller numbers. In addition to crustaceans, the trawlers also catch large quantities of bony fishes and elasmobranchs, which are retained if they can be sold, or discarded if their commercial value is considered to be low (Groeneveld 2012a).

Trends from Mozambique show a long-term decline in fishing effort and catches, with the number of vessels having declined from 45 in 1990 to approximately 15 vessels in 2010. There has been an increase in nominal CPUE since 2004 (Figure 1-22a-d). It is however not clear whether this is a result of stock recovery, or is as a result of increased fishing power of vessels, or is due to reduced competition for trawling space, with fewer vessels competing, or even improved data collection. Fishing effort in the South African fishery declined from 8 vessels in 2001 to 3 vessels in 2009. In 2010 there were only 4 vessels in South Africa. Catches in South Africa have however remained relatively stable and nominal

CPUE has increased since 2004. As in Mozambique, the reason for the CPUE increase is not clear. No conclusions can be drawn from the limited data of the Madagascar and Tanzania deep-water trawl fisheries. In Mozambique, numerous surveys of deep-water trawl grounds have been undertaken using research vessels and wet-leased trawlers. Most of these surveys were for stock assessment and fisheries development purposes, and information from the surveys is incorporated into fisheries management decisions. In South Africa, data are collected based on skipper logbooks, landing weights, and information gathered by fisheries observers. No stock assessments are undertaken by the national fisheries department and the relatively small fishery is managed through effort restrictions on the number of rights holders and fisheries permits. All management strategies for this fishery are currently at national level, despite the apparent transboundary distributions of fished stocks (Groeneveld 2012a).



(a)



(b)

Figure 1-22: Status of deepwater prawn stocks in (a) South Africa (nominal CPUE per species) and (b) Mozambique (Total catch and CPUE combined) (Groeneveld 2012a).

3.12.2.5 Industrial Trap Fisheries (Deep)

Deep-water trap fisheries for spiny lobsters and crabs are industrial, utilising large ocean-going fishing boats that are able to deploy hundreds of baited traps along anchored bottom longlines. Trap-fisheries mainly target high-value *Palinurus* spiny lobsters (several species) for export markets. Slipper lobster (*Scyllarides elisabethae*) and deep-sea red crab (*C. macphersoni*) make up substantial retained bycatches of the trap-fisheries in eastern South Africa and in Mozambique. *Octopus magnificus* is a retained bycatch in traps set for *Palinurus gilchristi* off southern South Africa (Groeneveld 2012b).

Four distinct deep-water trap-fishing sectors have been identified in the WIO: (i) Industrial trap-fishery for *P. gilchristi* (southern South Africa); (ii) Experimental trap-fishery for *P. delagoae* (eastern South

Africa); (iii) Industrial trap-fishery for *P. delagoae* (Mozambique); (iv) Exploratory trapping for spiny lobsters, crabs and deep water shrimps in other countries (Madagascar, Mozambique, Kenya, Mauritius and Seychelles) and on high-seas seamounts (Groeneveld 2012b). Only the trap-fishery for *P. gilchristi* off southern South Africa is presently active as a stable and well-managed fishery. Long-term spatially explicit databases of fishing effort and catches (logbooks) and high resolution catch rate and biological data collected by fisheries observers at sea support annual stock assessments which inform a robust management strategy with good enforcement. The two fisheries for *P. delagoae* are less stable, and are presently inactive. An experimental fishery for *C. macphersoni* off Mozambique has however recently started (2009). In international waters, exploratory trapping was undertaken for spiny lobsters (*Palinurus barbarae* and *Jasus paulensis*) on seamounts of the Madagascar Ridge (Walters Shoals) and the Southwest Indian Ridge by Soviet and Ukranian vessels (1970s-2000), and more recently by EU and South African vessels in 2010 and 2011 (Groeneveld 2012b). The actual numbers of vessels working in this area, frequency of trips, and quantities of lobsters caught by traps are however unknown (Groeneveld 2012b). Trap-fisheries operating within the Exclusive Economic Zones (EEZs) (200 nm) of countries in the WIO are controlled according to national management strategies. No regional management strategies exist, even where stocks are apparently transboundary (Groeneveld 2012b). The South Indian Ocean Fisheries Agreement (SIOFA), which came into force in 2012, does however aim to ensure sustainable use of fishery resources (other than tuna) in areas that fall outside of national jurisdictions.

3.12.2.6 Artisanal/Small-scale Crustacean Fisheries

Shallow-water prawns are targeted in the artisanal fisheries of Kenya, Madagascar, Mozambique, Tanzania and Somalia using gill and seine nets as well as fence traps (‘valakira’) in Madagascar (WIOFish 2011). Catches from the artisanal fishery in Tanzania are nearly equal to landings from trawlers (Tanzania MEDA 2012) and inshore populations of prawns are declining in Somalia (Somalia MEDA 2012). The artisanal fisheries also target spiny lobsters, using tangle nets, traps, spearguns or reef gleaning methods using snorkelling or SCUBA diving. This is a valuable fishery but monitoring is limited and information on stocks is insufficient, although the status of this fishery is thought to be mainly fully-fished to depleted (FAO-SWIOFC 2011). The exploitation of crabs is common in several countries in the WIO region. The main target species include the mangrove swamp crab, *Scylla serrata*, and swimming crabs; coconut crabs are exploited in Comoros and ghost crabs are caught in the artisanal and recreational fisheries of South Africa (WIOFish 2011).

3.12.3 Demersal Fisheries

All countries in the WIO have demersal fisheries, with demersal fish species (and an inseparable component of small pelagic species) constituting the largest category of reported landings by WIO countries (~200,000 tonnes; FAO data for “Other marine fishes” for 2003) (Fennessy 2009). The demersal fisheries are predominantly artisanal in nature, except in Madagascar, Mozambique, South Africa, and Seychelles, which also have industrial and semi-industrial sectors that target demersal fish (line fish). 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 of 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).

Information on catches made by artisanal fishers is often sparse, and official estimates grossly under-represent actual catches. These fisheries are generally multi-gear and multispecies, with catches comprising of almost 600 species, although certain species might be dominant, depending on season and area, or targeted by some sectors (e.g. line fishing) (Heileman 2012).

Seven distinct demersal fishery sectors have been identified in the WIO: (i) Drop-line conducted on offshore banks and drop-offs (Mauritius and Seychelles); (ii) Crustacean trawl for shallow-water prawns and deep-water crustaceans (mainland African countries and Madagascar); (iii) Line fishing conducted either using hand-line or rod and reel, generally on reefs in shallow water; (iv) Small-scale fishing using a wide variety of fishing gear, including traps, hook and line, seine nets, gill nets and small trawls, using motorised or non-motorised boats; (v) Longline targeting hake in South Africa and sharks in Tanzania; (vi) Fish trawl targeting hake (South Africa); (vii) Experimental trap (Mozambique) (Fennessy 2009).

The region's demersal stocks, especially in nearshore areas have experienced heavy fishing pressure over the past decades (Table 1-10). Most of the priority species for which stock assessments have been carried out are either overexploited or fully exploited. Annual catches of 12 species showed a general decline. Catches that increased in more recent years did so following a decline and did not return to previous levels. In some countries, total annual catch (all species) was stable or increased, which could be attributed to a shift to other fishing grounds following localised stock depletion (Figure 1-23) (Heileman 2012).

Table1-10: The status of demersal fish stocks in the 9 WIO countries as agreed during the 5th session of the Scientific Committee of the SWIOFC (FAO-SWIOFC 2012).

Country	Species/Complexes/Groups	Stock Status
Comoros	Slope-water snapper	Fully Exploited
Kenya	Demersals (mixed)	Fully Exploited
Madagascar	Snapper	Moderately Exploited
Mauritius	Coastal fisheries (demersal)	Recovering
	Slope-water snapper	Moderately Exploited
	Lethrinids (shelf)	Moderately – Overexploited
Seychelles	Slope-water snapper	Recovering
	Demersal line fish stocks	Fully to Overexploited
Somalia	Demersals (groupers, snapper)	Moderately Exploited
South Africa	Handline fishery (mixed)	Overexploited – Depleted
Tanzania	Reef fish	Fully Exploited
	Demersal fish	Moderately – Fully Exploited

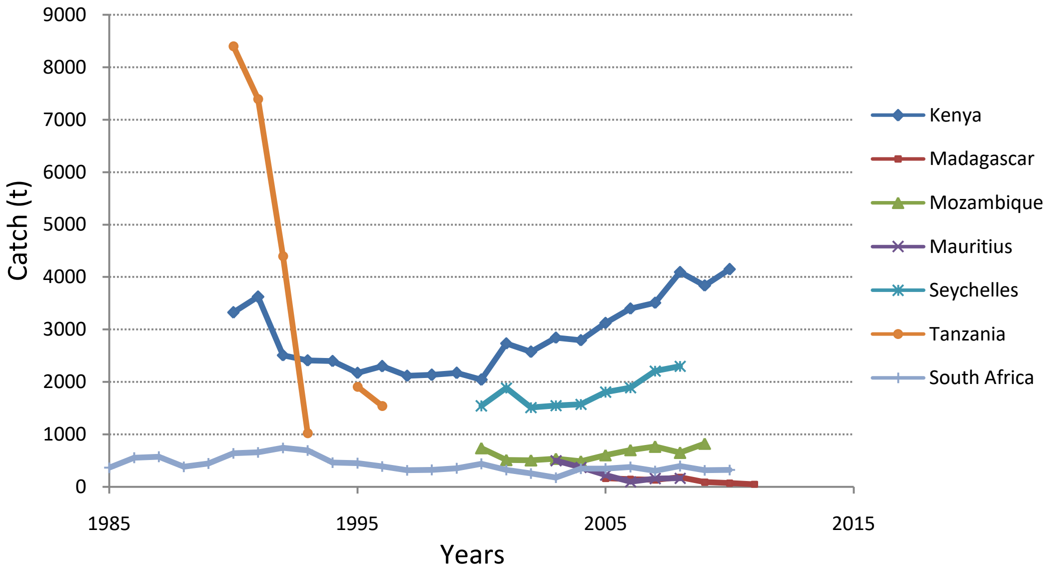


Figure 1-23: Trends in annual catch of demersal fish in SWIOFP member countries (Statbase data) (Heileman 2012)

Most of the countries have limited knowledge of the status of the stocks of priority species. Similarly, comprehensive stock assessments have been sporadic, with only two countries (Mozambique and South Africa) conducting regular assessments and the others “one off” assessments. Few priority species are explicitly covered in national fisheries management plans, or have established biological reference points, and even these are limited to sparids in Mozambique (considered overexploited South of 21°S and moderately exploited North of 21°S) and South Africa and *Pristipomoides filamentosus* (Lutjanidae) in Seychelles. Where management exists (e.g. license fees, limited entry, catch quotas, size and gear restrictions), it is at the national level only. Several of the priority species including *Lethrinus nebulosus*, *Lutjanus bohar*, *Epinephelus chlorostigma*, *Lethrinus mahsena*, *P. filamentosus*, *Etelis coruscans* and *Johnius fuscolineatus* are widely distributed in the WIO region and could be shared or transboundary. There is however, little or no information on the identity and spatial and temporal distribution of the stocks (Heileman 2012).

3.12.4 Drop-line and Line Fisheries

In Mauritius, vertical longlines (drop-lines) are used to target snapper and grouper species on the drop-offs of the Nazareth and Saya de Malha Banks at depths of 100 – 300 m. In Seychelles, drop-lines are deployed from schooners. The drop-line consists of a very long mainline with a buoy at one end and a weight at the other end. The mainline extends from the surface to the seabed, with a series of baited hooks attached at approximately 1 m intervals by snoods. The fishery targets red snapper, groupers and jobfish at depths of up to 350 m on the Mahé Plateau (WIOFish 2011).

The Mauritian banks fishery is a mothership-dory fishing operation, which has been operated by a single licensed fishing company since the 1950s. This fishery operates on the banks of the Mascarene Plateau and the Chagos Archipelago and targets *Lethrinus mahsena* which constitutes 80–90% of the annual catch (Mauritius MEDA 2012). Management measures include a licensing system for all fishing vessels operating on the banks since 1992 and a quota allocation system since 1994. Data for the last ten years show that the stocks have been moderately fished at about two thirds of the total MSY (Munbodh 2012). In Seychelles, the two main fishing grounds for the demersal hand-line fishery are the Mahé Plateau and the Amirantes Plateau at depths from 25-70 m. Other fishing areas include the offshore banks and around the southern group of coralline islands. Important demersal species include red snappers, groupers, job fish, and emperors (Seychelles MEDA 2012). The semi-industrial and industrial line fisheries in Mozambique are multispecies hook and line fisheries, comprising more than 200 species, and are conducted over a wide area and mostly at a depth of 30-200 m. It takes place mainly on rocky bottoms that are not suitable for trawling. Some linefish species are also targeted by sport fishers. Linefish resources are subject to a high level of exploitation with a recorded 50 % increase in effort from 2008 to 2010 (República de Moçambique Ministério das Pescas 2012).

3.12.5 Small-scale Coastal Fisheries

The small-scale and artisanal fisheries are an important sector in the WIO region providing food and income to coastal communities. Rising coastal populations and the open-access nature of the fisheries has meant that reef and nearshore demersal fish are heavily exploited throughout the WIO region. The artisanal/traditional fisheries use many different gear types including harpoons, spears, hook and lines, traps and nets (e.g. cast nets, gill nets, seine nets) and target a wide range of reef and demersal species. Many of the preferred food fishes such as jacks, groupers, snappers, emperors and parrot fishes are becoming increasingly rare throughout the region, and some species are now recognised as being of international concern for conservation, including some groupers (Serranidae), the humphead wrasse, *Cheilinus undulatus* (Labridae) and the double-headed parrotfish *Bolbometopon muricatum* (Scaridae). As resources become more depleted there has been an increase in the use of more destructive and non-selective fishing methods, including the use of dynamite, plant derived poisons or smaller mesh size nets, such as mosquito nets.

3.12.6 Longline Fisheries and Hake Fishery

Longlines are traditionally set on or close to the bottom and the length of main line varies in extent. The longline fishery in South Africa is hake-directed and is relatively selective compared to the trawl fishery. Over-harvesting of deepwater stocks is however a concern as the deep-water hake stock levels are estimated to be <30 % of BMSY (the biomass that can support the Maximum Sustainable Yield, MSY).

There is little information readily available on the longline fisheries in Tanzania and Kenya, although the former appears to be directed at sharks (Heileman 2012).

South Africa is the only country that targets deep-water and shallow-water hake. This fishery also has quite a substantial bycatch and many other fish species such as kingklip, horse mackerel, angelfish, snoek and monk are caught. The trend in the hake-directed offshore trawling, particularly on the South and East coasts, towards deeper fishing (> 600 m) has resulted in the exploitation of a new "deepwater" species regime with a unique set of biodiversity impacts linked to the continental shelf break (500–2000 m water depth) (Heileman 2012).

3.12.7 Deep water Trawl Fishery

Deep-sea trawl fishing started several decades ago in the high seas of the Western Indian Ocean when exploratory surveys were undertaken by vessels from USSR in the 1970s. USSR vessels conducted periodic deep-sea trawl research cruises on a commercial scale throughout the 1980s and 1990s. Deep-sea trawlers from both New Zealand and Australia were also reportedly fishing in the region during the 1990s. In the period 1999–2001, there was a major increase in deep-sea trawling on the high seas with the discovery of orange roughy (*Hoplostethus atlanticus*) stocks by a New Zealand vessel. The dominant bottom fishery in the high seas of the Western Indian Ocean over the past several years has been the mid-water and bottom trawl fishery on and around seamounts for alfonsino (*Beryx splendens*) and orange roughy (*Hoplostethus atlanticus*). In addition to the trawl fishery, a deep-sea longline fishery on the high seas developed over the past several years targeting primarily deepwater longtail red snapper (*Etelis coruscans*).

Exploratory fisheries surveys around the Madagascar shelf and slope in the 1970s and 1980s discovered >50 species (FAO 1998). A relatively new short-lived industrial fishery launched in 2007 by a South African company used deepwater trawling techniques to target alfonsino (*Beryx splendens*). The fishing grounds included seamounts to the south of Madagascar, and there is concern about the impact of the deepwater gear on these habitats (Madagascar MEDA 2012).

3.12.8 Pelagic Fisheries

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).

FISHSTAT data suggest that large pelagics make up nearly 50% of marine fishery catches in the WIO. The national industrial fleets are evenly matched by the foreign fleets as they account for 55% of large pelagic catches in the national EEZs. National catch projections (excluding foreign fleet data per EEZ) show a boom in large pelagic catches over the last decade (four-fold increase between 1995 and 2005). The Seychelles is the only country to have shown a marked interest in large pelagics in the last few years, gradually adding new vessels to the national fleet since 1995 while setting up joint ventures to supply the tuna cannery in Port Victoria (Seychelles MEDA 2012). The development of a semi-industrial fleet in Madagascar since the end of the 1980s boosted production from 5,000 t to 25,000 tonnes today. In the other countries there has been no significant increase in catches of large pelagic (Failler *et al*. 2011).

There are numerous other coastal net-based fisheries targeting small to medium pelagics, the majority of which are data deficient (Cochrane and Japp 2012). Medium pelagics mostly include large mackerels including the kingfishes (caranyx), dolphin fish (*Coryphaena hippurus*) and the larger spanish mackerel (*Scomberomorus commerson*) and the wahoo (*Acanthocybium solandri*). The taxonomic groups supporting the highest catches of small pelagics include Carangidae, *Scomber japonicus* (Scombridae) and Scombridae nei, and *Trachurus delagoa* (Carangidae) and *Rastreliger kanagurta* (Scombridae). These small pelagic fisheries commonly operate at night with purse nets and gill nets. In most cases these smaller pelagic fish provide are a staple food source and may also be used for animal feed. These species are also the primary source of bait for many fisheries, in particular live bait for the large pelagic tuna pole and line fisheries.

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).

As part of its management process, the member States of the Indian Ocean Tuna Commission (IOTC) collect information on the fisheries and the biology of tuna and tuna-like species that is submitted for stock assessment analyses. For three of the main tuna species, the data available for analyses have been reinforced by the results of a large-scale tuna tagging programme, tagging more than 200,000 fish in recent years. There is, however, the need for further studies and better data collection in the SWIO region. As the range of these stocks extends beyond the SWIO, management strategies are discussed in the context of the IOTC for the overall Indian Ocean. Advice from the IOTC Scientific Committee on the status of the stocks relative to biological reference points is taken into account for the adoption of management by the IOTC countries. Several of the target or bycatch species of the region have high commercial value and are heavily fished by foreign fleets and on a more localised coastal scale by artisanal fishers (Lucas *et al*. 2009). National assessments suggest that many stocks are fully or overexploited (Table 1-11), however regional assessments conducted by the IOTC suggest that for the species were sufficient data are available, stocks are not currently overfished (Table 1-12).

Table 1-11: The status of pelagic fish stocks in the 9 WIO countries agreed during the 5th session of the Scientific Committee of the SWIOFC (FAO-SWIOFC 2012)

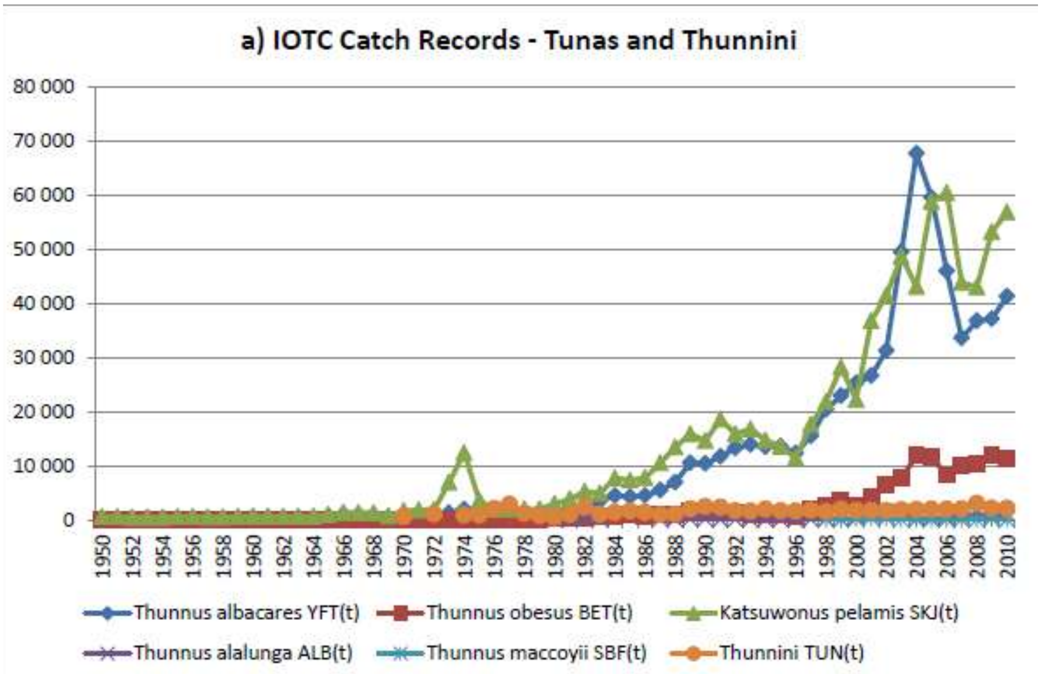
Country	Species/Complexes/Groups	Stock Status
Comoros	Coastal tunas and related species	Fully Exploited
	Medium pelagic	Fully Exploited
	Small pelagic	Moderately Exploited
	Sharks and rays	Fully Exploited
Kenya	Small pelagic	Fully Exploited
	Sharks and rays	Fully Exploited
Madagascar	Coastal tunas and related species	Unknown
	Sharks	Overexploited
Mauritius	Coastal tunas and related species	Moderately Exploited
	Offshore tunas and swordfish	Moderately Exploited
	Small pelagic	Under Exploited
Mozambique	Medium pelagic	Fully Exploited (Mozambique states the status is unknown)
	Small pelagic	Moderately Exploited
Seychelles	Offshore tunas	Fully – Overexploited
	Shark (inshore)	Depleted
	Sharks (offshore)	Overexploited
	Medium pelagic	Moderately exploited

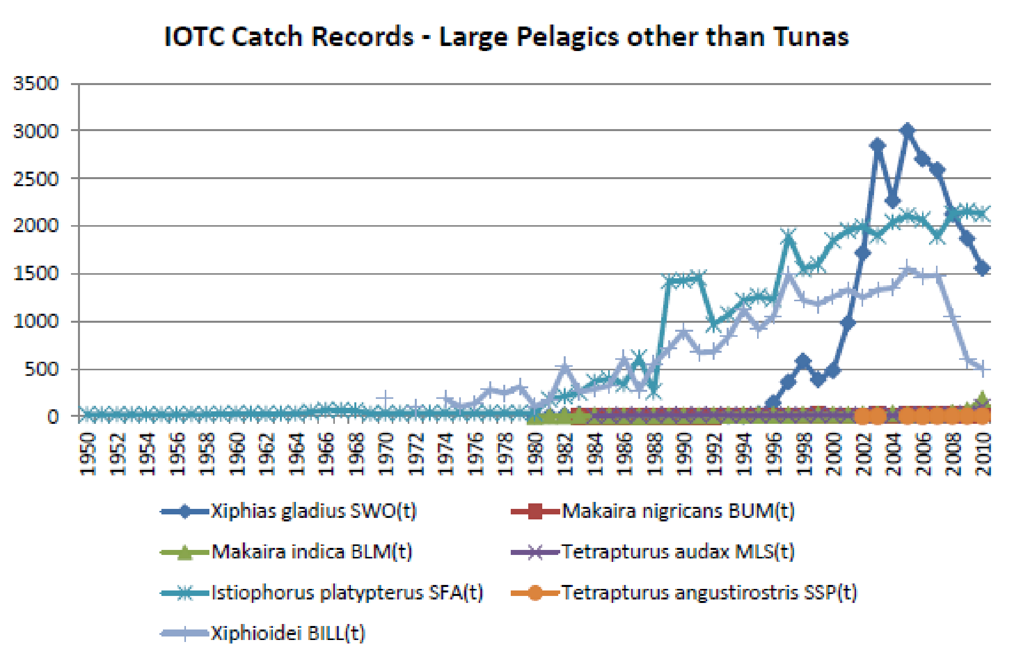
Somalia	Coastal tunas and related species	Unknown
	Sharks and rays	Overexploited
	Small pelagic	Moderately exploited
South Africa	Coastal tunas and related species	Under exploited
	Sharks	Unknown
Tanzania	Coastal tunas and related species	Under exploited
	Sharks	Moderately exploited
	Small pelagic	Moderately exploited

Table 1-12: The status of priority large and medium pelagic fish stocks in the Indian Ocean as reported by the IOTC Scientific Committee (IOTC 2011)

Species	Status	Date
Thunnus albacores	Stock not overfished; Stock not subject to overfishing	2009
Thunnus obesus	Stock not overfished; Stock not subject to overfishing	2009
Katsuwonis pelamis	Stock not overfished; Stock not subject to overfishing	2009
Xiphias galdius	Stock not overfished; Stock not subject to overfishing	2009
Thunnus alalunga	Stock not overfished; Stock subject to overfishing	2010
Thunnus tongol	Uncertain	2010
Istiophorous platypterus	Uncertain	2010
Makaira indica	Uncertain	2010
Makaira mazara	Uncertain	2010
Tetrapturus audax	Uncertain	2010
Euthynnys affinis	Uncertain	2010
Scomberomorus commerson	Uncertain	2010
Auxis thazard	Uncertain	2010

Tuna catches are largely made up of skipjack (*Katsuwonus pelamis)* and yellowfin tuna (*Thunnus albacores)*, followed by bigeye tuna (*T. obesus)*. Catches of large pelagics other than tunas are much lower than for the main tuna species and consist mainly of swordfish (*Xiphias gladius)* and the Indo-Pacific sailfish, (*Istiophorus platypterus*) (Cochrane and Japp 2012). Catches of bigeye, skipjack and yellowfin tuna have all declined in recent years (Figure 1-24a-b) although this may be related to the expansion of piracy in the WIO and the resulting drop in fishing effort. The swordfish stock in the south west Indian Ocean has been overfished in the past decade and biomass in the SWIO remains below the level that would produce MSY (BMSY). The abundance of silky sharks (*Carcharhinus falciformes*) has also declined significantly in recent decades and other shark species are vulnerable to overfishing due to their life history characteristics (IOTC-SC14 2011).





(b)

Figure 1-24: Catches of SWIOFP priority large pelagic species reported to IOTC (a) tuna species and *Thonnini* and (b) other large pelagic species (Cochrane and Japp 2012)

3.12.9 Longline and Vertical Line Fisheries

Industrial longliners operates in the EEZs of virtually all countries in the WIO as well as on the high seas (Lucas *et al*. 2009). The fishery is dominated by fleets from countries in Asia (Taiwan, Japan and China) targeting bigeye, yellowfin and albacore tuna (*Thunnus alalunga*). The European and Taiwanese longliners also target swordfish with a bycatch of pelagic sharks, tuna-like species and billfishes (WIOFISH 2011). A semi-industrial longline fishery was established in Seychelles in 1995 targeting yellowfin tuna, bigeye tuna and swordfish with a bycatch of sharks (Lucas *et al*. 2009). A semi-industrial fishery for sharks was also started in 2003 but this ceased to operate in 2010/2011. Artisanal longline fisheries also take place in Kenya, Madagascar, Mozambique, Seychelles and Tanzania targeting sharks, billfish and medium pelagic species (WIOFish 2011).

Fisheries using vertical lines are generally of a coastal nature, and are dominated by artisanal and recreational (or sport) fisheries, either around anchored fish aggregation devices (FADs) or without FADs (i.e. 'free'). These fisheries target a larger range of pelagic species than longline fisheries, extending from small to medium and large pelagic species (Lucas *et al*. 2009).

The deployment of FADs in countries of the SWIO in the early 1980s (Comoros, Madagascar, Mauritius and the Seychelles) and more recently in Tanzania (2005) clearly shows that while small-scale fishing catches have subsequently increased, this is largely dependent on the level of technological development of the fisheries when the FADs were installed and on the absorption capacity of the pelagic fish markets. It is important that the influence of FADs on the amount and species and size composition of catches must be included in the assessments and management plans for IOTC to avoid increasing the risk of over-exploitation (Cochrane and Japp 2012).

Artisanal line fisheries are particularly important in Comoros where large pelagic fish account for approximately 75% of the fish consumption. There are two main pelagic fisheries: an artisanal fishery for tuna, swordfish and sharks concentrated around FADs and a traditional fishery for small pelagics: clupeids, small carangids, scombrids and half beaks (Lucas *et al*. 2009). In Mauritius, over 20 FADs have been deployed in water depths of 250–3,500 m and fishers target tuna and medium pelagic species. Free vertical line fishing in Kenya, Madagascar, Mozambique, Seychelles and Tanzania targets sharks as well as large and medium pelagics.

Recreational fisheries, usually aimed at local and international tourists, operate in the mainland African countries as well as Mauritius and Seychelles targeting billfish, tuna and medium pelagic species (WIOFish 2011). These fisheries are becoming an increasingly popular tourist attraction in some countries (Mauritius MEDA 2012). Landings are often not recorded as the fishery may be licensed under a different ministry.

3.12.10 Purse Seine Fisheries and Artisanal Small-scale Coastal Net Fisheries

Two types of purse-seine fisheries operate in the WIO region for small pelagics such as scads, sardines, small mackerels and for tuna and tuna-like species (Lucas *et al*. 2009). The purse-seine fisheries for tunas and tuna-like species are generally operated by foreign fleets under license. The European fleet (Spain, France and Italy) has the highest landings in the region and skipjack tuna and yellowfin tuna are the main species caught. Seychelles has the largest purse-seine fleet in the region. The potential for purse-seine fisheries for small pelagics is generally unknown in the region.

Coastal net fisheries (beach seine, small purse-seines, cast nets, ring nets) are of an artisanal nature and these usually target small and medium pelagic fish species for own consumption and local sale in all countries within the WIO region (Lucas *et al*. 2009). The annual catches of medium pelagics recorded on WIOFish range from zero tonnes in four of the countries to 8 165 tonnes in South Africa. Mozambique and Seychelles reported values of between 500 and 600 tonnes. Catches are composed of seventeen species or species groups but no catch estimates are provided for 11 of those taxonomic groups (Cochrane and Japp 2012).

Artisanal fisheries in Madagascar use cast nets and gill nets to catch medium and small pelagic fish species. The most affected species by traditional and artisanal fisheries are small Scombridae, such as the eastern little tuna, *Euthynnus affinis*, the wahoo, *Acanthocybium solandri*, the narrow-barred Spanish mackerel, *Scomberomorus commerson*, the Indian mackerel, *Rastrelliger kanagurta* and *Auxis* spp., Sphyraeindae, Carangidae, sardines (Clupeidae), anchovies (Engraulidae), Hemiramphidae, Belonidae and others (Madagascar MEDA 2012).

In the case of artisanal purse seine fishery operating in Tanzania, the main species caught are sardine and anchovy, which together form 30-50% of total fish landings in the country. Bottom-set gillnets are also used to target sharks and rays and these vary in length up to 450 m, with mesh sizes ranging from 20-40 cm (Tanzania MEDA 2012). In Kenya, gill nets are used to target sharks and tuna, whilst ring nets, cast nets and seine nets are used to catch medium and small pelagic species (Maina 2012).

3.12.11 Coral reef fisheries

The coral reefs of the WIO support thousand of species of animals and plants including 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 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).

3.12.12 Other Coastal Fisheries

High coastal population densities within the countries of the SWIO results in intense exploitation of various other nearshore resources by recreational and subsistence fishers. Many coastal invertebrate stocks are overexploited as a result (Table 1-13), with significant impacts on both target and non-target species having been recorded. In addition, Mozambique records stock status of Cephalopods offshore as under exploited; Bivalves inshore - Moderately exploited; sea cucumber–overexploited; Octopus offshore- under exploited; and Cephalopods inshore: Under exploited.

Table 1-13: The status of invertebrate stocks in the 9 ASCLME countries as agreed during the 5th session of the Scientific Committee of the SWIOFC (FAO-SWIOFC 2012)

Country	Species/Complexes/Groups	Stock Status
Comoros	Cephalopods	Under Exploited
	Bivalves	Under Exploited
Kenya	Octopus	Fully Exploited
	Sea cucumbers	Overexploited
	Bivalves	Fully Exploited
Madagascar	Octopus	Fully Exploited
	Sea cucumbers	Overexploited
	Bivalves	Fully Exploited
Mauritius	Octopus (St Brandon)	Moderately Exploited
	Sea cucumbers	Depleted
Seychelles	Sea cucumbers	Overexploited
South Africa	Octopus	Under exploited
	Bivalves	Fully – Overexploited
Tanzania	Octopus	Overexploited
	Cuttlefish and Squid	Fully Exploited
	Sea cucumbers	Overexploited
	Bivalves	Overexploited

3.12.13 Bivalves, Gastropods, Cephalopods and Beche-de-mer

Mollusc resources are exploited in nearshore habitats, most often by reef walking or snorkelling. Molluscs are often collected opportunistically as additional catch alongside other fishing methods. The main molluscs targeted are the edible and ornamental species such as oysters, clams, whelks and mussels. Most of the shells collected for the curio trade are threatened species (Tanzania MEDA 2012, Somalia MEDA 2012) and their stock status ranges from fully to overexploited (FAO-SWIOFC 2011).

There are also fisheries targeting cephalopods mainly squid, cuttlefish and octopus within the region, the most widespread of which is the artisanal octopus fishery which occurs in every country in the WIO region. Declines in octopus fisheries landings have been reported by several countries and this has been attributed to overexploitation but also often associated with habitat damage. The South West Indian Ocean Fisheries Commission (SWIOFC) has classified the octopus fishery as overfished in the WIO region. Octopus fishing is usually undertaken by walking on the reef flat at low tide. The most common fishing technique employed throughout the region is the use a long metal spike or harpoon to lure the octopus from its den in the reef rock. The squid-jigging fishery in South Africa is an important commercial fishery targeting spawning aggregations of chokka squid (*Loligo vulgaris reynaudi)* in sheltered bays on the south coast (South Africa MEDA 2012).

Sea cucumber (also known as bêche-de-mer when semi-processed) fishing is not a traditional fishery within the WIO, but it has rapidly and significantly increased in importance due to the high export value of the product. Sea cucumbers are typically targeted by fishers using a mask and snorkel or SCUBA equipment or are collected as bycatch by spear fishermen and other gleaners. Fishers typically target the six highest value species (*Holothuria nobilis, H. fuscogilva, H. scabra, Thelenota ananas* and *Actinopyga mauritiana*). Sea cucumber resources in all countries in the WIO are largely over-exploited (FAO-SWIOFC 2011). Management regulations to control the fishery and processing were implemented in Seychelles in 1999 (Seychelles MEDA 2012). Sea cucumber fishing in Comoros has been banned since 2004 (FAO-SWIOFC 2012) and in Mauritius, a two-year moratorium period was implemented from October 2009 to September 2011. This moratorium was extended to February 2016 (WIOFish 2011).

3.12.14 Biodiversity and Vulnerable Species

The WIO sustains significant fisheries in a region of high biodiversity, endowed with vulnerable and iconic species. New fisheries opportunities therefore need to be environmentally sustainable, including their relationship with vulnerable species and the biodiversity of the region (van der Elst 2012). The incidental catch of marine megafauna, including marine mammals, sea turtles and elasmobranchs, poses one of the main threats to these species at the global scale. These taxa are particularly vulnerable for biological reasons, such as late maturity and low reproduction rates (Kiszka 2012).

In contrast to other regions of the world, WIO industrial fisheries, including the oceanic purse seine fisheries, do not catch large quantities of marine mammals. Dugong populations in Mozambique, Tanzania, Madagascar and Comoros continue to decline through incidental and targeted artisanal gill netting. The population now remaining is estimated to be composed of less than 500 animals, the majority of which are found in Mozambique, particularly in the Bazaruto Archipelago (van der Elst 2012). Recent surveys have also found potentially significant populations in northwest Madagascar (Ridoux *et al*. 2010), and Mayotte (Kiszka *et al*. 2007) but the viability of these populations remains uncertain. The capture of delphinids in artisanal gillnet fisheries in Zanzibar and several other locations in Tanzania as well as Madagascar, may be high enough to negatively impact local populations. In particular, dolphins that are opportunistically hunted by fishermen in Madagascar are under threat (van der Elst 2012).

Among the 1,160 species of cartilaginous fishes known from around the world, 200 species have been recorded in the WIO, and these include iconic species such as whale sharks and the critically endangered sawfish. Declared landings of elasmobranchs (sharks and rays) in the WIO peaked at 180,000 metric tonnes in 1996, which was due partly to increased effort targeting tuna which has since subsided (Smale 2008). Landings of elasmobranchs have halved since then and are currently reported to be. Few if any shark management plans are in place in the region. High levels of bycatch are frequently associated with longline, trawl and line fisheries. Specific issues of concern are the mortalities associated with shark netting on the KwaZulu-Natal coast of South Africa, artisanal harvesting of reef manta rays in Mozambique and uncontrolled catches made in shrimp trawl fisheries (van der Elst 2012). IOTC member States have agreed to ban the practice of finning sharks, as well as banning the landing of thresher sharks from their fisheries.

Threats to the five main WIO sea turtle species are imposed by both artisanal and industrial fisheries including a large turtle bycatch in the South African pelagic longline fishery. While most of the turtles are caught on the Walvis Ridge by this fishery, there will undoubtedly also be impacts on WIO turtle populations considering the high incidence of loggerheads which nest on the KwaZulu-Natal coast. Industrial inshore prawn trawl fisheries in all countries capture sea turtles. However, the use of turtle excluder devices (TEDS) is progressively reducing the problem, especially in Madagascar. In South Africa protective shark nets in KwaZulu-Natal impact sea turtles as well as sharks, while artisanal gill nets in Zanzibar, Tanzania Somalia, Mozambique and Madagascar take both a directed and bycatch of sea turtles. Madagascar in particular, has a long history of fishers taking sea turtles for meat while eggs are commonly collected for human consumption. Annual turtle catch in one province alone has been estimated to be between 10,000 and 16,000 individuals (van der Elst 2012). IOTC has adopted measures to reduce the impact of interactions between marine turtles and fisheries for tuna and tuna-like species.

Fisheries impacts on seabird populations include incidental capture or entanglement with gear, (longline, trawl and gillnet fisheries), loss of foraging opportunities due to depleted fish stocks and direct competition with fisheries targeting low trophic level fish. Direct seabird mortality mostly affects long lived more temperate species, such as albatrosses, which are under extreme pressure. The rich and abundant seabird assemblages in tropical waters of the WIO are however largely immune to direct, incidental mortality from fishing as their foraging strategy is different from the more temperate seabirds (van der Elst 2012). IOTC has adopted measures to mitigate the incidental mortality of seabirds in the fisheries of its member States.

The Indo-West Pacific region has the greatest diversity of fishes of all the oceans' eight biogeographic regions with about 2,200 species found in the WIO, representing some 83% of all the fish families known. Included are many iconic fishes, ranging from the world's "oldest" fish the coelacanth (*Latimeria chalumnae)* to the world's largest- the whale shark (*Rhincodon typus)*. A high level of endemism is found: for example southern Mozambique and South Africa have 227 endemic fishes. Several fisheries report capture of vulnerable species included in the IUCN Red List, especially artisanal and recreational fisheries. Linefishing often targets serranidae and labridae including the red-flagged species, which are often slow growing and therefore vulnerable to overexploitation. Some fisheries target spawning aggregation with the potential to rapidly deplete fish stocks (van der Elst 2012).

3.12.15 Bycatch and Trawl Impacts

There is a consensus that the issue of bycatch is an important matter in the context of an ecosystem approach to fisheries and hence ultimately for environmental sustainability (van der Elst *et al*. 2010). However, bycatch is a complex issue and the definition of bycatch is not straightforward, particularly in artisanal and other less-sophisticated fisheries. The bycatch can be split into retained and discarded components, and the proportion of each is similarly variable depending on numerous factors. Artisanal fisheries will often have negligible discards (van der Elst 2012). There is little formally published information on bycatch or discards in the WIO. Levels of bycatch are particularly high for the prawn trawl fishery followed by the pelagic longline and purse seine fisheries (van der Elst 2012). Trawl fisheries have a variable level of bycatch, only a proportion of which is discarded. There is however very limited information about the species composition of the bycatch. Similarly, there is lack of information relating to the incidence of bycatch within the longline fishery, although in South Africa, sea turtle bycatch, mostly comprising leatherback turtles is of concern (van der Elst *et al*. 2010). Bycatch has been particularly poorly documented within the artisanal fisheries in the region. A recent study revealed the high extent of large marine vertebrate bycatch in artisanal fisheries especially in drift, bottom-set gillnets and beach seines (Kiszka 2012). At least 59 species have been identified as bycatch and by-product species, including five species of sea turtles, eight species of marine mammals and 46 species of elasmobranchs. The study revealed that gillnet fisheries (both drift and bottom-set) have the highest impacts, especially for marine mammals and sea turtles. Beach seines were also noted for their high impact on sea turtles, especially the green turtle.

A further topic of concern is the effect of uncontrolled trawling on the seabed through removal of non-target species and its impacts on seabed habitat ecology and the ability of the ecosystem to support the resources being trawled. Almost no attention has been given to this potentially deleterious practice in the WIO, despite the fact that it is well documented from other seas (Fennessy 2012). There is a pressing need to develop an understanding of this problem and to improve environmental management of trawl fisheries to prevent further habitat degradation and loss of biodiversity (van der Elst 2012).

3.12.16 Species of special concern

In addition to the diverse ecosystems described earlier, the WIO 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 m 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 in 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 determine the local population of coelacanths and protect this area from this form of fishing.

Cetaceans (Marine mammals): Marine mammals in the WIO 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 in 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 off Zanzibar and mainland Tanzania, for unknown reasons. Threatened whales within WIO are shown in Table 1-14.

Table 1-14: 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 Archipelago (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*) (Frazier, 1980; Howell, 1993). All five turtle 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 coming 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 has been 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 their 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 largest 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, 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 1-15.

Table 1-15: 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)

3.13 Biodiversity

The coastal zone and marine waters of the WIO LMEs host a high diversity of species and communities, the distribution of which is determined by physical-chemical conditions (water temperature, currents, nutrient regimes and substrate) and biological interactions. Oceanographic characteristics already discussed, particularly the predominant currents, eddies and upwelling cells have an influence on the distribution of species.Richmond (2001) presents a comprehensive inventory of the known biodiversity of the Western Indian Ocean; from which some statistics are presented in Table 1-16.

Table 1-16: Summary of the minimum estimated species number for major macroflora and macrofauna taxa from littoral and shallow sublittoral waters of the western Indian Ocean. Data from Richmond (1997) unless indicated.

Taxa	Minimum no. of species	Taxa	Minimum no. of species
Mangroves	10	Caridea	150
Seagrasses	12	Palinura	20
Macroalgae[1]	1011	Thalassinidea	20
Porifera[2]	200	Anomura	50
Ctenophora	20	Brachyura	100
Scyphozoa[3]	30	Scaphopoda	10
Hydrozoa	100	Polyplacophora[4]	39
Octocorallia	300	Prosobranchia[4]	2550
Ceriantharia	20	Opisthobranchia[5]	400
Actiniaria	30	Pulmonata	20
Corallimorpharia	10	Bivalvia[4]	667
Zoanthidea	5	Cephalopoda	20
Scleractinia	200	Echinoidea[4]	62
Antipatharia	10	Holothuroidea[4]	148
Platyhelminthes	100	Asteriodea[4]	58
Echiura	22	Ophiuroidea[4]	132
Sipuncula	50	Crinoidea[4]	19
Polychaeta[4]	300	Phoronida	5
Oligochaeta	10	Brachiopoda	5
Cirripedia	30	Bryozoa	500
Nemertea	59	Hemichordata	20
Amphipoda	300	Chaetognatha	50
Isopoda	100	Thaliacea	30
Stomatopoda	30	Ascidiacea[6]	100
Dendrobranchiata	10	Pisces	2000
Total			10,627

By 2005, Griffiths noted that although no species lists exist for individual countries of tropical Africa, 11,257 marine species have been recorded from the Western Indian Ocean region (including island states). This, however, is estimated to be less than 50% of the marine species actually present (Griffiths 2005). Charismatic species such as turtles, dugongs, coelacanths and cetaceans, as well of those of commercial importance tend to be better studied, while the microfauna and meiofauna, although highly diverse, tend to be poorly studied worldwide (Gage 1996). Existing species lists are based largely on shallow water surveys, and the fauna of deeper waters, abyssal plains and seamounts are less well known (Griffiths 2005). Research surveys by the ASCLME Project and partners have led to the discovery of new species (Randall and King 2009).

Each of the national Marine Ecosystem Diagnostic Analyses presents an overview of species groups per country and the status of species of concern. The SWIOFP Biodiversity report contains a comprehensive overview of biodiversity of the WIO (SWIOFP 2012). Figure 21 illustrates areas recently identified to be of particular ecosystem importance, after: a) The SWIOFP Biodiversity Retrospective Analysis: Hotpots of biodiversity importance (SWIOFP 2012); b) The WWF East African Marine Ecoregion Vision (WWF 2004); c) The WWF Western Indian Ocean Marine Ecoregion Report (WWF 2010).

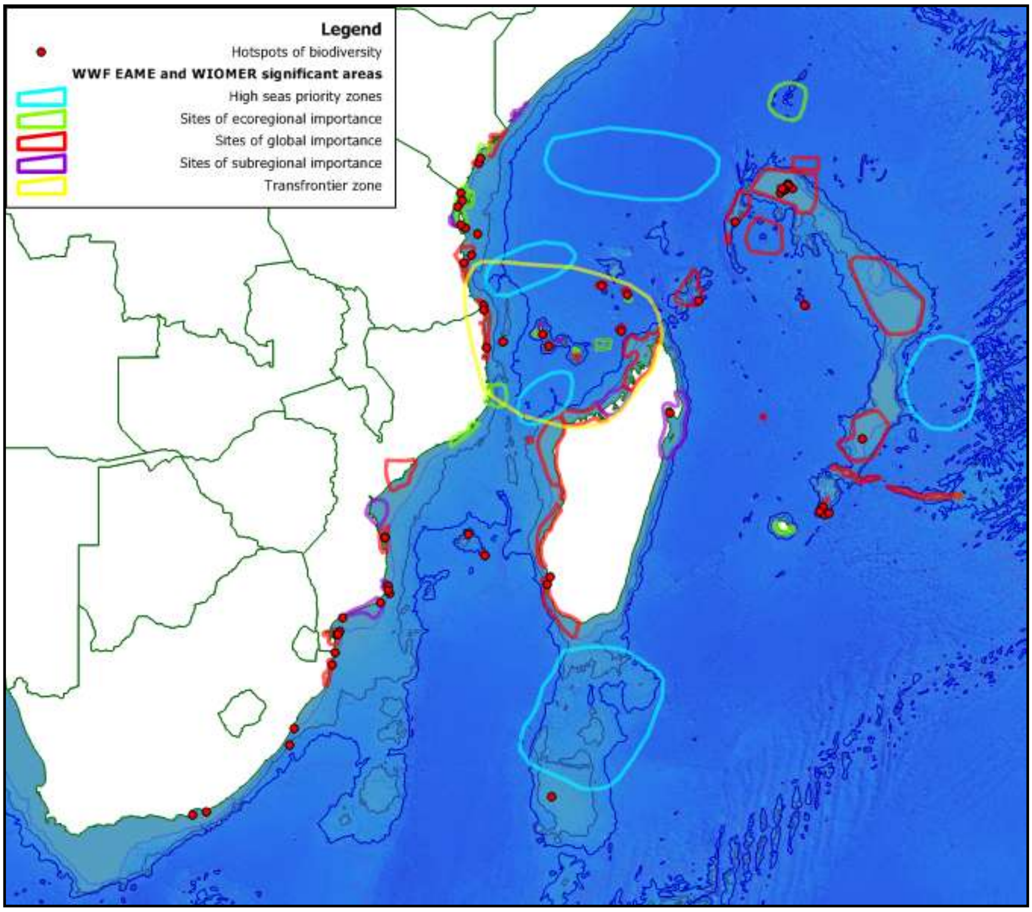


Figure 1-25: Area of ecosystem importance according to SWIOFP Biodiversity Retrospective Analysis (SWIOFP 2012), WWF East African Marine Ecoregion Vision (WWF 2004) and WWF Western Indian Ocean Marine Ecoregion Report (WWF 2010).

Biogeographically, most of the WIO LME region falls into a region that is characterised by Indo-Pacific biota. The dominant coastal habitats are mangrove forests, seagrass beds, and coral reefs, interspersed with estuarine and lagoon systems, sandy beaches, and rocky shores. The subtropical East Coast Province starts in southern Mozambique and extends to the Eastern Cape of South Africa, where the warm-temperate South Coast or Agulhas Province starts (Griffiths 2005).

3.13.2 Marine mammals

Within the WIO, a total number of 37 marine mammal species have been recorded (authenticated records, including sightings and/or strandings), including 32 cetaceans, 1 sirenian (the dugong) and 4 pinnipeds. Only one species of sirenian occurs in the region- the dugong (*Dugong dugon*). Extralimital records of pinnipeds have also been recorded on various tropical islands, such as Madagascar (Garrigue and Ross 1996) and the Comoros (David *et al.* 1993). However, pinnipeds are not regularly present in the region. The South African fur seal (*Arctocephalus pusillus*) is found along the south and southwest coasts of South Africa (Best 2007).

Among baleen whales, there are still several taxonomic uncertainties. However, there are currently nine species that are known to occur in the WIO region. Within the blue whale group, two subspecies possibly co-occur: the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Concerning the toothed whales, some uncertainties exist regarding the range of several species, especially among beaked whales (Ziphiidae). For example, there are a number of unpublished records mentioning sightings of anti-tropical species, such as True's beaked whale (*Mesoplodon mirus*) and Shepherd's beaked whale (*Tasmacetus shepherdi*). Unconfirmed records of ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) also exist from Mayotte (Kiszka *et al.* 2007a) and eastern Madagascar (Ballance and Pitman 1998).

Marine mammal mortality through fisheries interactions in the WIO, while not exhaustively studied, are generally low and certainly lower than many other regions of the world. While this is primarily true for offshore regions, there is greater concern for coastal species and fisheries. It is suggested that three coastal marine mammal species are particularly affected by human activities, including fisheries, and are consequently highly vulnerable: *Dugong dugon* (classified as Vulnerable by IUCN), *Sousa chinensis* (classified as Near Threatened by IUCN) and *Tursiops aduncus.*

The dugong is probably the most endangered and threatened marine mammal in the WIO (WWF EAME 2004, Muir and Kiszka 2011). Dugongs have progressively declined in most WIO countries and the only known viable population is located in the Bazaruto Archipelago in Mozambique (Cockroft *et al.* 2008, Findlay *et al.* 2011). Along the northwest coast of Madagascar, recent aerial surveys highlighted the existence of a potentially important aggregation of dugong (Ridoux *et al.* 2010), while populations in Mayotte are of uncertain viability (Kiszka *et al.* 2007b).

In Zanzibar, Madagascar and South Africa, coastal dolphin bycatch and direct hunting is threatening several species (including those previously cited), and potentially others such as the spinner dolphin. The three vulnerable species are patchily distributed in the WIO region, and that critical attention should be given to the following areas: Bazaruto Archipelago (critical area for dugongs in the WIO, *T. aduncus* and *S. chinensis*), Northwest coast of Madagascar (important area for *T. aduncus, S. chinensis* and potentially a critical habitat for *D. dugon*, as underlined by a preliminary survey in 2010 (Ridoux *et al.* 2010) and South coast of Zanzibar (critical habitat for both *T. aduncus* and *S. chinensis*, with high bycatch level). These areas may be considered as hotspots, as they are critical habitat for at least two of the three most vulnerable marine mammal species in the WIO. It is clear that other areas are also potentially important for these species (for example off the coast of Kenya), but need to be further identified in the future. A clear priority should be given to the study and conservation of these three species. For management purposes, stock boundaries should be further investigated, as management of marine mammal population is clearly transboundary. Fisheries development in these sensitive areas needs to be carefully controlled if not restricted.

3.13.3 Turtles

Sea turtles are highly vulnerable reptiles that have been subjected to direct exploitation for centuries, resulting in severely depleted populations in many cases. As the awareness of their plight and threatened status grew, so too has the advent of their protection in many regions, including the WIO. Whilst this protection has been successful in many cases, the threat to sea turtles remains high because of inadequate compliance with regulations and especially indirect mortality posed by fisheries. The region has over the past few decades seen a huge increase in fishing diversity and effort, invariably resulting in higher turtle mortalities as a bycatch.

The WIO is known to host five species of sea turtle (Marquez 1990, Ratsimbazafy 2003, Seminoff 2004). Of these, the green turtle (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) are the most widely distributed and abundant in this region, with the green turtle being by far the most numerous. These two species have also been the most severely impacted by directed exploitation (Hughes 1974a, b, Frazier 1980, 1982). Loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) are most common in South African waters, but less common in the rest of the region, and have little importance in relation to commercial and directed exploitation (Hughes, 1974a, b, Hughes 2010). Relatively little has been documented on the olive ridley (*Lepidochelys olivacea*) and this species is not considered to be much more that a vagrant to the region.

3.13.4 Seabirds

Eleven seabird families occur within the geographical scope of the Western Indian Ocean as breeding species. They are typically referred to as penguins (Spheniscidae), albatrosses (Diomedeidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), tropicbirds (Phaethonidae), gannets and boobies (Sulidae), cormorants (Phalacrocoracidae), frigatebirds (Fregatidae), skuas (Stercorariidae), gulls and terns (Laridae). Most of the seabirds found in the WIO fall broadly into three categories: Indo-Pacific or pan-tropical, highly migratory Procellariiformes from high southern latitudes, or predominantly Atlantic species with distributions that are relatively marginal to the WIO. Consequently, levels of endemism are relatively low compared with other regions. There are however, at least nine extant, breeding endemics (Table 1-17) of which five are listed as globally threatened, including two critically endangered species (BirdLife International 2008). Half of these are from Subantarctic islands, two from Reunion Island and two from the Arabian seas.

Table 1-17: Endemic seabirds of the WIO region and their status on the IUCN-Red List. CR = Critically endangered; EN = Endangered; VU = Vulnerable; NT= Near threatened; LC= Least concern; ? indicates no threat assessment due to taxonomic uncertainty.

Species	**IUCN Status**	**Breeding islands**
Amsterdam Albatross *Diomedea amsterdamensis*	CR	Amsterdam
Indian Yellow-nosed Albatross *Thalassarche carter*	EN	Amsterdam, St Paul, Prince Edward Crozet and Kerguelen archipelagos
Barau's Petrel *Pterodroma baraui*	EN	La Réunion
Jouanin’s Petrel *Bulweria fallax*	NT	Socotra Archipelago and islands off Oman
Reunion/Mascarene Petrel *Pseudobulweria aterrima*	CR	La Réunion
Salvin’s Prion *Pachyptilia salvini*	LC	Prince Edward, Marion, and Crozet Archipelago
Persian Shearwater *Puffinus [bailloni] persicus*	?	Islands off Arabian peninsula
Socotra Cormorant *Phalacrocorax nigrogularis*	VU	Islands in Persian Gulf and Arabian Sea
Kerguelen Tern *Sterna virgate*	NT	Prince Edward, Marion, Crozet and Kerguelen archipelagos

In addition to some endemic and very range-restricted species, the WIO region is host to globally important numbers of more widespread seabird species. The Seychelles and French islands together hold significant proportions of tropical seabird populations, some of which have huge numbers of breeding species. The region has 25% of the world’s Sooty Terns *Sterna fuscata*, with prodigious colonies at Juan de Nova in the Mozambique Channel (2 million pairs), Cosmoledo Atoll, Seychelles (1.8 million), Bird Island, Seychelles (1 million) and Europa Island, French Mozambique Channel (1 million) (Le Corre and Jaquemet 2005, BirdLife South Africa unpubl data). Aride Island in Seychelles has more than 10% of the world’s tropical shearwaters and lesser noddies *Anous tenuirostris*, and Seychelles holds roughly 15% of the global population of the latter (Fishpool and Evans 2001, BirdLife International 2012). Aldabra Atoll has the world’s second-largest frigate bird colony, estimated to be 10,000 pairs in 2000, and is the only oceanic breeding site for the Caspian Tern *Sterna caspia* (Fishpool and Evans 2001). For two of the southern African endemic seabirds, the Nelson Mandela Bay area (where the city of Port Elizabeth is located in southeastern South Africa) has always been important for seabirds. Subsequent to the implosion of African Penguin numbers at Atlantic colonies, the WIO island of St Croix now hosts the largest colony (>8,000 pairs in 2011) and hosts approximately 50% of the global population (Crawford *et al.* 2011). Similarly, the near-total collapse of Namibia’s Cape Gannet *Morus capensis* colonies has resulted in Bird Island, next to St Croix Island, now hosting 65% of the global population (~90,000 out of ~120,000 pairs in 2005/2006) (Crawford *et al.* 2007). For species breeding in the Sub Antarctic, the WIO holds significant numbers of several Procellariforms: Wandering Albatross (*D. exulans*–74% global breeding pairs), Sooty Albatross (*Phoebetria fusca*–39% global breeding pairs), Light-mantled Albatross (*P. palpebrata*–32% global breeding pairs), Grey-Headed Albatross (*T. chrysotoma*–20% global breeding pairs) and Southern and Northern Giant-Petrels (*Macronectes giganteus* and *M. halli*– 30% and 26% global breeding pairs, respectively) (ACAP 2010). Tropical WIO waters are dominated numerically by the tropicbirds (two species), boobies (three species), frigatebirds (two species) and terns (>10 species), with *Puffinus* shearwaters also common, but less abundant and usually less visible than the other groups. None has substantial ranges during breeding. However, because there is not the marked seasonality in the tropics as there is further south, there tends to be less rigid periodicity in the breeding cycles, with some species’ breeding cycles being less than 12 months. It is usual to find seabirds present at breeding colonies year-round (Le Corre 2001). The main breeding grounds are the islands off Arabia and the Socotra Archipelago, Seychelles, the Mascarenes and the Mozambique Channel.

Migration patterns are not well understood for most tropical seabird species. With few exceptions, tropical seabirds associate very strongly with tuna, and feed in association with them (Le Corre 2001). As a consequence, their post-breeding dispersal is likely to be linked to broad-scale oceanic features (such as productive upwelling or mixing areas) to which forage fish, and consequently tunas, are attracted. Recent work using tracking technologies to identify foraging ranges of seabirds in Reunion, Seychelles and other Southern Hemisphere tropical sites has identified five large-scale important bird areas (IBAs) in the WIO (Le Corre *et al.* in press). A sixth important site is located in the central Indian Ocean. The WIO sites include 1) the Seychelles basin (east of the granitic Seychelles), 2) the pelagic waters encompassing the Aldabra Group northwards and west of the Seychelles Basin, 3) from Reunion southwards, 4) the area south of Madagascar and 5) the southern third of the Mozambique Channel and southwards to ~30˚S. The principal species for which these areas are important are Wedge-tailed Shearwater (1), Greater Frigatebird (2, 5), Red-tailed Tropicbird *Phaethon rubricauda* (5) and Barau's Petrel (3-5).

Temperate and sub-antarctic pelagic waters, Subantarctic and cool-temperate islands and the highly productive South African continental shelf waters are dominated by the procellariiform seabirds (albatrosses, petrels and allies, storm-petrels and diving-petrels) and a cameo role from the Subantarctic Skua *Catharacta antarctica*. In addition, several species of near-shore-foraging Larids and cormorants breed here, with only one breeding species (Antarctic Tern *Sterna vittata*) migrating northwards during the austral winter.

Of the eight WIO countries, three hold exceptional diversity of breeding species. These are the French islands, Seychelles and South Africa. Between them they have all the major breeding sites in the WIO, and all the endemic species of the WIO beside the two species from the islands of the far northwestern Indian Ocean. Nevertheless, all eight countries have sites that BirdLife International has identified as of global importance for seabirds, hosting >1% of the global population of at least one species, or congregations of >20,000 individuals (Fishpool and Evans 2001).

As tracking technology continues to miniaturise, and thereby bringing the technology within reach of researchers interested in smaller, tropical seabirds, there is increased possibility of discovery of more pelagic sites in the WIO that are globally significant. Climate change, and with it the profound, but yet unpredictable consequences for the marine environment, may also add or subtract breeding and visiting species from the WIO countries' national lists.

Le Corre *et al.* (in press) has summarized current understanding of migratory behaviour of birds in the tropical WIO. Frigatebirds from Aldabra and Europa range widely, primarily northwards, and into the Maldives area. White-tailed tropicbirds also range extremely widely outside the breeding season, with a hotspot that overlaps with the non-breeding distribution of Barau's Petrel, in the central tropical Indian Ocean. None of the typical tropical species is currently of global conservation concern. However, the two Reunion-endemic petrel species are of high conservation concern, as are most of the larger procellariiform seabirds that breed in or visit the WIO. The African Penguin and Cape Gannet are the most threatened coastal South African species in the WIO region.

Most conservation efforts for seabirds relating to mitigating impacts from fisheries will require concerted and coordinated approaches. Seabirds are the most international of all birds, spending more time than any other bird group in international waters, which are by definition beyond national jurisdictions. Most species within the WIO are migratory or dispersive outside the breeding season to some extent, and can be expected to cross national boundaries and enter into international waters.

The meta-population dynamics of the more widespread and commoner seabirds in the WIO region are poorly understood, and losses of breeding colonies or subpopulations in one area cannot necessarily be compensated for by healthy colonies or subpopulations elsewhere. Fortunately, seabirds are the most conspicuous components of above-water marine biodiversity, making them easier to monitor than virtually any other group of marine animals. Secondly, they are obligate terrestrial breeders, returning predictably to colonies to lay eggs and raise their young, which facilitates more accurate counting and estimation of productivity.

3.13.5 Elasmobranchs

Among the 1,160 species of cartilaginous fishes known, less than 200 have been recorded in the Western Indian Ocean region. Except for South Africa (especially the coast of KwaZulu-Natal province), little effort seems to have been made to assess the status of sharks and rays in the WIO, although some species have been more investigated than others in the region, notably the larger and emblematic species. This is despite the fact that sharks and rays seem to be heavily impacted by fisheries, and probably other activities in the region. Based on voluntary declared FAO records there is evidence that shark catches in the WIO have more than halved after reaching a peak of 180,000 Mt in 1996.

The highest elasmobranch diversity in the WIO region has been recorded from Mozambique waters, with 108 species (73 sharks and 35 rays. Around 30 species of elasmobranch spend much of their life away from land masses in oceanic waters. The most abundant pelagic shark families in the WIO are Lamnidae, Carcharhinidae and Alopiidae. Among Lamnidae, great white sharks are mostly confined to southern Africa but occasionally make incursions in tropical waters. Large adults have also been recorded in the tropical Western Indian Ocean, including Zanzibar, northern Madagascar, Mauritius, Kenya (Cliff *et al.* 2000) and on several occasions around Mayotte (Jamon *et al.* 2010). The short-fin mako shark (*Isurus oxyrynchus*) is the most abundant mackerel shark in the WIO, and this area takes the highest catch rate for this species in the Indian Ocean (Smale 2008). This species is rarely seen on the continental shelf. Between 1978 and 2003, annual catches of this species in KwaZulu Natal Sharks Board nets were low (mean=13.4; SD=4.5 sharks), and no trend in catch rate or size of sharks was detected over the period (Dudley and Simpfendorfer 2006). In the Carcharhinidae, silky and blue sharks are the most abundant species. Silky sharks are found near the surface in open waters, from 50 to 3,000m (Compagno 1984). Blue sharks occur in deeper waters and are probably one of the most prolific shark species in the world. However, they are less abundant in equatorial waters and their abundance tends to increase with latitude, including in the WIO (Nakano and Stevens 2008). All three species of thresher sharks occur in the WIO, but are far less abundant (Romanov *et al.* 2010).

3.13.6 Teleost fishes

The Western Indian Ocean is characterised by high marine fish species diversity with 2,200 species of fish, equivalent to about 14% of the global total of marine fishes (Smith and Heemstra 1986, Nelson 2006). The fish species found in the WIO can be grouped into 270 families, representing about 83% of all the fish families known. This richness is due to the large variety of habitats and oceanographic conditions of the region (van der Elst *et al.* 2005, UNEP 2009b). On a national scale, the diversity of fishes is also considerable. For example, the Tanzanian national fish species list may reach 1,000 species (Benbow 1976), that of the Seychelles over 1,000 species, and at a smaller scale, 552 species of fish for the Grand Reef at Toliara alone in south-west Madagascar (Gaudian *et al.* 2003). Mozambique has several thousand species of marine fish with at least 307 species of linefish, La Réunion boasts 885 species (Letounreur *et al.* 2004) while the South African list is also around 2500 species. Many of these species are transboundary and shared between the WIO countries. The West Indian Ocean marine fish assemblage includes many remarkable and iconic fishes, ranging from the world's "oldest" fish the coelacanth *Latimeria chalumnae* to the world's largest, the whale shark *Rhincodon typus*. The origin of the region's ichthyofauna is diverse, with about 50% considered to be from Indo-Pacific (Smith and Heemstra 1986), about 13% are endemic to the WIO, 29% are from the global deep sea and the rest made up of species that are from southern ocean or original migrants from different regions.

The distribution of this diversity of fishes in the WIO is not necessarily uniform. There are regions of higher diversity such as the East African coast and Madagascar and also regions of relatively low diversity, such as the northern parts of the WIO bordering the Arabian Gulf, with its shallow seas, high salinity and temperature fluctuation from 10^{o}C to 35^{o}C (Cohen 1973, Randall 1995). Significantly, there are also regions of high endemism. A surprisingly high level of endemism is also found off southern Mozambique and South Africa, the latter country with 227 endemic species equivalent to 13% of its marine ichthyofauna (Smith and Heemstra 1986). This endemism is largely due to five key families. The reason for this high level of endemism in South Africa can be attributed to the unique environment of the southern tip of continental Africa. This is the only coastal region in the Western Indian Ocean that has a temperate climate with distinctly different environmental conditions in association with the Agulhas large marine ecosystem (Beckley *et al.* 2002). Some of the endemics in the WIO may be glacial relics, meaning that they were once more widespread during the Pleistocene (Randall 1995). In some cases, upwelling systems may have contributed to their isolation, such as off South Africa and Somalia. There is also evidence of disjunct distribution of fishes, such as the croaker, *Argyrosomus hololepidotus* (Griffiths and Heemstra 1995). Surveys have suggested anti-tropical distribution of several inshore species that have been found off Puntland in Somalia and KwaZulu-Natal in South Africa, but not in between these latitudes. Examples of this are the elf *Pomatomus saltatrix*, the blackail *Diplodus sargus*, the Cape fur seal *Arctocephalus pusillus* and the Natal rock lobster *Panulirus homarus* (Mann and Fielding 2000).

3.13.7 Species under threat

Fishes of the WIO region are variably at risk. These risks may be attributed to causes that include ecosystem and/or habitat destruction, climate change and fishing. In the case of fisheries, the risks imposed can be either as a result of directly targeting or incidental as a bycatch or impact on the species' environment. Whatever the case, some species are more vulnerable than others and these require identification and protection. The identification of such species at risk can be done on the basis of several different criteria. Included are issues such as declining populations, limited distributions, endemism, slow turn-over life cycles, reduced distribution range, high mortality rates, etc. While traditional fish stock assessments should be able to deal with harvested fish stocks, it is often the less common but vulnerable species that require special attention. There are several approaches, including the IUCN Red List system as well as national conservation programmes. In most cases the capture of IUCN Red-Listed species is not seen as a matter of concern by management agencies, except perhaps the coelacanth, for which a marine park was recently declared in Tanzania. Similarly, the capture of elasmobranchs is not generally viewed in the light of their status.

Based on the IUCN red data listing for marine fishes there are presently a total of 738 marine fish species listed on the Red List for the WIO. Of these, 237 (32%) are elasmobranchs and 492 (68%) teleost fishes. Amongst the latter are 83 families dominated by coral reef species as shown below in Figure 1-26.

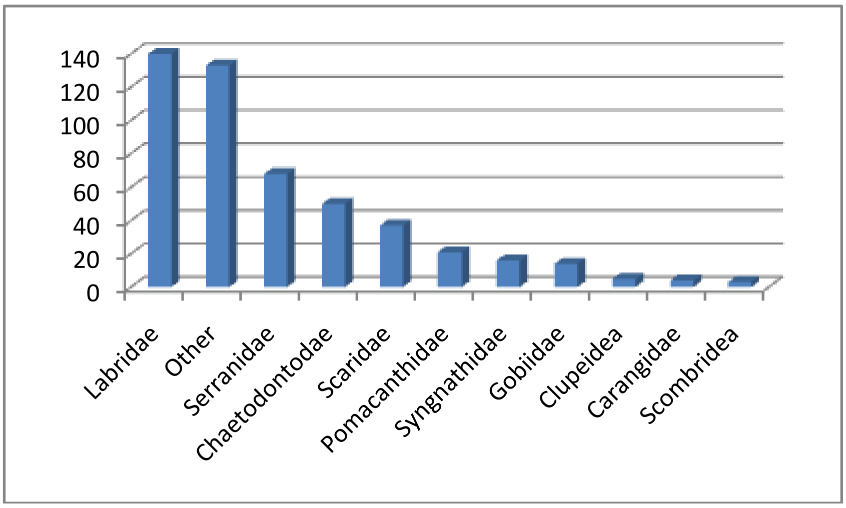


Figure 1-26: Distribution of the number of species listed on IUCN Red List for the main WIO teleost fish families (IUCN).

The IUCN Red List includes a total of 17 species (3.4%) that are listed as either Critically Endangered (2 species); Endangered (3) or Vulnerable (12). Of these, six are shallow water species and not threatened directly by commercial fisheries, while the remaining 11 are variably taken in fisheries in the Western Indian Ocean region, mostly by line. In contrast, there are 57 species of elasmobranch listed (24% of total) as either Critically Endangered (8 species); Endangered (8) or Vulnerable (41). The higher proportion of elasmobranchs listed signifies the higher levels of risk associated as well as the greater effort and progress made by the respective specialist group. One further species that is red- listed as Critically Endangered is the coelacanth *Latimeria chalumnae*, belonging to the class Sarcopterygii.

Table 1-18: The twelve non-elasmobranch species in the WIO included on the IUCN Red List as 'Threatened' (van der Elst 2012).

Latimeria chalumnae	Coelacanth	
Thunnus maccoyii	Southern bluefin tuna	CR CR
Argyrosomus hololepidotus	Madagascar kob/croaker	EN
Cheilinus undulates	Humphead wrasse	EN
Epinephelus marginatus	Dusky grouper	EN

Bolbometopon muricatum	Bumphead parrotfish	VU
Epinephelus albomarginatus	Captain fine	VU
Epinephelus gabriellae	Gabriella's grouper	VU
Epinephelus lanceolatus	Brindle bass	VU
Plectropomus areolatus	Spotted coral trout	VU
Plectropomus laevis	Black-saddled coral grouper	VU
Thunnus obesus	Big eye tuna	VU

In addition to the IUCN Red listed species, individual countries have also identified species in their ichthyofauna that require special protection. While some of these species are endemic and may apply to one country only, others are transboundary and shared by more than one country. In some cases species are partially protected by marine protected areas while in others they are fully protected and may not be landed at all. The table reflects that aside from the coelacanth there is considerable room for improved regional collaboration in the protection of IUCN Red Listed non-elasmobranch fishes. In most cases the IUCN Red Listed species are not even listed in national management regulations.

3.14 Governance of Fisheries in the WIO

3.14.2 International Fisheries Instruments

Several international fisheries instruments provide a governance framework for fisheries in the WIO region. Key legally binding instruments include the 1982 UN Convention on the Law of the Sea (the 1982 Convention), the 1995 United Nations Fish Stocks Agreement and the 2009 FAO Agreement on Port State Measures (not yet in force) (Table 5) (Swan 2012). A leading voluntary instrument is the 1995 FAO Code of Conduct for Responsible Fisheries and the international plans of action, elaborated under its provisions, on seabirds, sharks, fishing capacity and illegal, unreported and unregulated (IUU) fishing. Other voluntary instruments include the:

- 2003 FAO Technical Guidelines on the Ecosystem Approach to Fisheries.
- 2008 FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas.
- 2010 FAO International Guidelines on Bycatch Management and Reduction of Discards.

All countries in the WIO region have signed and ratified UNCLOS, which forms the foundation for the other instruments. It sets the standards for management of fisheries, including straddling fish stocks and highly migratory species. Four countries in the region are parties to the UN Fish Stocks Agreement (Kenya, Mauritius, Mozambique, Seychelles, and South Africa). Key areas of this Agreement include the requirements for compatibility of measures inside and beyond areas under national jurisdiction, an ecosystem approach to management of stocks and associated and dependent species throughout their range, functions of regional fisheries bodies or arrangements, information provision and exchange, flag state duties, port state measures and MCS provisions including procedures for boarding and inspection on the high seas (Swan 2012).

3.14.3 Regional Organisations

The Indian Ocean Tuna Commission (IOTC) established in 1996, has a mandate for the management of tuna and tuna-like species included in its constitutive Agreement. Its area of competence includes high seas and areas under national jurisdiction in the Indian Ocean. It seeks “to promote cooperation among its Members with a view to ensuring, through appropriate management, the conservation and optimum utilisation of stocks” and by “encouraging sustainable development of fisheries based on such stocks”. It has a management mandate and takes legally binding decisions (Swan 2012). Membership is open to Members and Associate Members of FAO that accept the IOTC Agreement and are coastal States or Associate Members situated wholly or partly within the Area, States or Associate Members whose vessels engage in fishing in the Area for stocks covered by the Agreement, or regional economic integration organisations to which states have transferred appropriate competence. IOTC currently has 31 Contracting Parties (IOTC 2001-2009). All of the 9 WIO countries are full Contracting Parties to IOTC with the exception of South Africa, which is a Cooperating non-Contracting Party (Table 1-19) (Swan 2012).

The South West Indian Ocean Fisheries Commission (SWIOFC) established in 2004, has an advisory mandate over all living marine resources within the national jurisdiction, without prejudice to the management responsibilities and authority of other competent fisheries and other living marine resources management. This effectively recognises the mandate of IOTC within national waters over the tuna and tuna like species set out in the IOTC Agreement- so there is no overlap with IOTC. Its main objectives are to promote the sustainable utilisation of the living marine resources of the region through management and development and to address common problems of fisheries management and development faced by the Members of the Commission (Swan 2012). Comoros, France, Kenya, Madagascar, Mauritius, Mozambique, the Seychelles, Somalia, and Tanzania are all members of the Commission (FAO 2012b).

The South Indian Ocean Fisheries Agreement (SIOFA) entered into force in 2012, and its area of competence falls within the high seas of the South Indian Ocean. It has competence over high seas fisheries resources, other than sedentary species on countries' continental shelves beyond the exclusive economic zone and, in order not to overlap with IOTC's highly migratory species. It has a management mandate and takes legally binding decisions (Swan 2012). Comoros, Kenya, Madagascar and Mozambique have signed the SIOFA and Mauritius and Seychelles have ratified the Agreement (FAO 2012b).

The Southern African Development Community (SADC), of which Madagascar, Mauritius, Mozambique, Seychelles, South Africa, and Tanzania are members, has a long experience of cooperation in fisheries. The 2001 SADC Protocol on Fisheries aims at promoting responsible and sustainable use of the living aquatic resources and aquatic ecosystems of interest to State Parties, and it contains Articles in relation to the management of shared resources, harmonisation of legislation, law enforcement, access agreements and protection of the aquatic environment. It allows for States to establish instruments for co-ordination, co-operation or integration of management of shared resources (Swan 2012).

The East African Community (EAC) is a regional intergovernmental organisation which includes Kenya and Tanzania as members. The EAC seeks to promote the co-management of natural resources, harmonise policies, laws and strategies for both the sustainable use of coastal and marine resources and fisheries, fisheries laws, policies and strategies and address a range of issues including reduction and prevention of pollution, introduction of alien species and monitoring, evaluation and control (Swan, 2012). The EAC adopted a Protocol on Environment and Natural Resources in 2005, which aims at promoting and enhancing cooperation amongst Partner States in the conservation and management of environmental and natural resources, adopt a common vision in addressing challenges of sustainable development, make concerted efforts to prevent and control environmental degradation and includes fisheries as one of its focal areas (East African Community Portal 2012).

The Indian Ocean Commission (COI-IOC) has a strong focus on fisheries and has several management programmes for fisheries resources and the protection of the marine environment. The Regional Fisheries Surveillance Plan Project (PRSP), which has been active since 2007 aims at eliminating illegal, unregulated and unreported (IUU) fishing in the exclusive economic zones of its Member States. It also contributes to the sustainable management of fisheries resources in the Western Indian Ocean and to the promotion of responsible fishing. In 2009, the IOC decided to develop a regional strategy for fisheries and aquaculture to ensure a greater coherence among all these initiatives and to encourage efficient and sustainable management of these shared fisheries resources. The SmartFish Programme, which was officially launched in 2011, aimed at contributing to an increased level of social, economic and environmental development and deeper regional integration in the Eastern and Southern Africa and the Indian Ocean (ESA-IO) region through improved capacities for the sustainable exploitation of fisheries resources. The Programme aims at achieving five main results which relate to fisheries development and management; fisheries governance; monitoring, control and surveillance; fish trade and food security (IOC 2011).

The New Partnership for Africa's Development (NEPAD) is a programme of the African Union (AU) adopted in 2001 which aims to enhance Africa's growth, development and participation in the global economy. NEPAD has developed the Partnership for African Fisheries which is working to improve the sustainability of Africa's fisheries and improve the returns provided by this sector by defining processes that will strengthen the region's capacity to implement policy reforms in fisheries governance and trade. Working groups have been established in 5 key areas: good governance; illegal fishing; trade and access to markets; aquaculture; and finance and investment in fisheries and aquaculture (NEPAD 2010-2012).

The African Union-Interafrican Bureau for Animal Resources (AU-IBAR) has included fisheries issues in its Strategic Plan 2010-2014 and supports regional fisheries organisations and member states to sustainably manage marine and inland capture fisheries based on international best practices. The Strategic Partnership for Sustainable Fisheries Investment Fund Project aims to promote sustainable use of fisheries resources and the management of marine ecosystems that support them with the overall aim of poverty eradication and enhancement of sustainable income growth of the fishing communities of Sub-Saharan Africa (AU-IBAR 2004-2012).

Table 1-19: International, regional, sub-regional instruments and organizations (shaded areas indicate States that are members or parties to the instrument/organization. Light shading indicates signature only of the instrument) (Swan 2012).

Country	**International Instruments**			**RFBS**			**Regional Organizations**			
	1982 UN Law of the Sea Convention	1995 UN Fish Stocks Agreement	2009 FAO Port State Measures Agreement	IOTC	SIOFA	SWIOFC	ASCLME	COI-IOC	EAC	SADC
Comoros										
Kenya										
Madagascar										
Mauritius										
Mozambique										
Seychelles										
South Africa				[1]						
Tanzania, U.R. of										

[1] Cooperating non-Contracting Party.

3.14.4 National Legislation

All countries within the WIO region have national fisheries laws and five of these countries (Kenya, Madagascar, Mauritius, Mozambique and Seychelles) have prepared, or are in the process of developing revised fisheries legislation (Swan 2012). However, many laws do not fully implement the binding obligations of international fisheries instruments or regional organisations, nor do they reflect up to date "best practices" of fisheries legislation. In addition, they do not provide a harmonised basis for fisheries conservation, management and development, including in related areas such as monitoring, control and surveillance, information requirements, jurisdiction and application, international cooperation, evidence and fines, penalties and other determinations.

3.14.5 Trade in Fish and related Fisheries Resources

Fish is the most internationally traded food commodity at the global level. In the WIO region, industrial fishing activities provide an important source of employment, foreign exchange revenue and food security. World exports of fish and fishery products reached 56 million tonnes with a value of US$96 billion in 2009 which showed a significant increase from 2000 (FAO 2012a). Growing exports can be attributed to the increase in consumption not only in the European Union (EU) and the United States of America, but also in other regions of the world such as in Asia. The development of processing, packaging, handling and transportation of fish and fish products, as well as the growth of international distribution channels, are all factors that contributed to the increase of fish exports (Tsamenyi and McIlgorm 2010). In 2009, fish exports were more than 30% of the value of agricultural exports in Madagascar, Mauritius and the Seychelles (Table 1-20). In the Seychelles, over 50% of all exports are fish and fish products (FAO 2012a). Fish exports from the WIO region primarily include unprocessed fresh or frozen whole tuna, canned tuna, small pelagic species such as mackerels and sardines, and crustaceans (mainly shrimp and rock lobsters) and molluscs. In the Seychelles, the fisheries sector is the main source of foreign exchange, and the country has the most important tuna port in the world (Port Victoria). The Seychelles has the second largest tuna processing factory in the world, with canned tuna exports representing 87% of the country's foreign exports. Seychelles also handles 88% of the total tuna catch in the WIO fleet (Kimani *et al*. 2009).

Table 1-20: The value of fishery exports to the economics of 8 countries within the WIO

Country	GDP (million US$) (2009)[1]	Exports (million US$)[2]	Imports (million US$)[2]	Fishery exports (% of agricultural exports)[2]	Fishery exports (% of total merchandise exports)[2]
Comoros	530	Not available	2.52	4.6	1.5
Kenya	29,412	57.11	6.58	2.3	1.3
Madagascar	8,790	115.19	18.00	38.1	10.9
Mauritius	8,668	284.53	235.46	48.1	14.7
Mozambique	9,579	66.41	39.82	17.7	3.1
Seychelles	788	210.20	87.45	97.8	53.2
South Africa	285,983	441.78	260.65	7.5	0.7
Tanzania	22,351	145.52	4.00	15.0	5.0

[1] UNdata (2012) [2]FAO (2012a)

Countries in the WIO have benefited from the trade preference provided under the non-reciprocal Lomé/Cotonou arrangement between the African, Caribbean and Pacific (ACP) countries and the EU. This agreement has led to a considerable export market in the EU for ACP produced fish and fish products, with the EU receiving 68.8% of total ACP exports by value. There have however, been recent developments in the international trade arena which will impact this situation. With the advent of Economic Partnership Agreements (EPAs) and Fishery Partnership Agreements (FPA), the relationship between ACP and the EU is changing (Tsamenyi and McIlgorm 2010). EPAs are a key element of the Cotonou Agreement that aim at providing a broad range of measures to support the gradual integration of ACP countries into the world economy. ACP countries are encouraged to enter into the EPAs in regional groupings and countries within the WIO are members of the different regional trade groups: Eastern and Southern Africa (Comoros, Mauritius, Madagascar, Seychelles and Somalia), East African Community (Kenya and Tanzania) and the Southern African Development Community (Mozambique and South Africa). Madagascar, Mauritius, Mozambique, Kenya, Seychelles and Tanzania all signed interim Economic Partnership Agreements with the EU between 2007 and 2009 (European Union 1995-2012).

In the past, the preferential access to EU markets for fish and fish products produced in ACP countries was a fundamental and important competitive advantage given to ACP producers. However, as a result of a general liberalisation of trade in non-agricultural products, including fish and fish products, average import duties on fish have come down substantially. This enables non-ACP producers to gain access to the EU markets at lower rates than previously applied. Other developments such as the establishment of Free Trade Agreements between the EU and Thailand, Philippines and Indonesia, the Everything but Arms concessions by the EU to the Least Developed Countries, and concessions accorded to Central American countries under the anti-drug concessions programmes have, cumulatively reduced considerably the preference accorded to ACP producers of processed fish (mainly tuna) for the EU market. As a result, fish exporting ACP member countries must now explore other potential opportunities such as market diversification and the expansion of intra-ACP fish trade is a potential opportunity for ACP member countries (Tsamenyi and McIlgorm 2010).

3.14.6 Improving management of WIO fisheries

The findings from the SWIOFP Gap Analyses and Retrospective Analyses indicate that all three of the main fisheries types (crustacean, demersal and pelagics) as well as other fisheries, lack the appropriate data on the priority species required for effective management of the fisheries in the WIO region (Fennessy 2012, Groeneveld 2012a, b, Heileman 2012, Cochrane and Japp 2012). Where data do exist, they have not been fully analysed to increase the knowledge and understanding about the priority species (Heileman 2012). There is a recognised need to harmonise sampling strategies across the region with particular recommendations to improve the sampling methods for the small and medium pelagic fishes (Cochrane and Japp 2012, Lucas *et al*. 2009) and to improve collection of catch and fishing effort data for the demersal fisheries (Heileman 2012).

For the industrial fisheries, scientific observer programmes should be expanded and regular training provided to observers, data collectors and other relevant persons (fisheries researchers and officers) in species identification and sampling methods, and collection of biological data (Heileman 2012). Additional surveys are also required to incrementally strengthen the IOTC's Tuna Tagging Programme, particularly for bigeye tuna and swordfish and the linkages between pelagic fisheries information and environmental information (integration of ASCLME with SWIOFP) should also be strengthened (Lucas 2009). For the artisanal fisheries, countries need to take urgent steps to ensure that at least the minimum monitoring and data analysis necessary for responsible management is routinely carried out. In pursuing these goals, the WIO countries need to identify and implement cost-effective methods for monitoring and assessing small-scale and multispecies fisheries, such as rapid appraisal methodologies and participatory processes (Cochrane and Japp 2012, Cochrane *et al*. 2011).

A significant regional effort also needs to be undertaken to identify areas of special interest for marine mammals, sea turtles and elasmobranchs, including more in-depth studies of their critical habitats, movement patterns and population structure of the most vulnerable species. It is recommended that a regional scientific observer programme should be initiated for all sizeable fisheries to collect reliable information about fishing impacts on target and non-target stocks. There is a particular lack of quantitative data regarding elasmobranchs, turtle and marine mammal bycatch and therefore this should be addressed at all levels (van der Elst 2012). There is a need for the monitoring of bycatch in the WIO region to include the recording of the fate of bycatch (i.e. discarded or used as bait).

All of the countries in the WIO region have planned or existing fisheries management plans, and fisheries regulations and measures for their fisheries in general or for certain sectors. A review of national fisheries legislation in the WIO region has shown however that fisheries related legislation in the region is generally outdated and weak (Swan 2012). Although all countries within the region have national fisheries legislation, many of the laws do not fully implement the binding obligations of international fisheries instruments or regional organisations, nor do they reflect up to date “best practices” of fisheries legislation (Swan 2012). Furthermore, few priority species are explicitly covered in the existing or planned fisheries management plans, or have established biological reference points (Heileman 2012). A further review of national legislation should therefore be considered and management plans should be revised to incorporate stock assessment information and to explicitly consider the priority species and the major fisheries that target them.

3.15 Invasive species in the WIO

Invasive alien species (IAS) are now generally recognised as one of the greatest threats to global biodiversity. They also have serious economic, environmental and health impacts and, as a result, can place major constraints on development and natural resource use. In the marine realm there are examples of invasive species from all different taxonomic groups, ranging from plants, to vertebrates and microbes. A total of 104 introduced or alien species and 45 cryptogenic species are listed within the WIO region. Of these only 5 are considered to be invasive. Globally, the incidence of species invasion is increasing drastically, as ongoing development leads to growth in maritime and shipping sectors, and also other human-mediated activities involving species translocation, such as aquaculture. The impacts of invasions are similarly increasing as marine ecosystems weaken under the combined stresses of over-fishing, pollution and coastal development.

There are several significant vectors of transfer for marine organisms, including intentional introduction (e.g. for fisheries or aquaculture) and unintentional means, such as biofouling on ocean-going vessels, accidental release from aquariums and discharge of ships’ ballast water, which is thought to be the most serious modern vector. Almost any type of organism can be transferred in situations where water is transported from one ecosystem to another, due to the planktonic life stages that most marine species experience. Ballast water is taken on by ships in order to stabilise them at sea when they are not fully loaded with cargo. It is estimated that upwards of 10 million tons of ballast water are transferred around the worlds oceans each year, containing up to 7,000 species of aquatic organisms at any given time.

The International Maritime Organization (IMO) has developed the *International Convention for the Control and Management of Ships’ Ballast Water and Sediments*, adopted by member states in 2004, which remains the most pertinent of international legal instruments in the fight against marine IAS. The Convention on Biological Diversity (CBD) (1992) provides a comprehensive basis for protection of biodiversity from IAS generally, and the FAO has developed framework for the management of species deliberately introduced for fisheries and aquaculture purposes. Efforts to implement the provisions of these instruments are being made at local and regional levels.

3.16 Harmful Algal blooms in the WIO

Although there have been hundreds of micro-algal species recorded within the WIO region, significant HAB events in the region have only been reported from Kenya, Mauritius (including Rodrigues), Somalia, South Africa and Tanzania. This is likely a reflection of the monitoring and assessment capacity in these locations, as it is generally understood that red tides and other HAB events occur occasionally throughout the region, usually associated with the beginning of the North-east monsoon season in East Africa. Coastal upwelling associated with offshore winds brings cold nutrient rich waters to the surface forming ideal conditions for blooming species to proliferate. Impacts of these events have been documented in all recorded locations, most commonly causing mass mortalities of fish or invertebrate species. HAB events in the WIO tend to be isolated and these are usually tied to less common weather or oceanographic phenomena.

Between 1998 and 2000, the UNESCO-IOC HAB programme coordinated a preliminary survey of the Western Indian Ocean region, as part of the WIOHAB programme. Study sites for the survey were located in Kenya, Zanzibar, Reunion, Mauritius and Madagascar (Ste Marie Island). A total of 60 potentially harmful species, representing 4 different classes, were recorded from the region during the survey. A list of the potentially harmful species found and an indication of the risks posed, as well as a guide to their sampling, handling and identification, was produced as the main publication of the programme. The publication can be downloaded from the UNESCO-IOC HAB programme website.

Harmful Algal Blooms (HABs) have received much attention due to the acute impacts some may have on coastal systems, local populations of fish and invertebrates, and human health. These microscopic species are particularly vulnerable to transport in ships' ballast water, both in planktonic and cyst resting stages in the ballast sediments. The algal species that form blooms may be dinoflagellates, diatoms, cyanobacteria or other types of micro-algae, and the blooms themselves may take various forms and colors, and cause impacts due to toxicity or other mechanisms such as localized oxygen depletion. The west coast of South Africa is well known for recurrent red-tides and other HAB events, many of which are naturally occurring and others are likely to have been introduced. The East coast of Africa is less nutrient rich, and therefore experiences far fewer phenomenon of this nature. There have however been some recorded events, with impacts on a relatively large scale. Regular monitoring in Reunion Island has shown cases of ciguatera fish poisoning (amongst other HAB species impacts/records) to be relatively common, likely throughout the region. Despite the potential acute threats to fisheries and other human interests, the only ongoing monitoring for HAB's is occurring in isolated areas of the South African west coast and in Reunion Island.

4 Socio-economic setting and coastal livelihoods

4.12 Introduction

The socio-economic characteristics of most countries in the WIO region are essentially determined by the exploitation of natural resources, a substantial part of which is derived from the coastal and marine ecosystems. The following sections provided baseline data and information on the socio-economic characteristics of the region paying special attention to the conditions in each of the participating countries.

4.13 Level of economic development and poverty

WIO countries are at different stages of economic development and there are considerable differences in Gross Domestic Product (GDP) between countries. Majority of the countries are classified as ‘poor’ according to the World Bank criteria (Table 1-21). Seychelles is the only country with the highest Gross National Income (GNI) per capita in the region, followed by Mauritius, South Africa, Réunion (France), Kenya, Tanzania, Comoros, Madagascar and Mozambique (World Bank, 2009a). Also, Seychelles and Mauritius are the only countries in the WIO region that are classified as High Income according to the World Development Indicators of the World Bank. Mozambique and Tanzania are classified as Low Income while the other four countries have been classified as Lower-middle Income (World Bank, 2009a). Also, considering the human development indices (HDI) for each of these countries, Seychelles, La Réunion (France) and South Africa are classified as ‘most developed’ in the region. However, in the last 40 years, there have been major improvements in HDI values for Mozambique, Madagascar, Mauritius and Comoros and there was a decline in the case of South Africa and Kenya (UNDP, 2007). These indices provides a reasonable clue on the standards of living of people in these countries and this ultimately has major implications on the ability of countries in the region to develop and implement strategies for addressing the causes of degradation of the coastal and marine ecosystem including the decline of fisheries resources in the Western Indian Ocean. Interestingly, data suggests countries with better HDI levels have a relatively longer coastline relative to their total land surface area. Thus, the island states of Seychelles (HDI = 50 out of 177), Mauritius (65/177) and Comoros (121/177) have better HDI levels than the continental countries in the WIO region.

4.14 Coastal livelihood systems

The WIO region is inhabited by more than 170 million people, out of which approximately 55 million people live within the coastal zone, and are to some extent dependent on the exploitation of the coastal and marine resources for sustenance and livelihoods. Coastal cities and settlements are growing and developing at a rapid rate, exerting more pressure on the coastal and marine ecosystems. Climate change and extreme events have also a disproportionately severe effect on communities in the WIO in view of their limited resilience and adaptation to the impacts of climate change. A summary of socio-economic statistics for the region is presented in Tables 1-21-1-23.

Table 1-21: Population and Area data for the WIO states

Country	**Popn (million)**	**% Coastal**	**Coastal Popn (million)**	**Terrestrial Area (000 km^2)**	**EEZ Area (000 km^2)**	**Coastline (km)**
Comoros	0.76	*100*	0.76	2.17	165	340
Kenya	47.00	7.6	10.00	580	112	536
Madagascar	22.59	55.1	12.44	587	1 199	4, 828
Mauritius	1.27	*100*	1.27	2.04	1 27	177
Mozambique	28.90	28.1	8.10	799	572	2,470
Seychelles	0.098	*100*	0.098	0.46	1 374	491
Somalia	16.80	54.8	5.5	638	830	3,025
South Africa	61.14	40	18.99	1,220	1, 067	3,600
Tanzania	44.90	24.4	10.95	884	242	1424
TOTAL	**193.75**	**59.61**	**65.44**	**4 775.565**	**6 791**	**16, 089**

Table 1-22a: Economic data for the WIO region (from the ASCLME Cost Benefit Analysis)

Country	Fisheries (million USD)	Coastal Tourism (million USD)	Coastal Agriculture & Forestry (million USD)	Mariculture (million USD)	Mining & Energy (Coastal) (million USD)	Ports & Coastal Transport (million USD)	Total Coastal Economy (million USD)	Coastal Domestic Product per capita	TCE / Coastline (million USD / km)
Comoros	45.2	16.7	0.86	7.6	-	24	94.36	127.99	0.28
Kenya	46.0	4 153	-	0.8	179	100	4 437.40	1 357.41	8.28
Madagascar	586.6	308.2	20.5	6.7	85	36	1 043.00	83.81	0.22
Mauritius	208.1	1190	11	0.3	-	52	1 461.40	1 112.94	8.26
Mozambique	356	145	526.5	-	82.5	60	1 170.00	84.33	0.47
Seychelles	313.7	247	5.33	9.6	-	6	581.63	6 460.83	1.18
Somalia	36.9	0	729.6	4.3	-	24	794.80	143.80	0.26
South Africa	769.3	1743	264	7.6	1450	1500	5 733.90	301.99	2.05
Tanzania	31	4008	2097	0.8	932	30	7 098.80	771.61	4.99
Total	**2 351.40**	**11 810.90**	**3 654.79**	**37.70**	**2 728.50**	**1 832.00**	**22 415.29**	**1 160.52**	**2.89**

Table 1-22b: Economic data for the WIO region derived from the ASCLME Cost Benefit Analysis

Country	GDP (PPP) (billion USD)	GDP Per Capita (USD)	Gini Coefficient	Rate of Urbanization (%)
Comoros	0.816	1 200	-	28.0
Kenya	70.850	1 700	42.500	22.0
Madagascar	20.600	900	47.500	30.0
Mauritius	19.280	15 000	39.000	42.0
Mozambique	23.870	1 100	45.600	38.0
Seychelles	2.244	24 700	-	55.0
Somalia	5.896	600	-	37.0
South Africa	554.600	11 000	65.000	62.0
Tanzania	63.440	1 500	37.600	26.0

Table 1-23: Key socio-economic statistics for the WIO region countries

Country	Popn growth rate (%)	Literacy (total %)	Education Expenditure (% GDP)	Popn below poverty line (%)	Unemployment (%)	Life Expectancy at Birth
Comoros	2.00	56.6	7.6	60	20	62.7
Kenya	3.00	85.1	7.0	50	40	63.07
Madagascar	2.952	68.9	3.0	50	20	64
Mauritius	0.705	84.4	3.2	8	7.8	74.71
Mozambique	2.442	47.8	5.0	46.1	21	52
Seychelles	0.920	91.8	5.0	-	2	73.77
Somalia	1.596	37.8	-	-	-	50.8
South Africa	-0.410	86.4	5.4	50	24.9	59. 30
Tanzania	1.960	69.4	6.8	36	-	53.14

NB this excludes French territorial areas of Mayotte and Reunion and other French Indian Ocean Islands.

EEZ Area from Sea Around Us; retrieved 19 June 2012 http://www.seaaroundus.org/eez/

Economic Values from CBA
Popn, area, coastline from CIA world factbook; accessed 19 June 2011; MEDA 2022 Reports.
% coastal from Table 2, pg 15, Burke L, Kura Y, Kassem K, Revenga C, Spalding M, McAllister D (2001) Pilot Analysis of Global Ecosystems : Coastal Ecosystems. World Resources Institute, Washington DC. 93pp
Coastal popn = popn * coastal %
Terrestrial area includes inland water

4.15 Socio-economic setting

4.15.2 Population and demographics

The total population in the WIO region in 2021 was estimated to be 250) million. Population distribution in the region is linked to a number of factors that includes economic development and the availability of natural resources (Figure 1-27). About, 1/3 of the region's population live within 100km of the coast, and 1/5 of the population is found within the 25 km coastal zone where regular access to coastal and marine resources is most pronounced. The main beneficiaries of coastal and marine resources in the region are more than 35 million who live within the 25km coastal strip. However, impact on the coastal and marine ecosystem is created by more than 60 million people who live within a distance of 100 km from the coast. (World Resources Institute, 2003; World Bank, 2009a) (see **Error! Reference source not found.**). The proportion of coastal population in the 25km strip varies substantially between countries from a low 9.2% in Kenya and 40% in South Africa to 100% in the small island states (South Africa MEDA, 2022; Kenya MEDA, 2022). There also significant differences in population densities with some countries such as Somalia and Mozambique being sparsely populated at population densities of 14 and 27 people per square kilometre respectively, while island states such as Comoros and Mauritius are densely populated ranging 315-407 persons per square kilometre (see Figure 3.1; UNEP/GPA and WIOMSA, 2004b; The Encyclopaedia of Earth, 2007, Demography Unit, Central Statistics Office, Mauritius, 2007; Comoros MEDA, 2022).

Many of the coastal zones of the mainland countries in the region have experienced a large influx of people from inland areas leading to rapid expansion of settlements and economic activities at the coast. Population growth in coastal areas places heavy demand on inshore marine ecosystems, particularly sandy beaches, seagrass beds, coral reefs and mangrove forests, leading to damage and depletion of some faunal and floral species that are associated with these habitats. All WIO countries have various forms of infrastructure developments at the coast most of which are related to economic activities such as tourism, fishing, ports and harbours, industry, mining, road and railway transport. These activities attract immigrant populations from inland areas seeking to better their lives and improve their standards of living (UNEP/GPA and WIOMSA, 2004b).

According to World Bank, 2009a projections[10], the annual population growth rate in the WIO region ranges from 0.4% in South Africa to 2.6% in Madagascar (Table 1-24). 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 and consistent increasing trend in the annual population growth for most of the WIO countries. While most countries in the region have in the past two decades experienced relatively high population growth rates, this trend has slowed down considerably and the latest population growth projections indicate that the rate of population growth has declined by 63%. Several factors may be responsible for this trend including increased level of education, increased family planning campaigns, erosion of local culture and traditions, mortality due to HIV/Aids and increased cost of living.

[10] 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.

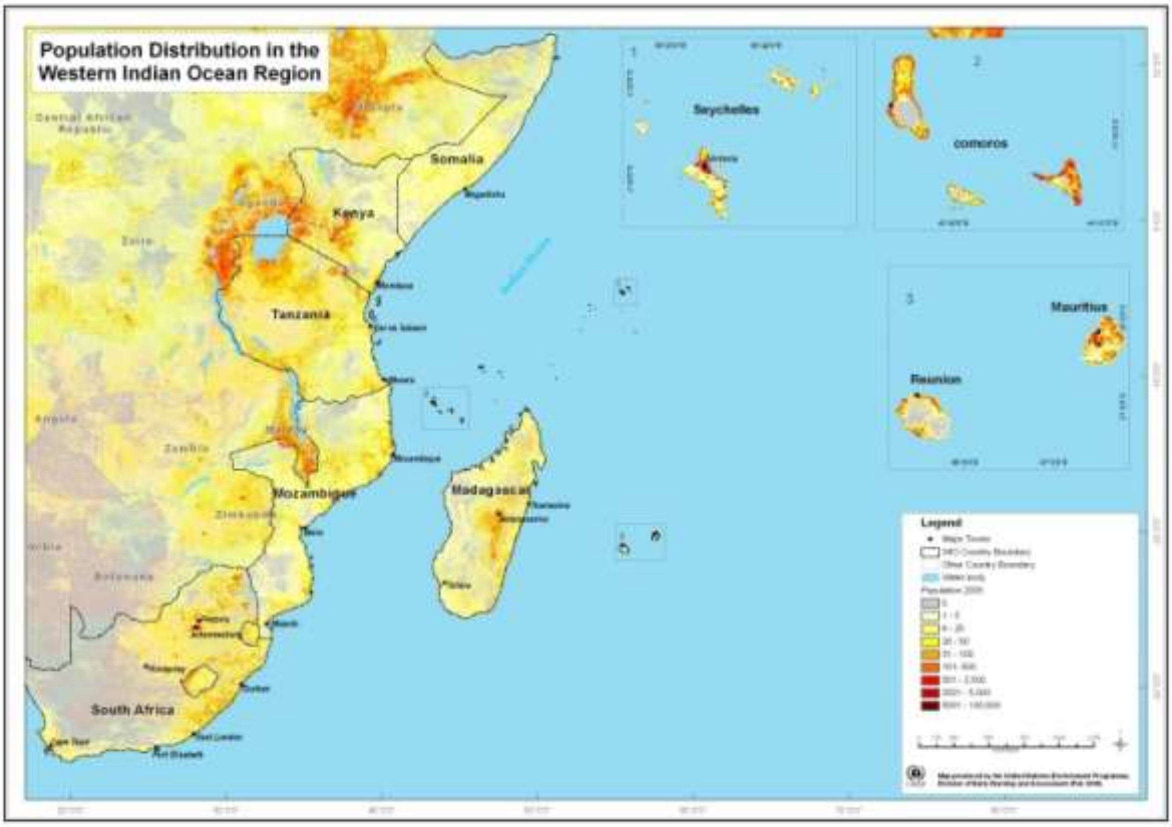


Figure 1-27: The distribution of population densities in countries of the WIO region

Table 1-24: Land area, population size, life expectancy and GDP of the Western Indian Ocean countries.

Country	Area (km^2)[1]	Pop. (millions)[2]	% Coastal pop. (<25km)	GDP 2007 (US$ billions)[4]	GNI Per Capita (US$)	HDI[5] 2005	Pop. growth rate[2]	Life expectancy[2]
Comoros	2,170	0.758	100	0.45	1,150	0.561	2.0	63
Kenya	582,650	50.0	9.2	29.51	1,540	0.521	2.6	53
Madagascar	587,040	19.67	23.2	7.33	920	0.533	2.6	59
Mauritius	1,865	1.26	100	6.36	11,390	0.804	0.7	73
Mozambique	801,590	30.80	28.1	16.67	690	0.384	1.9	42
La Réunion (France)	2,517	0.76	100	4.6	6,000	-	1.4	74
Seychelles	455	0.09	100	0.73	15,450	0.843	0.5	72
Somalia	637,657	16.8	30.5	-	-	-	2.9	48
South Africa	1,219,912	61.14	23.4	277.6	9,560	0.674	0.4	51
Tanzania	883,749	50.00	12.00	16.18	1200	0.467	2.4	52
TOTALS		178.04	20.1					

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; National MEDA Reports, 2022.

The following sections provide details on the demographic features of the WIO countries:

Kenya – It is estimated that 4.33 million people in Kenya equivalent to 9.2% of the total population of 50 million people in Kenya, live within 25km of the coast (World Bank, 2009a; Kenya MEDA, 2022). Population size and density on the Kenyan coast varies from place to place with the highest population density being found in the urban centres such as Mombasa, Malindi, Kilifi, Kwale and Ukunda as a result of significant rural-urban migration. Mombasa is the largest urban centre with a population of 1.3 million people (Republic of Kenya, 2005; Kenya MEDA, 2022). Rapid population growth along the coast has been identified as one of the major threats to coastal and marine ecosystems due to increased demand for coastal natural resources including land, forests and water (Government of Kenya, 2007).

Madagascar - About 23% of the total population of 19.7 million people in Madagascar live within 25 km of the coast (World Bank, 2009a). Much of Madagascar is sparsely populated with an average density of about 34 persons per square kilometre. Although the majority of the population in the country still live in rural areas, an increasing proportion resides in the large cities such as Toamasina, Antananarivo, Nosy Be, Sambava, Manakara, Farafangana, Mahajanga and Tulear, most of which are located along the coast.

Mozambique – It is estimated that approximately 28.1% of the population in Mozambique lives within 25 km of the coast ((INE, 2017; .Mozambique MEDA, 2022). Compared to other WIO mainland countries, Mozambique has the highest percentage of population living within the coastal zone. The country is also experiencing rapid population growth with the population in 2021 being 30.8 million. The population growth rate in the country is about 2.3% per year although recent estimates place the growth rate at about 1.9% (INE, 2000; UNDP, 2007). The population density along the coast varies: Maputo city is the most densely populated with 2,026 persons per km^2.

Somalia – It is estimated that out of the total population of 16.8 million about 30.5% live within 25km of the coast (World Bank, 2009a). However, Kelleher and Everett (1998) and Hatziolos *et al.* (1994) estimated that about 1 million people live within the coastal zone in Somalia. This latter estimate appears more realistic as Somalis are nomads and have not traditionally being associated with the coast until only in the recent past.

South Africa – It is estimated that about 61.14 million people lived in South Africa of which about 24.46 million live within 100km of the coast. This is equivalent to about 40% of the total population in South Africa (South Africa MEDA, 2022). The coastal population density is 81 people per square kilometre. Cape Town has taken over as the largest city within South Africa's WIO region with a population of 3.433 million, pushing Durban into second (population 3.120 million) despite its thriving commercial and industrial sector that has resulted in an influx of people in search of jobs and a better quality of life.

Seychelles and Mascarene Islands - The entire population of about 2.2 milion people in the Small Island States of Seychelles, Comoros, Mauritius, and La Réunion live within 25 km of the coast (World Resources Institute, 2003) (see Table 3-1) (National MEDAs, 2022).

Tanzania – It is estimated that about 5.5 million people out of the total Tanzanian population of 50 million live within the 25 km coastal zone. The population living within the coastal zone is equivalent to about 12% of the total population in the country. Coastal population 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 a significant rural-to-urban migration, particularly to Zanzibar and Dar es Salaam (Mvungi, 2003). Dar es Salaam has the highest population growth rate of 4.3% per annum followed by Zanzibar with a population growth rate of 3% per annum (Mvungi, 2003).

4.16 Socio-economic activities

Most coastal communities in the WIO region depend on coastal and marine ecosystems and their associated natural resources for their livelihood. The main activities at the coast are usually fisheries, tourism, agriculture, industry, forestry, shipping and ports, mining, conservation (e.g. national parks and reserves), urbanization and infrastructure development. However, the level of development of marine industries[11] is relatively low in most countries in the region (Hoagland and Jin 2008). Clearly, this presents opportunities for improvement of the overall socio-economic development in the region, through diversification of marine and maritime activities and industries. More details on the various types and levels of economic activities in the 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.

4.16.2 Fishery resources

The WIO is characterised by low productivity that is estimated at 0.15 tonnes of fish per square kilometre. This is much lower as compared to the northwest Pacific Ocean and northeast Atlantic Ocean where productivities are 1.03 and 0.65 tonnes of fish per square kilometre, respectively. This is mostly attributed to the absence of large nutrient upwelling systems in the region but is possibly compounded by the under-reporting of catches (van der Elst *et al.*,2005). In 2006, the WIO yielded 4.5 million tonnes of fish which is equivalent to 4.8% of the total global fish catches (FAO 2009). Countries in the region were responsible for about 7.6% of the reported fish catches in the WIO although this could be a gross under-estimation due to under-reporting of fish catches in some of the countries (van der Elst *et al.*,2005).

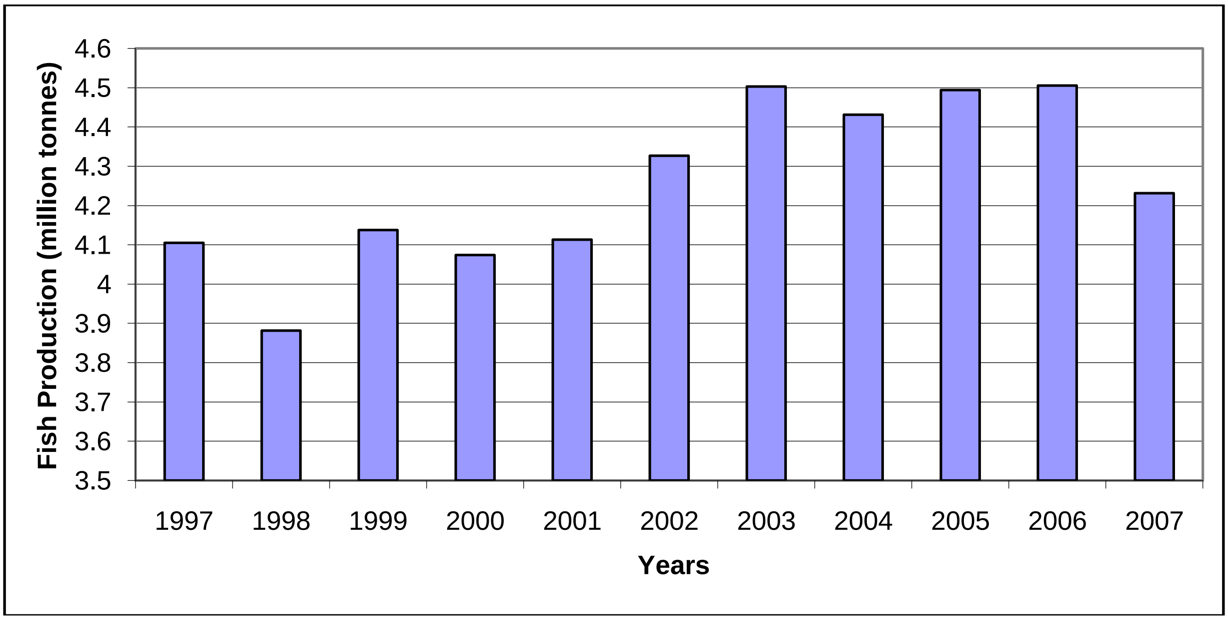


Figure 1-28: Total marine catch in the western Indian Ocean (Source: FAO Fisheries Statistics, 2009).

The livelihood of the 35.9 million people who inhabit the 25 km coastal zone in the region are intimately linked to coastal and marine ecosystems and their resources, with fisheries being especially important in terms of food security, employment creation and income generation. Approximately 2.7 million people in the region are thought to be engaged in full and part-time employment in the fisheries sector in the region generating wages of the order of US$ 366 million (Teh and Sumaila 2011; Sumaila 2011).

Fisheries statistics published by FAO indicate that marine fish captures in the WIO doubled in the period between 1997 and 2005 (FAO, 2007). There was a 41% increase in fish catches over the same period in most of the WIO countries (see Figure 1-28). Most of the increase in catches was attributed to a greater fishing effort directed at tuna particularly in Seychelles (SFA 2006). The reliability of the fisheries data is however a big problem in most countries in the region. While fisheries data for some

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

countries such as South Africa and Seychelles are reliable, those for other countries are less comprehensive. Fish catch records submitted to the FAO are often under-reported for both artisanal and industrial fishing sub-sectors. This is the situation for much of Mozambique, Tanzania, Kenya and Madagascar (van der Elst *et al.*,2005; Jacquet *et al* 2007, 2008). Consequently, use and interpretation of fisheries data should be undertaken with great caution. Despite these limitations, available data shows that annual fish catches in the region have largely levelled off in last 10 years, suggesting that fish production from wild stocks in the WIO may be approaching the 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 fisheries 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 region ranging from passive trap net fishing conducted at village level to extensive beach seine operations (Van der Elst *et al.*, 2005; WIOFish, 2008).

Table 1-25 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 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 to inshore waters. Examples include tuna, larger mackerel and sailfish. While much of the artisanal fishing is conducted using simple equipment with the catch primarily intended for own consumption or local market, others have graduated to more advanced fishing gear and use of boats with outboard engines. These small-scale fishers supply a wide range of domestic markets and some sell their catch to middle-men for export. Although individual daily catches per artisanal fishers are no more than a few kilograms, the cumulatively, the total fish catch landed by a large number of artisanal fishers is considerable (van der Elst *et al*, 2005). In the case of Tanzania, Kenya, Comoros and Madagascar, fish landed by artisanal fishers accounts for more than 80% of their countries' total marine catches. Artisanal harvests are not confined to finfish, but includes modest catches 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 or for export markets in small quantities. In some countries, especially in Kenya and Mauritius, live capture of ornamental species including collection of ornamental shells for trade in tourist areas and export is a significant activity.

Table 1-25: An overview of selected artisanal fishing statistics per country.

Country	**No. artisanal fishers**	**Artisanal catch (t/yr)**	**Principal fish families**
Comoros [1]	8,000	14,115	Scombridae, Gempylidae, Decapterus
Kenya [3]	13,400	7,774	Lethrinidae, Siganidae, Scaridae, Lutjanidae, Serranidae, Scombridae, Caranx, Penaeidae.
Madagascar [4]	80,000	25,000	Mugilidae, Serranidae, Carangidae, Gerridae, Hemiramphidae, Elopidae
Mauritius [5]	2,300	640	Lethrinidae, Mugilidae, Siganidae, Acanthuridae, Scaridae.
Mozambique [6]	260,000	120,000	Siganidae, Monacanthidae, Labridae
Réunion (France) [2]	900	866	Scombridae, Sparidae
Seychelles [7]	1,800	4500	Carangidae, Sphyraenidae, Scombridae, Siganidae, Serranidae, Scaridae
Somalia [8]	4,200	8,000	Lobsters, Sharks

South Africa (KwaZulu Natal only) [9]	5,183	2,153	Mugilidae, Carangidae, Ambasidae, Scombridae, Leiognathidae, Gerridae,
Tanzania (Zanzibar) [10]	49,332	30,000	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; Republic of Kenya-Ministry Agriculture Livestock and Fisheries, 2016; Tanzania MEDA, 2022; Kenya MEDA, 2022; Mozambique MEDA, 2022.

All counties identified overexploitation of fisheries resources as a threat to the sustainability of the sector and the livelihoods of coastal communities that depend on it. Increasing pressure is being placed upon fisheries resources in the region due to lack of alternative income generating activities, use of destructive fishing techniques, weak law enforcement capacity and rapid population growth and expansion. Many coastal communities also rely on the sector for food security, which leads to overdependence on fisheries resources. Data from most countries in the region shows that fish catch rates have declined significantly in the recent years (Kaunda-Arara *et al.* 2003, Ochiewo 2011, Soondron 2011).

Weak governance of the fisheries sector has made enforcement of laws and regulations difficult. This has resulted in limited fisheries data being produced in some of the countries particularly in Madagascar, Mozambique, Somalia and Kenya. Without data on fisheries coupled with weak enforcement of legislation, it is difficult to manage overfishing in the region. Recent work, undertaken by the University of British Columbia, revealed severe under-reporting in official fisheries statistics of large fish catches by small-scale fishers in the region (Le Manach *et al.* 2011 and Jacquet *et al.*, 2010).

Lack of infrastructure has also resulted in negative impacts on the fisheries sector in the region. For example, poor storage facilities continues to result in extensive post-harvest losses in Madagascar and Tanzania, while weak post-harvest and processing activities limits the sector in South Africa, Mozambique, Tanzania and Somalia. Poor infrastructure has also hindered the marketability and commercialization of fisheries products from the sector.

Access to finance also constrains development of the sector. For example, lack of access to credit and capital has constrained commercial development in Tanzania, Mozambique, Mauritius, Madagascar and Comoros (Sobo 2011, Pereira 2011, Soondron 2011, Andrianaivojaona 2011, Youssouf 2011). High investment costs have also been cited as being problematic in the sector in Seychelles, while a dependence on external finance has been identified as a weakness in Tanzania. Many countries in the region have, however, taken steps to mitigate these financial limitations. For example, in Kenya private-sector investments in fish processing has opened up opportunities for small-scale fishers to venture into non-traditional fishing grounds such as North Kenya Banks and also strengthened value chain links (Kenya MEDA, 2022). Also, a local bank has developed a credit program for the sector, which allows fishers to upgrade their fishing equipment. In Mauritius and Seychelles, the provision of soft-term credit and duty concession by the government has increased productivity in the sector. This is allowing small-scale fishers to upgrade equipment and access new fishing grounds (Soondron 2011, Lucas 2011). In Comoros, the government has reinvested revenue accrued from the large-scale industrial sector into the small-scale sector, which has not only facilitated the development of a cold chain and fisher training programs, but has also allowed the sector to grow and benefit from the industrial fishery (Youssouf 2011). Thus, in many cases, the provision of microfinance and duty concessions has been instrumental in not only allowing the sector to upgrade equipment and increase production, but has also given the sector the opportunity to become more competitive.

The advancement of co-management systems across the region is also a positive initiative in the region. For example, in Kenya, the government's Oceans and Fisheries Policy, along with its new co-management programs, have led to improved compliance in licensing requirements in coastal communities (Ochiewo 2011). In Mozambique, co-management committees have integrated local chiefs from fishing villages into the administrative process as a means of sustaining traditional management techniques. In Tanzania, oversight and planning is gradually being decentralized to the community level through Beach Management Units (BMUs) and Collaborative Fisheries Management Areas (CFMAs) (Afonso 2006, Sobo 2004). One of the success stories in fisheries co-management is in the case of KwaZulu Natal in South Africa, and lessons from this and other successful initiatives need to be analyzed and used to inform best practice for the region (Napier *et al.* 2005). Nevertheless, it is clear that any co-management system requires advancements in capacity at the local level, which is lacking in many of the countries in the region. The building of this capacity requires serious commitment and allocation of resources from government and civil society.

There are a number of opportunities that countries in the region can be take advantage of to expand their fisheries sectors. For example, increased international demand for fishery products, as well as untapped niche markets, is an incentive to increase production, investment and exports in the sector. Similarly, opportunities for value-addition have been emphasized throughout the sector, which, if promoted in conjunction with strong marketing strategies, could be beneficial to the communities that depend on it, without further endangering the resource. Increasing returns for the small-scale fisheries does not necessary require production to be increased, but it rather implies more effective marketability of existing catches and value addition. Promoting alternative streams of income such as mariculture could also be fruitful, not only in terms of providing employment opportunities and reducing poverty, but also as a means of reducing overfishing in coastal communities. Thus, while obstacles are clearly prevalent in the sector in most countries in the region, there are a number of opportunities to mitigate many of the challenges highlighted. The following sections describe the salient features of the fishery sector in each of the WIO countries.

Comoros – The fisheries on all three of the islands are mainly artisanal, using pirogues and vedettes, some powered by outboard engines, hand-lines, gill-nets and traps. Being largely volcanic, with a limited continental shelf, many operators fish in deep water with lines for tuna, tuna-like species and oilfish (*Ruvettus ruvettus*), coincidentally also taking coelacanths (locally *Gombessa*) at times. Within the inshore areas, large shoals of scad (*Decapterus*) are an important target for fishers and a valuable source of food at local markets. The annual productivity per unit area in the Comoros fishing grounds is about 7 tonnes/km^2 which is higher than 5 tonnes/km^2 for highly productive coral reef (Williams, 1988). The total catch in 1985 was 5,500 tonnes, increasing to 9,134 tonnes in 1990 and 14,115 tonnes in 2003. The catch comprises 70% pelagic species, 10% shark and 5% reef species such as Lethrinidae. Limited reef fish resources are at or near their maximum level of full exploitation (Aboubacar, 1991; Talla *et al.*, 2004; FAO, 2007). However, pelagic stocks including tuna, are less impacted by local artisanal 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 for the local communities. However, some fisheries production is for export markets. It has been estimated that up to 30,000 tonnes of fish are landed every year from the Comorian EEZ. This is usually done 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).

Kenya – The small-scale fishery in Kenya is a major source of livelihood to the local population, employing over 13,400 fishers (Republic of Kenya; Ministry Agriculture Livestock and Fisheries, 2016). It has about 3,000 small scale fishing crafts which are dominated by dug-out canoes, small dhows, traditional wooden planked boats and outrigger canoes, of which less than 10% are motorized (Kenya MEDA, 2022). The small-scale fisheries mainly occur in inshore waters around coral reefs, mangrove creeks and seagrass beds (Degen et al., 2010; FAO, 2004; Hoorweg et al., 2009; Kimani & Okemwa, 2018; Ochiewo, 2004). Most of the fishing activities take place during the calmer Northeast monsoons. The small-scale fisheries supply over 80% of the country's total marine catch and a small fraction of the landed catch is retained by the fishers for their consumption while most of the catch is for sale (Degen et al., 2010). The marine fishery production in Kenya contributes 10% of the total fish production in the country (Kenya MEDA, 2022). Marine landings range from 4,763 to 7,774 tonnes per year although more realistic estimates for all 'inshore' landings are put at 12,000 tonnes (Sanders *et al*., 1990). Kenya's EEZ is known to include considerable tuna and tuna-like resources which are harvested by international fleets (IOTC, 2008). A total of two longliners operated under the Kenyan flag and 59 and 49 foreign longline licenses were issued in 2006 and 2007, respectively.

In the marine sector, the small-scale fisheries generate an estimated US$ 33 million per year out of US$ 46 million generated annually in the entire marine fisheries sector (Kimani & Okemwa, 2018). The small-scale fisheries support small-scale fishers, fish traders and processors, small scale boat builders and repairers, and fishing gear sellers and repairers, with an estimated 100,000 coastal residents depending on this sub-sector for their livelihood. The level of dependence on the small-scale fishery is higher in rural areas where alternative livelihoods are limited. Hence while the entire fisheries sector only contributes 0.5% to national GDP, it is a vital component of the economy of the coastal region of Kenya. The importance of fisheries as a livelihood is particularly pronounced in Lamu, Kilifi and Kwale Counties (Ochiewo et al., 2020).

After decades of growth, the artisanal fishery is now considered fully exploited in Kenya with over-fishing and intense fishing over coral reefs leading to 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 impacting on fish productivity and diversity. There are also conflicts between artisanal fishers and trawler operators in Ungwana Bay (KMFRI, 2002; King *et al.*, 2003). The high levels of by-catch, impact on turtles and general environmental threats posed by the trawl fisheries, prompted the government in 2006 to ban trawling within 3 nm of the coast, effectively closing the trawl fishery in the Bay (Fulanda and Munga, 2006). The conflict of resource-use in Ungwana Bay has been aggravated by lack of a management strategy for the Ungwana Bay fisheries. Kenya fisheries also has a strong recreational element, mostly targeting yellowfin tuna, sailfish, marlins and swordfishes.

Madagascar – Madagascar 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 supplying high quality shrimp directly to large processing plants. Shrimp fishing is seasonal taking place 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 – Mauritius has a considerable diversity of fisheries 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). There has been a significant decline in catches from 1,302 tonnes in 2002 to 640 tonnes in 2007. The decline in total catches has in part been attributed to a decline in effort by artisanal fishers.

The banks handline fishery involves 7 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 contributes 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 due to dredging and siltation of the lagoon systems. Initiatives are underway to create artificial reefs to 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 which forms the basis of a local tuna processing industry and also supports as an important tuna trans-shipment port since 1960s (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 2005after licences were issued to six operators. The total catch in 2006 and 2007 were 414.5 tonnes and 620 tonnes, respectively (MAIFDS, 2007). Species harvested are mainly *Actinopyga echinites* (brownfish), *Actinopyga mauritiana* (surf redfish), *Bohadschia marmorata* (brown sandfish), *Stichopus chloronatus* (green fish), S*tichopus variegatus* (curry fish), *Holothuria scabra* (sandfish) and *Holothuria nobilis* (black teatfish).

Mozambique - The fishing industry is traditionally one of the largest foreign exchange earners in Mozambique. The export of shrimp from Sofala Bank contributes about 40% to the foreign revenue generated in the late 1990s (FAO, 1997). The contribution made by fish, including shrimp, has however declined substantially in recent years, in part due 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 contributes significantly to overall landings, artisanal fisheries provide livelihoods for more than 260,000 fishers, while also providing food to a large section of the population in the country (Mozambique MEDA, 2022). 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 fishing gear types. Although extensive data collecting systems are in place, the historic data of artisanal landings are considerably under-reported (Baloi *et al*., 1998; 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). A new linefish management plan will 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 – Réunion has three main fisheries-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 in length 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 are Japan, 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 valued at approximately US$ 13 million is derived from small-scale artisanal fisheries activities, of which a large part is sold locally.

Seychelles – Seychelles fishery sector is one of two major foreign exchange earners, along with tourism. It is comprised of industrial, semi-industrial and artisanal fisheries. In 2005, Seychelles earned US$ 192 million from tuna exports, equivalent to 41% of total export value for that year derived mainly from the industrial fishery (FAO, 2007b). 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). Over the last decade, there has been considerable decline in the annual catch of the artisanal fishery. In 2017, the total catch for the artisanal fishery was 4,211 tonnes (Seychelles MEDA, 2022). Over the years, the *Carangoides spp.* remain the most dominant species group. The main threats to this fishery are high level of exploitation, coral bleaching, habitat loss and overcapacity in the fishery. 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 m 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” - 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 – Somalia has one of Africa’s longest coastlines (3,200 km) and one the region’s richest fishing grounds driven by seasonal upwelling off the Horn of Africa. Traditionally, Somalia is 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 due to a variety of reasons, these fisheries and their infrastructure failed. Considerable tuna harvests are made in the Somali EEZ by foreign operators and are mostly offloaded in Seychelles. However, piracy has curtailed tuna fishing significantly (IOTC, 2008).

Acoustic research surveys in the mid 1970s estimated fisheries potential with a maximum of 300,000 tonnes per annum, about half of which are small pelagics. An estimated 4,200 artisanal fishers target diverse resources in Somalia (Hatziolos *et al.*, 1994; Lovatelli, 1995). Artisanal fishing at Bosasa, Berbera, Eyl and Zeila land no more than 4,000 to 8,000 tonnes of finfish per year for the 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. 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 recognised government administration and are thus not recognised by different communities along the coast. Unfortunately, Somali fisheries data are sparse and unreliable due to many years of civil strife in the country.

South Africa – South Africa's Indian Ocean fisheries 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 to reflect progressive change within the management structures as well as changes in international fisheries management 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. 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 (combined for anchovy and pilchard) approximating 697,766 tonnes (Fishing Industry Handbook, 2007). 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 in South Africans depend on coastal food sources through subsistence activities that are 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 –In Mainland Tanzania, the marine fisheries support about 53,000 artisanal fishermen operating about 9,200 fishing vessels and landing an average of 60,976 tonnes of fish annually (Ministry of Livestock and Fisheries 2019). In Zanzibar, artisanal fisheries employ 49,332 fishers who land 30,000 tonnes of fish per year (Department of Fisheries Development 2017). The main groups of fish that dominate marine catches in Tanzania are demersal fish species such as bream, grouper, parrot fish, snapper, rabbit fish, emperor, sharks and rays. These are caught using hand lines, traps and nets. The small pelagics consist primarily of sardines, small tuna and mackerel. These are caught mainly using purse seine nets or ring nets. Large pelagics such as kingfish, tuna, sailfish and marlin are caught by surface gill nets and trolling lines (Jiddawi and Stanley, 1999; Tanzania MEDA, 2022). Over 95% of the catch is attributed to small-scale artisanal fishing using primitive crafts and gears (Tanzania MEDA, 2022). The coral reefs of Tanzania support 70% of the total marine artisanal catches (Ngoile and Horrill, 1993). In addition, shrimp exports are an important source of foreign exchange in the country. The trawling companies operate as joint ventures between Tanzanian and foreign companies (TCMP, 2001), and combined with the artisanal contribution, the shrimp export fishery is worth over US$ 6 million annually.

Along much of the Tanzania coast, the collection and fishing of marine products is not restricted and there is little monitoring and control of the artisanal fishery. Some species of sea shells and sea cucumbers are now over-exploited due to high demand for the export market (Marshall *et al.,* 2001*)*. There have been few population studies of commercially exploited species; however fish sizes have reduced tremendously. Shark fin trade has also declined and some fish species are rarely seen in Tanzania waters today (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 massive fractured framework of coral colonies, craters and rubble patterns, exacerbated by anchoring techniques employed by artisanal fishers. These have reduced the recruitment rate of many species (Francis *et al*., 2002).

Problems related to fisheries in the WIO region

The artisanal fisheries in all of WIO countries experience similar problems and challenges. Lack of management plans, failure to implement management plans, inadequate scientific information and absence of monitoring, all pose long-term threats to the fisheries (van der Elst *et al*., 2005; WIOFish, 2008). Improved management is needed across the entire coastal fisheries sector in much of the region. It is estimated that 54% of the artisanal fisheries in the region is now fully- or over-exploited with limited possibility for additional growth (SWIOFC, 2006). Some of the problems facing the fisheries industry in WIO region include the following:

- 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 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.

4.16.3 Mariculture

The WIO is 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 these are providing valuable contributions to local economies. The rate of growth of mariculture in the WIO region has however been slow. Mariculture comprises different categories, ranging from intensive pond culture to extensive culture using cages, rafts or impounding larger natural areas. The status of mariculture in each of the WIO countries is provided in the following section based on the details provided in the national MEDAs:

Kenya: Mariculture in Kenya was introduced over three decades ago (Deutsch et al., 2011), to provide economic opportunities to coastal communities and bring about development in the rural coastal areas (Mirera & Ngugi, 2009; Ochiewo et al., 2020). Mariculture was also initiated in Kenya through research, development and conservation projects to address the widespread poverty and livelihood needs with varying degrees of successes and failures (Mwaluma, 2002; Mirera & Samoilys, 2008; Mirera, 2011; Munguti et al., 2014). The main culture species in mariculture in Kenya include milk fish, mullets, mud crabs, seaweeds, oyster and prawns (Mirera, 2014; Mwaluma, 2002; Ochiewo et al., 2020; Wakibia et al., 2011). The mariculture projects involve production systems operated by self-help groups that consist mainly of female farmers because the males are engaged in artisanal fishing (Mirera & Ngugi, 2009). Prawn culture in Kenya began in the mid-1980s at Ngomeni in Kilifi County with large scale demonstration ponds established with the support of the Food and Agriculture Organization of the United Nations (FAO) (Balarin, 1985; O. D. Mirera, 2011; Munguti et al., 2014; Ochiewo et al., 2020; Rönnbäck et al., 2002). Mud crab fattening was later introduced in the coast of Kenya in the late 1990s as a strategy to support mangrove conservation, and provide food and income to the local communities (Mirera, 2009, 2011, 2014; Naylor et al., 2000). Seaweed farming was established on an experimental scale in the early 2000s in the south coast of Kenya with *Eucheuma denticulatum* and *Kappaphycus alvarezii* being the main commercial species farmed. Seaweed farming is mainly carried out by women and employs about 100-400 farmers (Wakibia et al., 2011). Unfortunately, some of the major mariculture projects such as the prawn culture at Ngomeni and oyster farming at Gazi Bay collapsed (Balarin, 1985; Munguti et al., 2014; Ochiewo et al., 2020), while other mariculture projects such as mud crab farming that began in the late 1990s have stagnated at small scale for many years (Mirera, 2011). In the year 2009, the Government of Kenya initiated an Economic Stimulus Programme to establish a vibrant aquaculture industry but the Stimulus Programme did not cover mariculture because it focused on freshwater aquaculture (Munguti et al., 2014). Challenges to mariculture include theft, conflict with other coastal users, poor training lack of financial support, poor pond quality and the seasonal availability of fingerlings. Issues of land tenure are also constraining the development of community based mariculture initiatives. Environmental issues have also been reported, with the destruction of mangrove habitats being witnessed in prawn farming.

Mozambique:
The main marine species farmed in Mozambique are native and include black tiger prawn (*Penaeus monodon),* Indian white prawn *(P. indiscus, P. japonicus, Fenero penaeus indicus),* pink prawn *(Macrobrachium monocerosi*), Kuruma prawn (*Modiolusphilippinarum*), bivalves, (*Pernaperna, Meretrixmeretris, Modiolousphilippinarum, Eumarciapau perculata, Sacrostreacucullata, Cassostreagigas, Veneruspis Japonica)* and mud crab *(Scylla serrata*). The exotics species farmed are seaweeds (*Kappaphycus alvarezii* and *Eucheuma spinosum* the red algae) (Ministry of Fisheries 2006). The exotic seaweed species were introduced from Zanzibar, Tanzania in the late 1990s (FAO 2009). Exotic seaweeds are farmed in Northern Mozambique (Cabo Delgado and Nampula Provinces) in a system of poles installed in shallow inshore areas. In 2008 the total production of seaweed was about 70 tonnes (INAQUA 2008). There is a legislation that regulates all rights and obligations of all stakeholders in the mariculture sector. The legislation defines specific norms and requisites for

aquaculture farms and establishes restrictions on the import of live animals and the conversion of mangrove wetlands into aquaculture ponds and also establishes other environmental and consumers protection measures (Mozambique MEDA, 2022).

South Africa: Medium and large-scale mariculture activity is well established in South Africa, with commercial farming prevalent in abalone, seaweed, mussels and oysters. Pilot commercial projects are underway for dusky kob, silver kob and yellowtail finfish (South Africa MEDA, 2022). Research is also ongoing for the production of clownfish, white margined sole, west and east coast rock lobster, scallop and blood worm. The largest marine aquaculture subsector in South Africa is abalone (*Haliotis midae*), which occurs in the Western Cape with the majority of farms situated in the Overberg region. Small-scale production is however, scarce in the country as most projects are being developed by the private-sector with an emphasis on pump ashore systems. This lack of small-scale production has been attributed to several factors including poor environmental conditions, inadequate participatory approaches, poor fish growth, very low returns, lack of interest and neglect. Medium and large-scale farms are, nevertheless, providing employment outside urban areas, particularly in the Eastern and Western Cape. The strengths and opportunities in mariculture that can be capitalized on in the future include good infrastructure, technical expertise in the country's universities, training in aquaculture at the tertiary level and suitable climate that all highlight the positives that could be utilized to develop the sector in South Africa.

Mauritius:
Mauritius formulated Aquaculture Master Plan in 2007 to showcase Mauritius as a base for marine aquaculture. Thirty one fish farming zones have been proclaimed around Mauritius. Only one mariculture farm is active on Mauritius Island, with cage culture being utilized to presently produce european sea bass *(Dicentrarchus labrax)*, red drum *(Sciaenops ocellatus)* and dusky kob *(Argyrosomus japonicus)* in Mahebourg. The farm production is intended both for domestic consumption and export. The farm produces around 3,000 tonnes of the three different species of fishes and employs more than 100 persons. Seaweed culture of *Gracilaria salicornia* has been tried at Grand Sable, Albion and Vieux Grand Port in Mauritius as well as at Petite Butte, Jean Tac and Baie du Nord in Rodrigues with the support of the Mauritius Research and Innovation Council. In the Southern Region of Rodrigues at Petite Butte, a group of women entrepreneurs are currently carrying out seaweed farming of *Gracilaria salicornia* with a small scale production over an extent 200 m^2. The seaweed is used in the agro-processing industry, including for the production of pickles mostly for the local market as well as for export to Mauritius. Despite the support of the Government of Mauritius, there are some constraints in the mariculture sector such as high investment requirements; limited space in lagoons; conflicting use with the tourism industry, fishermen community and for recreation use by the local population; and lastly limited availability of land-based facilities. The high production cost compared to relatively low priced imported products compete with locally potentially aquacultured products (Mauritius MEDA, 2022).

Although mariculture has great potential throughout the WIO, constraints such as weak infrastructure, limited research capacity and a lack of finance and environmental degradation need to be overcome to ensure further development in the sector. Limited research capacity has been a sectoral constraint across many countries in the region. Finance and in some cases private-sector involvement has also been problematic in the sector. Private-sector involvement is also limited in most of the WIO countries. Environmental issues, particularly with regard to sustainability and biosecurity, have also been raised around the mariculture sector throughout the region (Andrew *et al.* 2011). However, governments throughout the region appear to be committed to developing the mariculture sector as a means of promoting alternative streams of income.

Overall, the Western Indian Ocean region clearly has the natural assets with which to further pursue the development of the mariculture sector. Growth in the sector will however require upgrading of capacity including infrastructure, research, finance and governance, and enhanced sensitivity to environmental impacts. These improvements are likely to be worthwhile considering the impact the sector could have in terms of mitigating the over-exploitation of coastal resources and providing coastal communities with employment opportunities and income. Thus, while a dependence on international donors and NGOs for technical and financial support is not necessarily sustainable in the long-term, with backing from the private sector, it is possible for mariculture to further develop throughout the WIO region in the near future.

4.16.4 Tourism

Tourism sector is important in the WIO region in view of the fact that the region is endowed with good climate, beautiful sandy beaches, clear tropical seas and a rich biological and cultural diversity. 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 (UNEP, 2006)[12]. Tourism is also a vital sector through which to create less resource-intensive streams of income and subsequently reduce the pressure being placed on coastal resources (Andrew *et al.* 2011). Tourist arrivals in the WIO region, their average length of stay and total spending vary enormously between countries (see Table 1-26). 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 (Figure 1-29).

Table 1-26: 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	2,000	8.7	1,000	500
Madagascar	170	21	115	677
Mauritius	1,384	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; Kenya National MEDA, 2022.

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 the WIO region.

Tourism is also highly vulnerable to the global economic situations. Usually, in times of crisis, tourist numbers decline considerably as was the case during 2008-2009 economic recession period. Other factors, such as natural disasters also have an important effect, such as for example the outbreak of Chickungunia disease in 2006 which had profound effects on tourism in Mauritius and Réunion[13]. The Covid-19 pandemic in 2020-2022 had devastating impact on tourism in all countries in the WIO region.

[12] 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.

[13] 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.

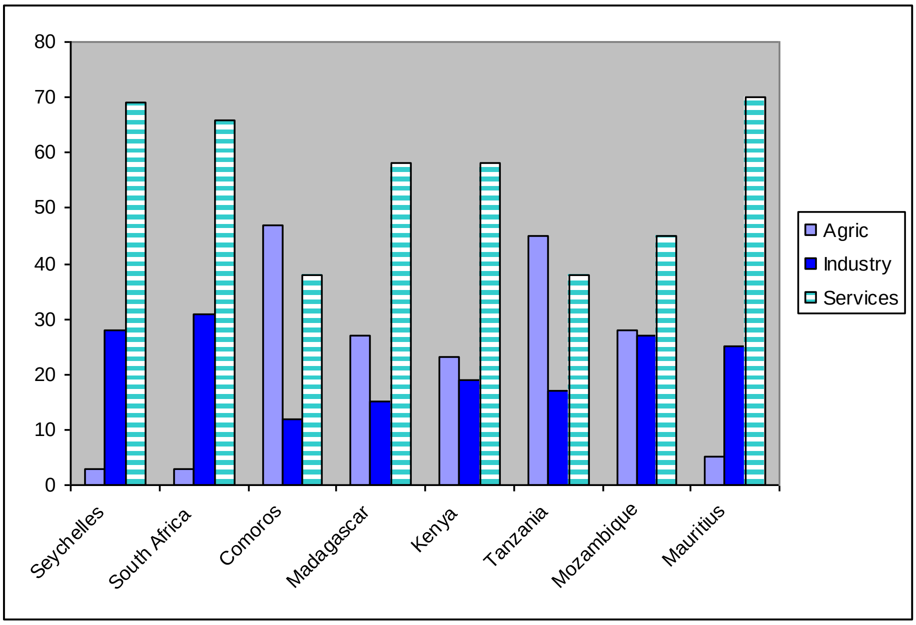


Figure 1-29: Relative percent contribution made by different sectors to the GDP of WIO countries in 2007 (World Bank, 2009a).

The contribution of tourism must however be viewed in the light of extensive revenue leakages prevalent in the region. It is also estimated that leakages in the tourism are more than 85%. Such leakages are often due to the fact that companies from industrialized countries tend to dominate the tourism market through control of knowledge about the market and control of the means of distribution, which results in many cases, in the host country only providing the infrastructure and social foundation in the sector. This reduces both the amount of revenue and employment that could have otherwise been gained by the host country.

There appears to be a great dependence on the European tourist market throughout the region. For example, Europe accounts for over 76% of total visitors to Seychelles, while 31.6% of all arrivals to Mauritius in 2009 came from France alone (NSB 2010, Picard 2011). Similarly, in Madagascar, France represents nearly 70% of total arrivals, while Europe accounted for over R16.7 billion of total tourism revenue in 2008 in South Africa (Rajeriarison and Picard 2011, SATOUR 2008).

Environmental degradation has been highlighted as a key issue in the tourism sector throughout the region. Most tourist activities are directly dependent on the natural beauty of the respective countries, and therefore degradation of the coastal and marine environment has a negative impact on the sector. In response, ecotourism has become a means through which to not only enhance and diversify the product, but also facilitate the protection of the region's environmental assets.

The following section provides further details on the status of tourism in the WIO countries.

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 the country receives 20,000 tourists annually (UNEP/GPA and WIOMSA, 2004a and b), contributing about 9.1% to the GNP and employing about 500 people in direct and indirect activities[14]. 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 area most frequented by tourists are the beaches of northern Grande Comoros, plus the beaches of Chomoni and Bouni, the salt lake and Turtle Island,

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

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; (Government of Kenya, 2009).). 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 Old Towns in Mombasa and Lamu. The main tourist sites are the coastal areas immediately south (Diani beach) and north of Mombasa including Watamu, Malindi and Lamu (Republic of Kenya, 2005). These sites are associated with the well-established marine park network managed by the Kenya Wildlife Service. The sector has been strong with tourist arrivals increasing from 814,000 in 1990 to over 2 million in 2007. The revenue from the sector increased from US$864 million to US$ 1 billion in the period between 2006 and 2007, representing a growth rate of 11.6% (Kenya MEDA, 2022). More than half of the tourism revenue is generated from coastal tourism where over 500,000 people work in the sector directly or indirectly. Since the disputed election of 2007, the number of tourism travelling to Kenya have declined by more than 40% (World Bank, 2009b). Situation has been made worse by economic recession and covid-19 pandemic which has led to near collapse of the sector in Kenya.

Madagascar – Madagascar has large tourism potential due to its unique assemblage of biodiversity which is second to none 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. There are numerous coastal tourist destinations such as Cape d'Ambre, Nosy Be, Tulear and Anakao, Diego Suarez. The country receives over 80,000 tourists every year. Revenues from this sector were US$ 91 million and US$ 119 million in 1998 and 2000, respectively. Tourism contributes about 2% of the GNP (UNEP/GPA and WIOMSA, 2004b). The main factors limiting tourism in Madagascar include extreme climatic events (cyclones), social unrests and political instability.

Mauritius – Mauritius has a well developed tourism sector whose success is largely attributed to the exceptional natural coastal assets linked to the development of high-end hotels and resorts along the coast. The country received 1,383 488 tourists in 2019. The tourism sector contributes between 8.1% of the GDP and employed 31,239 people in 2019. Mauritius is planning to further develop new resort complexes near the coast targeting 2 million tourist arrivals per annum (Central Statistics Office, Mauritius, 2007). The COVID-19 pandemic and the subsequent closure of the borders both locally and internationally have placed a heavy toll on the Mauritian tourism sector. The number of tourist arrivals for the first semester of 2020 decreased by 53.1% to reach 304,881 as compared to 650,082 tourist arrivals for the first semester of 2019. The COVID-19 pandemic has brought tourism and nautical recreational activities in Mauritius to a standstill and has had a significant negative impact on coastal communities who rely on tourism and other ocean-based activities for their livelihood (Mauritius MEDA, 2022).

Mozambique - Mozambique has many excellent natural and cultural resources that have the potential to serve as world-class tourist attractions. These include beautiful beaches, rich mangrove-fringed 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, the country received 136,000 tourists and the number increased to 470,000 in 2005 (UNWTO, 2006). The tourist sector created approximately 32,000 jobs in 2013 (MITUR, 2013). 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 game-fishing and diving being prominent.

Réunion – Tourism on the island is dominated by visitors from France. The island receives 342,000 tourists, 80% of which came from France 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 that offer 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 people and generates an annual income of around US$ 500 million which is equivalent to 3-4% of the GDP.

Seychelles – Tourism sector is well developed and is central to the Seychelles economy. The natural beauty of the islands as well as the unique creole culture has attracted visitors from all over the world. It's contribution is particularly important in terms of foreign exchange earnings, stimulation of economic activity, generation of income through linkages with other sectors, employment creation, government revenue and the preservation of natural and cultural heritage. Tourism is concentrated on Mahé Island and the nearby granitic islands of La Digue and Praslin. Seychelles offers excellent natural history, avifauna and geological features. More than 50% of all terrestrial areas are gazetted protected areas and many are linked to marine areas. Seychelles has successfully tapped on high-value tourism and there are plans to turn the country into a "3-5 star destination" (Gössling, 2006; Gössling and Horstmeier, 2003).

The number of tourist arrivals in Seychelles grew 2.7 times in the period from 2000 to 2017 to reach 349,861 visitors in 2017. In 2019, there were 384,204 tourists. The direct contribution of tourism to gross domestic product (GDP) increased steadily from 16.3% in 2004 to 21% in 2019. The World Tourism and Travel Council (WTTC) estimated that the direct contribution of tourism to GDP in Seychelles will increase by 2.9% per annum in the period 2018-2028. Gross total earnings from international tourism were US$559 million in 2018 and US$590 million in 2019. Tourism sector contributes 60% of foreign exchange earnings in the country (Shah, 2002). The tourism industry also provides employment to 5,000 people (UNEP/GPA and WIOMSA, 2004b). In 2019, tourism performance was driven by strong growth from traditional European markets, whereas the number of visitors from the main emerging markets such as China and South Africa declined, reflecting a continuation of trends observed in 2018 (CBS, 2020). 70% of the total visitor arrivals came from Europe. Visitor arrivals from United Arab Emirates, South Africa and China amounted to 6%, 3% and 2% of the total visitor arrivals respectively. The average length of stay way 9.9 days

South Africa – In 2018, tourism contributed 3% (R130.1 Billion) to GDP, making it the third largest contributor to GDP and the fourth largest source of foreign exchange. Tourism accounted for 4.5% employment in South Africa[15], making it a vital sector in the country's economy. The distribution of tourists by region of residence shows that 74.8% of the tourists who arrived in South Africa in 2020 were residents of the Southern African Development Community (SADC) countries and 1.5% were from 'other' African countries. Residents of overseas countries made up 23.6% of the tourists. Tourism is also one of South Africa's fastest growing sectors. Between 1995 and 2017, international tourist arrivals to South Africa more than doubled from around 4.5 million to over 10 million and over the same period, employment directly related to tourism tripled reaching 4.5% of total employment in 2017 (OECD, 2020)[16.] Domestic tourism is also vibrant, generating R16 billion annually, making up 67% of all activity in the sector. Provincially, Gauteng and Western Cape are the most frequented destinations for foreign travellers, while KwaZulu Natal is the largest beneficiary in the domestic market. The outbreak of the COVID-19 pandemic had a significant impact on the South African tourism industry. Lockdown measures to combat the spread of COVID -19 resulted in tourism numbers dropping drastically. According to the Tourism, 2020 report by Statistics South Africa, foreign arrivals dropped by 71% from just over 15.8 million in 2019 to less than 5 million in 2020. The overall number of travellers decreased by 50.7% over a 15-year period from nearly 24.6 million

[15] http://www.statssa.gov.za/publications/Report-04-05-07/Report-04-05-072018.pd

[16] OECD (2020), OECD Tourism Trends and Policies 2020, OECD Publishing, Paris, https://doi.org/10.1787/6b47b985-en

recorded in 2006 to 12.1 million travellers recorded in 2020. While growth in tourist activity has been rapid, numerous challenges are still prevalent in the sector. For example, the seasonal-based fluctuations in activity, along with the over-dependence on tourism as a means of promoting economic development, particularly in coastal communities, has clearly become problematic. Similarly, weak capacity at the provincial and municipal level has made local governments ineffective in promoting further development, while community tourism still remains a supply-driven industry with lack of value chain distributions within community structures (South Africa MEDA, 2022).

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 has taken place in Zanzibar island of Unguja, with modest development in Pemba and Mafia Islands. Furthermore, since the 1990s, tourism has expanded 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 in WIO tourism

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, high cost of visas and long time taken to process passports, puts off most tourists.

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 local 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 that tourism can have significant impacts on the environment. Waste management, water abstraction, physical destruction and modification of habitats and other issues, pose challenges for sustainable tourism. Climate change is also a matter of concern that requires carful consideration as they can affect tourism activities in a country. For instance, changes in rainfall patterns, coastal erosion and coral bleaching can discourage tourists from visiting a country. Thus, while tourism does provide significant potential for economic development of most of the countries in the WIO region, this will not succeed without careful and integrated planning involving effective governance and participation of key stakeholders in the industry.

4.16.5 Industry

WIO region is not well industrialised despite considerable mineral resources, availability of raw materials, favourable climate and established shipping routes. The level of industrial development in most of the WIO countries is relatively low. The low level of industrial development has been attributed to low domestic demand for industrial goods, isolation from complex industrial markets, lack of technological infrastructure and innovations and lack of affordable sources of energy. Political instability has also hindered industrial development, especially since stable governance is a prerequisite for sustained direct foreign investment - a major requirement for most of the industrial development projects. As globalization strengthens, and access to foreign markets improves, opportunities for industrial development in the WIO will emerge. 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 of industrial sector to the GDP of WIO countries varies substantially (World Bank, 2009a). The services sector in which tourism is included accounts for about 58% of GDP for the WIO countries, followed evenly by industry (22%) and agriculture (23%). Where industrial development has taken place in the coastal zone of WIO countries, this is largely through output of primary products linked to agriculture, forestry, 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 in Europe, America and Asia. 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.

There has been limited expansion of the industrial sector in most countries in the WIO region. Between 2000 and 2006, sector's contribution to the GDP increased by only 2% in most countries. In some countries, there was even a significant decline of the industrial sector. For instance, the industrial sector in Mauritius declined by almost 20% in the period 2000-2006. The following section provides details on the status of industrial development in each of the WIO countries.

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 I the Comoros. 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 has been the focus of coastal industries, many associated with export and trade. Over the last six years, the coast has experienced a rapid increase in industrial development due in part to the incentive to exploit the United States 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 also takes place within coastal areas. 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 a poor country, largely due to decades of economic mismanagement (World Bank, 2009a). High population growths continue to limit economic development. Climatic change impacts such as frequent cyclones, alternating heavy rains and droughts further limit development in the country. 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 has 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 that produced 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 growth of the sugar industry. The manufacturing sector which is 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 from Asian textile manufacturing industries, is placing increasing pressure on this traditional sector. Nevertheless, these industrial activities contribute to the economy of Mauritius which has 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 increased by 27.4% in the period 2000 to 2006. 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 pipeline to South Africa have all strengthened industrial development in the country. Increasingly, port cities of Beira and Pemba have also witnessed growth in the industrial sector. Heavy industries in the country include production of non-metallic minerals, chemical industries, basic metallurgical industries, building materials industries, transport construction industry and fishing industry. The light Industries include those for sugar production, production of food stuffs and beverages, footwear and clothing production, tobacco, cotton ginning and sisal shredding (Mozambique MEDA, 2022).

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 large 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 – Industrial sector is not well developed and few industries in Seychelles 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 – KwaZulu-Natal has the second largest manufacturing sector in the country after Gauteng Province. The manufacturing sector is geared for export, with nearly a third of South Africa's manufactured exports being produced in KwaZulu-Natal. Manufacturing contributes significantly to provincial economic growth rate and generates 20% of provincial employment. The diverse industrial sector has developed around the port of Durban as well as agricultural and forestry. A number of industries have also been promoted by the development of Richards Bay, some of them based on the mineral resources in the province. The major industries in the province are sugar, forestry, aluminium, petro-chemicals, automotive manufacturing, steel production, plastics and packaging, paper and board manufacturing, and a range of industries associated with imports and exports through the two major ports of the Durban and Richards Bay. The largest manufacturing industries in the KwaZulu Natal region are the automobile and component sector, pulp and paper products, chemicals and petrochemicals, and food and beverages. The mining sector which includes titanium dioxide, zircon along with iron, steel and ferroalloys is also important. The vehicle-manufacturing industry has created a considerable multiplier effect in component and service providers. The automotive leather industry has grown rapidly, with exports significantly increasing foreign exchange earnings.

The Eastern Cape is best known for its automotive industry and its strong and varied agricultural sector. The established companies in the automotive industry (such as Volkswagen SA and Mercedes-Benz SA) have been making major investments in the automotive sector, and have been joined by two large Chinese concerns in recent years[17]. The mountainous regions of the north and east of the Eastern Cape Province support timber plantations while the coastal belt in the south-west is good for dairy farming. The province has a strong agricultural base and is the leading livestock province in terms of numbers and supplies a quarter of South Africa's milk. A key logistics factor is the large port at Ngqura, within the Industrial Development Zone (IDZ). The ports of Port Elizabeth and East London are well-established, with the latter breaking a record in April 2016 by handling 10,000 Mercedes-Benz vehicles for export in the month. The automotive industry provides 30% of the jobs in the province's manufacturing sector and accounts for 32% of gross added value.

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 hosted small to medium industries, especially those 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 located on land. Severe drought events and power shortages have limited industrial development to some extent (NEPAD, 2003). Nevertheless, the last decade has seen major improvements of industrial units driven by a stable economy and improved power supply, partly derived from the Songo Songo gas reserves.

Somalia-The economy of Somalia is intimately linked to rangelands and livestock. Even during the pre-war days, industrial development was very limited, except fish processing and canning plants that were established by international donors such as DANIDA and Soviet support (Lovateli, 1995). Today these industries are all defunct. Although Somalia has known hydrocarbon reserves, lack of reliable energy sources, access to markets and political instability has impeded industrial development in the country.

[17]Google.com/search?q=Industries%2C+Eastern+Cape&oq=Industries%2C+Eastern+Cape&aqs=chrome..69i57j0i22i30.12965j0j15&sourceid=chrome&ie=UTF-8

4.16.6 Agriculture and forestry

Agriculture and forestry is one of the largest economic sectors in the Western Indian Ocean region, with most countries exhibiting some degree of dependence on production from these sources for both subsistence and commercial purposes (Andrew *et al.* 2011). The level of employment in agriculture is to close 90% of the labour force. The overall contribution of agriculture to the GDP in most of the countries is comparatively low. 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 agricultural production as a result of a longer growing season, the projection is that countries in the WIO region will see negative impacts on their agricultural production in the years ahead due to changes in rainfall patterns and increased incidences of droughts (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 large-scale agriculture and cattle ranching can be conducted. Small island states 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 – Comoros is not conducive to agricultural production due to its barren volcanic landscape characterised by lack of fertile soil. Substantial quantities of agricultural products such as rice, meat and oil have to be imported. 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. The sector contributes to more than 45% of annual government revenue. However, its contribution to the GDP has shrunk in relative terms from 33% in 2000 to 23% in 2007.

Agriculture within the coastal region of Kenya is mostly directed to the production of food and non-food products at subsistence and small-scale commercial levels. Cash crops include cashew-nut, coconut, mango, bixa, sugarcane, sisal, cotton, rice and oranges while, food crops include maize, cassava, beans, sweet potato, tomato, watermelon, banana, vegetables, passion fruit and sorghum (Government of Kenya, 2017). 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. Livestock production also contributes significantly to the Kenyan coastal economy. Livestock keeping is practiced either as part of mixed farming or on its own with the main livestock products being milk, meat and eggs. There are 85 ranches within the Coast Province of which 25 are operational. Livestock rearing is mainly concentrated on marginal semi arid land of the coastal region that accounts for 69% of the total area. Agricultural production in the coastal region has remained low due to climate change that has been manifested in unreliable rainfall, frequent occurrence of droughts and dependence subsistence farming and over-reliance on rain-fed agriculture (Wekesa et al., 2017; Kenya MEDA, 2022).

Madagascar – Agriculture, jointly with fisheries and forestry, account for one-third of GDP, employs over 70% of active population and contributes more than 70% of export earnings (FAO, 1997; 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 Mauritius island is potentially arable, only 3% is under permanent cultivation mostly set aside for sugar cane, producing around 500,000 tonnes of sugar annually (NEPAD, 2002). 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 practised in the highland pastures (NEPAD, 2002).

Mozambique - Agriculture is a very important sector in Mozambique and is mostly carried out by small-scale farmers. The commercial 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 contributes to about 40% of the country's export earnings (Hoguane et al., 2002). Agriculture contributed 28% to the GDP of Mozambique in 2007 (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 cashew nut industry has been revived since its demise after 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 sub-sector in Réunion, accounting for 33% of total agricultural production valued at 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, vegetables and animal husbandry mostly for the local market.

Seychelles –Due to the restrictive nature of land-based opportunities in Seychelles, agriculture and forestry contribute considerably less to the GDP than the more lucrative tourism sector (World Bank, 2017). Total arable land in Seychelles is estimated at 500 hectares of which 50% is exploited for agriculture through a land tenure system (Agriculture Census, 2011; CAADP, 2015). Agricultural production is carried out on three main islands Mahé, Praslin and La Digue with the bulk of production on Mahé and Praslin (GoS, 2005). Most agricultural practices are found in the South of Mahé consisting mainly of small-scale commercial farming conducted in small open fields and greenhouse tunnels (World Bank, 2017). The size of farms leased to farmers is usually around 0.5 hectare with a lease of 5-years (Ministry of Fisheries and Agriculture Seychelles, 2015). The mountainous terrain and low soil fertility greatly reduce productivity in the agricultural sector (World Bank, 2017). Nearly three quarters of farms on Mahé are located in mountainous regions with less than 20% of these using terracing on slopes (Seychelles Agricultural Agency, 2015 as cited in Krütli and Stauffacher , 2017). Agriculture is practiced at altitudes ranging from 5m to 260 m above sea level (GoS, 2005). The performance of the Agricultural Sector of Seychelles has oscillated around the average figure of SCR 214 million, with a spread of SCR40 million in terms of GDP contribution at current market prices during the period 2012-2016 (SAA, 2020). The high dependence on food imports means Seychelles is highly vulnerable to disruptions in global food markets (Ministry of

Fisheries and Agriculture Seychelles, 2015). Agricultural land has been decreasing rapidly in the past decade due to development of tourism, housing and other socio-economic sectors (Moustache et al, 2011). In recent years farming production has been almost entirely overhauled by introduced hybrid varieties that have proven to be more productive and tolerant to local conditions than the traditional local varieties (GoS, 2020) . In 2015, there were 500 farmers on Mahé (Ministry of Fisheries and Agriculture Seychelles, 2015) (Seychelles MEDA, 2022).

Somalia – Almost ¾ of Somalia has agricultural potential but is not fully exploited. Cattle rearing in rangelands is the most important and successful economic activity in the country. The country also used to produce high quality bananas for export from the Juba-Shebeelle lowlands. 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 as millions of livestock are exported from Bosaso, Berbera and other ports annually (van der Elst, 2000). Charcoal production, mostly based on indigenous Acacia trees provides the primary source of energy and is a source of income to many poor people in the country. 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).

Somalia is the largest importer of *qaat*, a semi-narcotic plant, the leaves of which are chewed daily by most of the adult male population. Most of this product is imported fresh from Kenya and Ethiopia and it underpins much of the Somali local economy, estimated to be over US$ 150,000 per day (van der Elst, 2000)

South Africa – Agriculture and forestry in the coastal zone of South Africa contributes 35% of GDP. The forestry sector alone accounts for 4.1% of total export earnings, while deciduous fruit exports account for 15% of total agricultural export earnings. Livestock production and dairy industry are also significant sub-sectors, with 4,300 milk producers employing 60,000 workers and indirectly providing employment for an additional 40,000 people. The broilers and other fowls sub-sector also generated nearly US$1.24 million in 2001, making it the most important contributor to agricultural production in South Africa (South Africa MEDA, 2022). Major agricultural products include cereals, deciduous and citrus fruits, livestock, dairy products and silviculture. The coastal zone provides more diverse opportunities for agriculture, with generally 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 production is important. 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 of South Africa, tea production has flourished while there has been a significant growth of horticulture with the export of flowers to Europe. Despite South Africa's large commercial farming sector, small-scale and subsistence agriculture prevails in most regions. These activities provide food and other products to local and village markets. Though inadequately documented, medicinal and traditional herbal agriculture is of enormous consequence (Cunningham, 1988). The majority of the 61 million people in South Africa make use of traditional medicines at some stage, placing demands on wild stocks of medicinal plants but also stimulating a new emerging agricultural industry. One other important activity is the tapping of sap from Ilala palms in several parts of KwaZulu-Natal for the production of a locally popular wine (Cunningham, 1988).

Tanzania – The agricultural sector in Tanzania employs more people than any other sector and is considered a mainstay of the economy. Coastal agriculture is mostly rain-fed and dominated by 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**.** The main 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 in some areas (World Bank, 2009a).

4.16.7 Coastal Mining

The WIO region is generally endowed with non-renewable mineral resources and in some cases these minerals are especially prevalent in the coastal zone, where fluvial-geological processes have contributed to concentrating certain deposits. In areas where mining for minerals is undertaken, there are many cases of major environmental degradation. The highly invasive extraction of heavy minerals from dunes, for example, has resulted in major environmental concerns (Weaver *et al.*, 1996).

The potential spillovers from the mining sector, particularly in ports and coastal transport, could bring great benefit to the region. For example, in Mozambique, mining opportunities in the Tete province have facilitated the reconstruction of the Sena rail line linked to Beira (Cushman 2011e), while port expansion in Nacala is largely contingent on the development of mineral sands mining in Moma (Cushman 2011e). Likewise, the development of the Mtwara corridor in Tanzania, which will require port and rail upgrades, is based on iron ore and coal developments near Lake Nyasa, while the development of the Lamu corridor under the LAPSET programme in Kenya is largely targeting expansion of crude oil exports. Port upgrades in Madagascar have also been directly linked to the mining sector (Cushman 2011b). Increased mining activity will also induce spillovers into the public sector and subsequently local communities, as increased activity will lead to growth in government revenue and an increased provision of social services.

Local communities are generally benefitting from mining sector through both employment and community development programs initiated by the mining companies operating in their regions. For example, mining activity in Kenya coast has created over 1,000 jobs and mining companies have contributed to the development of education in the region (Cushman 2011a). In Mozambique, development of the Moma Mine has led to the creation of the Moma Development Association, which is not only promoting the provision of employment opportunities, but is also contributing to the development of schools, health care and financial services for rural communities (Cushman 2011e). Likewise, in Madagascar, Moramanga and Tamatave mines have created over 11,000 jobs and mining companies such as Ambatovy and Qit Minerals have developed projects that support job skills improvement, enterprise development and microfinance (Cushman 2011b). Similarly, perhaps one of the most productive examples of corporate community engagement has been in South Africa, where Richards Bay Minerals has initiated a Black Economic Empowerment program, which has helped historically-disadvantaged populations develop small-businesses, as well as supply goods and services to the company, now worth an estimated $61 million USD (Cushman 2011f). These programs implemented by Richards Bay Minerals, in particular, provide a great model of corporate social responsibility that other companies operating in the region could emulate, as not only has the company created employment in economically-marginalized communities, but they have integrated these communities into their own supply chain. Overall, the mining sector in the WIO region clearly has the potential to produce great benefits. While environmental issues and the effects of the resource curse should be carefully monitored and managed by policymakers, the spillovers and increases in government revenue facilitated by the sector should allow local communities in the coastal zone to benefit from mining activity. Thus, with proper management, responsible growth in the sector will likely contribute significantly to economic advancement in the region.

The following section provides details on the status of mining within the coastal zone in each of the WIO countries.

Kenya: There are several mineral occurrences in the coastal region that provide livelihoods to the coastal dwellers. Traditionally, coral limestone has been mined for building blocks and cement manufactures (Government of Kenya, 2017). Consequently, there are thousands of people who work in the coral limestone quarries and the cement factories. Three largest active cement manufacturing companies- Bamburi Cement Ltd., Athi River Mining Ltd and Mombasa Cement Ltd, have provided full time employment to over 1,500 people and have supported coastal communities through their corporate social responsibilities. Mombasa Cement Ltd. has for example, invested heavily in development of schools including construction of perimeter walls to secure school land and property as part of its community education support program. It has also constructed perimeter walls to secure other government properties. The cement companies also pay taxes and royalties to the government, which supports provision of services to coastal dwellers. Sand has also been traditionally mined for construction thus providing livelihood to many coastal dwellers (Government of Kenya, 2009). Titanium is mined in south coast creating employment opportunities and has become a leading mineral export from the coast. Coal deposits also occur in the coast and the government is considering developing a coal-fired power plant in Lamu County. Nationally, the contribution of mining to the GDP increased from 0.5% in 2012 to 0.9% in 2015 and registered a significant increase in the number of people employed in the sector (Government of Kenya, 2017; KNBS, 2016). The environmental issues around the sector such as erosion associated with sand mining are likely to cause problems if not addressed. The lack of dedicated legislation or regulation for sand and coral mining complicates the situation. However, the existing environmental regulations and integrated coastal zone management action plans can be relied on to promote sustainable use of coastal resources.

Mozambique:
Mozambique has some of the gas and coal deposits in the world. According to the National Petroleum Institute, Mozambique has more than 2.8 billion cubic meters of natural gas reserves. The Pande/Temane gas fields in the province of Inhambane have enormous natural gas reserves estimated at more than 5 million tons of joules. The coal deposits are estimated at 6 billion tonnes occur with greater abundance in Tete Province (Mozambique MEDA, 2022). The other main mineral resources mined include heavy sands, iron, vanadium, titanium, tantalite, tourmalines, bentonite, pegmatites, marbles, bauxite, graphite, diamonds, gold, phosphates, limestone, gemstones, rhyolite, platinoid uranium, cobalt, chromium, nickel, copper, granite, fluorine, diatomite, emeralds, and apatite (EITI-Mozambique, 2011; 2014). Gold, copper, iron, bauxite and similar resources occur most in Manica in the western Mozambique.

South Africa:
South Africa has the world's largest reserves of chrome, gold, vanadium, manganese and platinum group metals, making mining the most dominant sector in the country's economy. In 2008, mining accounted for 9.5% of GDP, 41% of total exports and employed over half a million people. Mining of coal occurs mainly within the Mpumalanga Province, which produces some 81% of the country's total output. Other significant producers of coal include Limpopo Province with 11%, Free State Province with 6%, and Kwazulu-Natal Province with 2%. Following exhaustion of anthracitic coal deposits in the east, bituminous coal from the central and northern coalfields make up most of South Africa's coal production, contributing 98.8% in 2012. About 64% of South Africa's coal is mined by open-cast methods and 36% by under-ground methods. The number of coal mines had increased to 117 in 2012. Of these, seven very large mines producing more than 10 metric tons per annum, are responsible for 46% of the total output. As a result of the increase of the number of small labour intensive operations, coal mining industry's labour force has increased from 83,200 to 85,100 workers in the period 2011-2012 (South Africa MEDA, 2022). Mining of titanium-bearing minerals accounted for about 22% of the 6.1 metric tonnes global production in 2007. South Africa’s titanium minerals (ilmenite and rutile) are produced from the extensive beach deposits located along the eastern, southern and north eastern coasts. Currently, titanium minerals are extracted at three major mines, namely Richard’s Bay Minerals’ Tisand (Pty) Ltd and Exxaro’s Hillendale and Namakwa Sands mines. There are also plans for exploitation of marine phosphates. In 2012 and 2014, South Africa’s Department of Mineral Resources granted three rights to prospect for marine phosphate to private companies. These rights cover approximately 10% of South Africa’s marine environment. The prospecting areas directly coincide with critically endangered ecosystems and the country’s largest fishing grounds including South Africa’s only Marine Stewardship Council accredited fishery. Since prospecting rights are being granted, there is indication that marine mining will become a reality (South Africa MEDA, 2022).

4.16.8 Salt Production

Salt works are an important economic activity in many countries in the WIO region. These range 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 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 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 in Somalia once exported 200,000 tonnes per annum (Anon, 1968). 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 are thought to be substantial to meet local demands and export to Ethiopia.

4.16.9 Oil and Gas

The WIO is endowed with oil and natural gas resources. Many countries in the WIO region including Tanzania, Mozambique, and South Africa, are currently producing natural gas, while deposits of gas have also been found in Somalia and Kenya (Kenya MEDA 2012, Somalia MEDA 2012). While South Africa is the only country currently producing crude oil, unconventional crude oil reserves have been found throughout Madagascar, there are prospective oil fields in northern Somalia, and oil exploration is currently ongoing in Kenya and Tanzania (Busson 2011a, b, c, d, e). Biofuels development is also generating much interest in the region, with Mozambique, Tanzania, South Africa, Madagascar and Mauritius all currently planning or initiating projects (Busson 2011a, b, e, f, g). Mozambique has the greatest biofuels potential in all of Africa. However, Mauritius, Tanzania and Madagascar appear to be the only countries that have initiated commercial production in the sub-sector (Busson 2001b, e, g).

Historically, the level and pace of development of the oil and gas industry in the WIO region has been variable. Similarly, the prospect of finding resources varies between countries. In Somalia, despite evidence of potential natural gas resources, political instability and security problems have deterred exploration. In Mauritius, Comoros and Réunion (France), the absence of a large continental shelf reduces the possibility of occurrence of oil or gas-bearing geologic formations. For the mainland Africa nations, Madagascar and Seychelles, the situation is different as the continental shelf areas do exist that may hold significant reserves.

There is much potential for further development in the energy sector throughout the Western Indian Ocean region, which is very promising considering the global and regional projections for increased energy demands. There are also numerous opportunities for biofuels development across many countries. There are, however, constraints in the sector, such as political instability, weak capacity, as well as the threat of oil spills and the ongoing debate on the use of productive land for the production of food crops instead of production of biofuels, all which could limit development in the near future.

Political instability has also been identified as a problem in the energy sector. For example, in Madagascar, not only has the past political crisis led to the suspension of a large number of biofuels projects, but it also inevitably led to lack of confidence from foreign investors. In Somalia, political instability and conflict led to the collapse of upstream activity in 1991, and has in addition produced a great degree of uncertainty around current exploration rights and resource ownership. Similarly, in Comoros political instability has reduced private-sector confidence. It has been suggested that oil discoveries will likely induce further political instability in the country (Busson 2011h). Establishing political certainty in the business environment, particularly around capital-intensive upstream activities is a prerequisite to developing the sector.

Weak capacity has also constrained development in the sector. For example, in Kenya, limited handling capacity at the Mombasa port continues to limit the amount of oil imported (Busson 2011d). Similarly, weak financial, operational and human resources capacity has made sectoral management difficult in Tanzania, while a lack of capacity at the Temane processing plant has limited gas export expansion in Mozambique (Busson 2011e, f). Lack of governance capacity in Madagascar has also led to weak enforcement and monitoring, while lack of data in Comoros has severely constrained planning and management in the sector. Weak capacity for environmental impact assessment was reported in Seychelles (Busson 2011i, King and Walmsley 2003). The lack of capacity around environmental impact assessment is particularly significant, as oil and gas exploration and accidents could be highly detrimental to local communities and ecosystems.

Kenya - Kenya currently imports refined oil fuels through the port of Mombasa. The oil is transported to the hinterland through the Kenya Pipeline Company Ltd, a state corporation charged with the responsibility of transporting, storing, and delivering petroleum products to the consumers in Kenya through its pipeline system and oil depot network. It has a total storage capacity of 612,271,000 litres with a total throughput of 7,025,900 cubic metres in 2019 (KNBS, 2020). Previously, the country relied on importation of crude oil which was refined by Kenya Petroleum Refineries Limited (KPR)(KNBS, 2020). Due to various reasons, the refinery has stopped operations. However, the petroleum sub-sector employs many people across the coast region. The National Oil Company (NOC) has demarcated 17 blocks for petroleum rights negotiations, after the offshore explorations have been undertaken by the private-sector. To date, bio-fuel development in the country remains in its early stages with limited progress. Increases in oil exploration and production at the coast could increase the likelihood of oil spills which, in conjunction with poor environmental management from emerging market companies, could potentially be detrimental to coastal ecosystems in the future. The government has also shown a commitment for further oil exploration at the coast, while there are also prospects for future oil and gas activities at the Lamu port (Kenya MEDA, 2022). Good quantities of crude oil have recently been discovered in Northern Kenya in Turkana County and plans are underway to export it through Lamu port.

Tanzania - Oil and gas exploration has been conducted for the last 50 years, more recently promoted by the Tanzania Petroleum Development Corporation (TPDC). Significant natural gas discoveries have been made at Songo Songo, Mkuranga and Mnazi Bay with exploration continuing along much of the coast. 35 exploration and development wells have been drilled (http://www.tpdc-tz.com /exploration.htm). Natural gas extracted from Songo Songo is used to generate electricity, with a potential of providing a reliable source of low cost electricity in Tanzania. The Mnazi Bay block allocated to the Artumas Group (Canada), includes a natural gas field with about 500 billion cubic feet of proven gas reserves. 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 surrounding areas. In addition, the Mafia Deep Offshore Basin in southern Tanzania has a high potential for exploration. Other areas of interest with high potential for exploration include sedimentary basins onshore and offshore with open acreage at Rufiji Basin among others (http://www.tpdc-tz.com/exploration.htm). The Government of Tanzania, through the TPDC, has engaged international petroleum and investor specialists in the exploration of hydrocarbons 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. There are two major pipelines that transport oil and natural gas in Tanzania: Tanzania-Zambia (TAZAMA) oil pipeline and Mtwara–Dar es Salaam natural gas pipeline. The TAZAMA pipeline transports crude oil from Dar es Salaam port to Ndola, Zambia a distance of 1,750 km. Mtwara–Dar es Salaam natural gas pipeline transport natural gas from two gas processing plants- Madimba in Mtwara region and Songo Songo in Lindi region (Tanzania MEDA, 2022).

Mozambique – Known natural gas reserves are exploited in Temane gas field in southern Mozambique and gas is exported to South Africa's Gauteng region via a 925 km 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 also signed three exploration agreements with Mozambique's state oil firm. Natural gas from Mozambique's Pande and Temane fields is planned to be used in new and existing industries in Maputo and Beira. Mozambique has issued offshore licensing for blocks in the northern Rovuma basin and 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 –The petroleum industry contributes 2% to GDP, providing direct and indirect employment for over 100,000 people and over R34 billion in tax revenue to the government. The country produces 35,000 barrels per day of crude oil, with proven reserves estimated to be 15 million barrels. The country produced 115 billion cubic feet of gas in 2008, with gas reserves estimated to be 320 billion cubic feet. South Africa also has Africa's second largest oil refinery system, comprised of four refineries and two synfuel plants that produced 692,000 barrels per day in 2008 (South Africa MEDA, 2022). Companies in the oil and gas sector are contributing to development of local communities. For example, PetroSA, Chevron, Sasol and Engen all support various programs around schools and education, while BP is supporting community-based job creation enterprises such as the Scarborough Fishersmen's Company in Ocean view. Chevron, BP and Total have also been supporters of various HIV projects, as well as multiple environmental awareness campaigns.

Madagascar – Crude oil and natural gas reserves have been discovered at Bemolanga and Tsimiroro oil fields (UNEP, 2006). However, actual oil and gas exploitation is still relatively under-developed with only modest crude oil production 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 – The potential for producing crude oil and natural gas exists on the Mascarene Plateau and Seychelles Bank. Oil exploration in Seychelles waters has been undertaken by several oil companies at different intervals in the last few years, but no oil deposits have been discovered yet (Petro Seychelles 2017 as cited in SAFESEAS 2017).

4.16.10 Shipping and maritime transport

Shipping and maritime transportation is a growing sector in the WIO region. Ports and coastal transport in the WIO has the potential to expand in the coming years to support increases in mining and energy activity by maximizing throughput and capacity. There are, however, many challenges in the sector, including a weak manufacturing sector, over-regulation and corruption, and capital constraints, all of which could potentially confine development in the future. Over-regulation, corruption and burdensome state intervention in the sector have been highlighted throughout the region. Capital constraints have also become problematic in the sector. In many cases, state management and overregulation are partly responsible for the capital constraints prevalent in the sector throughout the region as such activity is often a deterrent to private-sector investment.

A weak and, in some cases, uncompetitive manufacturing sector has also been highlighted as a weakness. For example, reductions in manufacturing output and an adverse trade balance with major trading partners, particularly India and China is likely to weaken port throughput in South Africa (Maasdorp 2011c). Similarly, the decline of manufacturing industries in Tanzania, Mozambique, Kenya and Mauritius and inability to compete with imports from the East, has also been identified as a threat to the expansion of the transportation sector in the region (Andrew *et al* 2011; Maasdorp 2011a, b, d, f).

Countries in the Western Indian Ocean do, however, hold a great comparative advantage in terms of strategic geographical position. For example, not only is Madagascar a strategic point for sea lanes linking the Far East with Africa and South America, but it has very easy access to a vast expanse of the ocean. Likewise, the sheer magnitude of the coastlines of Mozambique and Somalia provide a solid base through which to grow port activity, while the strategic location of ports in Kenya and Tanzania will be highly significant as economic activity in the region expands. Somalia, in particular, has huge potential in the sector through its strategic position near the Gulf of Aden, where an estimated 25,000 ships pass through annually. South Africa is also situated in one of the world's busiest ship transport routes, where the transport of crude oil from the Middle East to Europe and the Americas is prevalent. Thus, throughout the region, tapping into and maximizing this strategic comparative advantage should be a priority and could potentially be utilized as a catalyst to stimulate development in the coastal zone.

Increased mining and energy activity also has the potential of facilitating growth in the sector. For example, in Kenya, the potential for the development of a terminal for crude oil exports at the new Lamu Port could be very beneficial to ports and transport in the area, while the possible development of mineral sands mining at Moma, as well as coal fields in Tete province, could potentially facilitate the expansion of both the Sena railway to Beira and the Nacala port in Mozambique. Similarly, the development of the Mtwara corridor in Tanzania, which is based around iron ore and coal mining development, could stimulate rail construction and port expansion in the area, while upgrades in the D'Ehoala port, as well as the potential spillovers from oil and gas activity and mining activity in Sakoa and Tamatave, are likely to facilitate sectoral growth in Madagascar. Likewise, if the potential for increased oil production is realized in the region, it is likely that storage and transport capacity will be widely increased. The following sections provide details on the status and key features of shipping and maritime transportation in the WIO countries.

Somalia – Significant port development in Somalia began in 1960 with improvements in the port of Mogadishu and a new port at Kismayo. In the 1990s, the US government made substantial further improvements to Mogadishu port. Soviet support for the port of Berbera in 1968 enabled the port to accommodate large vessels (Anon, 1968). The port of Bosaso in Puntland remains a viable traditional port, especially for trade with Yemeni vessels. In addition there are smaller ports such as Zeila. Despite the political unrest and piracy, the northern ports remain operational, especially for export of livestock.

Kenya - Maritime transport accounts for 15% of the coastal economy (Kenya MEDA, 2022). The Mombasa port is the largest sea port in Kenya and is one of the largest and most important serving Uganda, Rwanda, Democratic Republic of Congo and South Sudan, which are landlocked countries (Government of Kenya, 2009). It is connected to the world's major ports and handles between 1,684 and 1,832 vessels annually (Government of Kenya, 2017). The port has undergone numerous improvements and a new Vessel Tracking Management System (VTMS), Global Maritime Distress Signaling System (GMDSS), as well as new safety regulations and a shift to 24-hour services, have been introduced to increase efficiency. Consequently, cargo handled at the port has increased steadily from 2011. The Government of Kenya is also developing a second commercial port at Manda Bay in Lamu to tap the South Sudan and Ethiopian markets under the LAPSSET project. A number of smaller ports which handle smaller vessels also exist and these include the Mombasa old port, old Lamu port, Malindi, Kilifi and Shimoni. Other designated ports along the coast of Kenya include Kilifi, Funzi, Takaungu, Mtwapa, Vanga, Ngomeni, and Malindi (Government of Kenya, 2009). All the ports are administered by the Kenya Port Authority (KPA) while sea safety matters are handled by the Kenya Maritime Authority (KMA).

Tanzania –The main seaports in the mainland Tanzania are Dar es Salaam, Tanga and Mtwara. Dar es Salaam is the largest seaport in Tanzania. In 2015-2016 period, cargo handled at Dar es Salaam, Tanga and Mtwara ports were 14,276,000, 676,906 and 272,865 tonnes per year, respectively. Small seaports include Kilwa, Lindi, Mafia, Pangani and Bagamoyo. The small ports of Kilwa, Lindi and Mafia handles a total of 28,402 tonnes of cargo per year (TPA, 2017). Both sea ports and inland waterways ports in mainland Tanzania are managed and operated by the Tanzania Ports Authority (TPA). In Zanzibar, Malindi Port which is located in Unguja Island is the main entry point handling international trade for the Islands of Zanzibar. About 95% of Zanzibar imports and export passes through this Port. The Port is also the busiest passenger terminal in East African Region handling an average of 1.5 million people per year. Mkoani is the main port in Pemba Island, handling most of the import and export for Pemba Island. Other seaports under Zanzibar Ports Corporation include Mkokotoni (Unguja), Wete (Pemba) and Wesha (Pemba). Zanzibar Ports Corporation (ZPC) which operates under the Ministry of infrastructure and Communication is responsible for managing, operating and developing Zanzibar seaports (ZPC, 2019). Types of cargo handled in Tanzanian ports include dry bulk cargo such as grains, fertilize, cement, coal, copper, and gypsum); Break Bulk Cargo such as iron, steel, metals, motor vehicles and parts and Bulk Liquid such as petroleum products and edible oil (TPA, 2017). Fishing ports are missing in all the coastal regions. However, plans are underway to establish national fishing ports that will provide services to deep sea fishing vessels (Tanzania MEDA, 2022).

Mozambique – The main ports are 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 serves land-locked countries such as Zimbabwe and Malawi. However, the natural habour in the Maputo Bay requires constant maintenance as the Polana entrance channel tends to become shallow due to siltation. Plans have been announced to develop a new port to the south on the Machangulo Peninsula although environmental impact of this new port 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). The utility and importance of engaging the private-sector is evident in Mozambique. Following the civil war, funding to rehabilitate the country's dilapidated ports and transport system was very limited. However, privatization and promotion of joint-ventures in the sector has led to rapid reconstruction. The Maputo port in particular, has reaped great benefits from private-sector engagement, as private-sector investments in the Matola terminal have accelerated development and expanded the amount of cargo handled by the port (Maasdorp 2011b). Beira and Nacala ports have also been extensively rehabilitated with private-sector investment. Thus, Mozambique does appear to provide a model through which capital constraints and underdevelopment in the sector can be alleviated.

South Africa - South Africa has six major commercial ports (Saldanha Bay, Cape Town, Port Elizabeth, Coega, East London, Durban and Richards Bay), all of which are connected to inland areas through road and rail. Durban is the largest port for imports and exports to and from inland South Africa, while the port at Richards Bay is the country's largest bulk port. Port Elizabeth is the Eastern Cape's busiest port, handling iron ore from the Northern Cape and providing container services for the city's vibrant automobile industry. The port at Mossel Bay is solely dedicated to the handling of petroleum products. The port in East London mainly serves the border and Transkei areas, while the port in Ngqura has largely been developed as a catalyst for industrial development. Ports, terminals, as well as the country's rail services, are all state-owned and operated by Transnet National Ports Authority, while road transport is provided and maintained by the private sector. South African ports handle an average of 13,000 vessels carrying 500 million tonnes of cargo annually. 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 the port 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 port exports mainly coal and woodchips, while Saldanha Bay port is dedicated to iron and steel exports. 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. In South Africa, over-regulation and state management in the sector has produced high levels of inefficiency (Massdorp 2011d).

Madagascar – Road and rail infrastructure is not well developed in Madagascar and therefore most coastal settlements place great reliance on ports for transport. The island has 19 ports that include Mahajanga, Toliara, Antsiranana (Diego Suarez), Tolagnaro, Manakara, Mananjary, Morombe, Morondava, Nosi-Be, Port Saint Louis, Ambilobe, Vohimarina, Antalaha, Maroantsetra, Ambodifoltatra, Analalava, Antsohihy and Maintirano. 60% of all vessel transport is international (long-distance) while the rest are domestic port-to-part transport. Total import-export traffic amounted to around 2 million tonnes in 1998 (Centre National de Recherche Environnemental, 2007). In

Madagascar, capital limitations around ports and sea-based economic activity have been identified as weaknesses in the sector (Maasdorp 2011e).

Comoros: The main ports are Moroni (Grande Comoro), Fomboni (Mohéli) and Mirontsi (Anjouan). These ports offer only limited service. For example, the largest port of Moroni does not accommodate ocean going vessels along a wharf and lighters are used to ferry goods ashore. Mirontsi port does have a modest wharf facility that can take a single medium sized passenger vessel. Comoros is on the main route of oil tankers transporting more than 500 million tonnes of crude oil, representing more than 5,000 tanker-voyages per year (Ministère de l'Agriculture, de la Pêche et de l'Environnement, 2007). The need to engage the private-sector and increase investment in the sector has been documented in Comoros.

Mauritius – The main port in Mauritius is Port Louis. The port handles approximately 6.5 million tonnes of cargo per year through more than 2,000 vessel calls. There has been a 9.0% increase in total cargo handling and a 15.3% increase in container traffic in 2007/2008 period. 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 in Réunion island is Le Port which is located on the east coast of the island, around 30 km to the south of the capital, St. Denis. Though small, this port has excellent and efficient facilities for coping with large volumes of vehicle imports, sugar exports and passenger liners. The main power plant is located in the port as well as various depots and several smaller industrial enterprises (Direction Régionale de l'Environnement, 2005).

Seychelles- Managed by the Seychelles Port Authority (SPA), Port Victoria is the major gateway for all commerce of the country. It is the point of entry for 95% of the country's imports (AFD, 2018) and offers a diverse handling capability including conventional and containerised cargoes, and also handles dry- and liquid-bulk imports. Port Victoria is also recognised as a major industrial fishing, cruise and super yacht port in the south-western Indian Ocean (SAFE SEAS 2017). The port is also a landing and transhipment port handling between 244,353 and 326,461 tonnes of tuna, representing 97% of the total landing and transhipment by Seychelles licensed vessels (SFA, 2019). Being the central point of economic activity in the country, it is vital for the fishery and the country's bulk imports, particularly fuel, which is the most significant sector of general cargo. Cruise ships and leisure vessels have also been documented as important contributors. Given the growth in importance of the blue economy and increasing container cargo movements, there is significant pressure on port infrastructure from both a safety and capacity perspective. After Victoria, Providence Fishing Port is the second largest fish landing port. It is mostly used mainly as a mooring base for fishing boats. To cope with increasing trade and tourism and also to be less vulnerable to climate change, plans are underway to renovate and extend the Port by an additional 230 m to accommodate two boats measuring up to 250 m in length at the same time. After the extension, the port will have an overall length of 600m (Seychelles News Agency, 2020) (Seychelles MEDA, 2022).

4.17 Valuation of ecosystem goods and services

The coastal ecosystems of the WIO 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 reinforced. 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 the four functional grouping adopted by the Millennium Ecosystem Assessment: 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).

4.17.2 Value of critical coastal ecosystems in the WIO

The following section provides analysis of the estimated value of the goods and services provided by various coastal and marine ecosystems in the WIO region.

Coral reefs

Coral reefs are not only areas of high biodiversity but also provide a great range of environmental goods and services in the WIO. Coral reefs are important to artisanal fishers and tourism and contribute immensely 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 generates genetic products, some of significant medicinal and pharmaceutical benefit.
- *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 marine fish and crustacean 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 importance 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

Coastal forests important generators of benefits in the WIO. 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* – Coastal forests play a significant role in the cycling of nutrients and are especially important in carbon sequestration.
- *Cultural* – Coastal 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 in several countries in the WIO region.
- *Support* – Coastal forests are major sources of primary production, acting as carbon sinks and oxygen generators. They also 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 Beds

Seagrass beds generate many benefits as indicated below.

- *Provisioning*–Subsistence fishers and gatherers collect sources of 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. Seagrass beds also provide variety of fishes such as seahorses and ornamental shells, ranging from large conch shells to the abundant cowries used thought the region in ornamental and traditional items.
- *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 and primary production. Seaweed farming takes place in areas adjacent seagrass beds thus benefits from the ecosystem.

4.17.3 Placing a value on ecosystem goods and services

Many studies on the valuation of coastal ecosystem goods and services have been undertaken in the WIO region. Despite their convincing results, most of the studies provide different estimates. For example, while the coastal zone covers only 8% of the world's surface, 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 which is equivalent to US$44 trillion (UNEP, 2006). The global value of ecosystem goods and services has been estimated to be US$ 33 trillion (Constanza *et al.* 1997). 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 following sections provide estimates of the value of ecosystem goods and services provided by the WIO coastal ecosystems.

4.17.4 Estimated value of key ecosystem services in the WIO

Based on the estimates made by Constanza *et al*. (1997), an extrapolation was attempted to determine the value of coastal and marine ecosystem goods and services in the WIO (see also Tables 1-27 and 1-28).

Coral Reefs

The value of coral reefs in the WIO region is estimated at US$ 7.291 billion per year (based on the sum of the individual indicator values for ecosystem services (Table 1-27 and Table 1-28). A recent study conducted by the South China Seas Project established the annual value of coral reef ecosystems to be US$ 1,181 per hectare per year.

Mangroves

The total economic value of mangrove forest goods and services in the WIO region is estimated to be US$ 8,791 million per year. However, this value may be an overestimate as studies in Thailand (World Resources Institute, 2008) and in the South China Seas provides values ranging from US$ 3,680 to US$ 2,872 per hectare per year, roughly one third of the values presented for the WIO region in Table 3-6.

Coastal forests

The total value of the coastal forests 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.

Table 1-27: 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 1-28: Valuation of annual ecosystem goods and services in the WIO region based on Constanza *et al.*, (1997)

	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**

4.17.5 Potential for contribution to economic growth

Most 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. 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 in all countries, 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. These and other opportunities in tourism development, do exist and can be pursued by each country.

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 of people who access these resources as subsistence or artisanal fishers and traders. Better control over access by foreign fishers is clearly a key objective that can be best achieved through regional collaboration. A clear need also exists to improve fisheries and socio-economics data collection and sharing in the region.

Population growth rates over the past few decades have been high and at a rate that has imposed huge pressures on coastal and marine ecosystems. Paradoxically, growth rates have slowed enormously in some regions due to the impact of HIV-Aids and population growth control initiatives such as family planning that are becoming popular among the women in the WIO region. This presents more than population health challenges as it also impedes capacity and skills development in a young sector of society. While the island states have relatively higher life expectancy, per capita GDP and human development indices, they are more vulnerable to climate change 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.

4.18 Cost- Benefit Analysis of the WIO fisheries

The cost benefit analysis presented in this section covers Comoro, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa, and Tanzania (together with Reunion (France) they form the WIO region countries). For the period between 2008 and 2010, the GDP18 per year for Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania were US$0.55, US$35.80, US$8.50, US$10.30, US$11.70, US$0.97, US$5.70, US$383.10 and US$23.30 billion, respectively. The total contribution to GDP from the coastal and marine resources in the region is almost US$ 22.4 billion a year (Dyck and Sumaila 2010; Sumaila et al., 2012). This is a significant amount, especially, when one takes into account that coastal communities that depend on these resources

[18] The gross domestic product (GDP) of a country refers to the market value of all final goods and services produced within the country in a given period.

are generally poorer that the more urban population. Coastal tourism contributed the largest to GDP at over US$11 billion a year, followed by coastal agriculture and forestry (Sumaila *et al.* 2012).

About half a 500,000 tonnes of fish are caught in the WIO. This catch brings in about 0.5 billion US dollars. More than 80% of fish landed is captured by WIO countries. The total cost of fishing is estimated at US$284.64 million a year and subsidies provided by governments in the region on annual basis are estimated to be US$ 177.86 million.

Table 1-29: Economic data on the fisheries active in the WIO region (Sumaila *et al.* 2012).

Country/entity	Catch (thousand tonnes)	Ex vessel price (US $/tonne)	Average variable fishing cost (US $/tonne)**	Catch value or revenue (mill US $)	Total fishing cost (mill US $)	Subsidies (US $/t)	Total subsidies (mill US$)
Comoros	26.87	214	128.49	5.75	3.45	45	1.21
Kenya	1.30	1,207	724.02	1.57	0.94	680	0.89
Madagascar	136.86	1,082	649.23	148.09	88.85	123	16.83
Mauritius	11.54	1,082	649.23	12.49	7.49	226	2.61
Mozambique	121.80	1,201	720.50	146.26	87.76	730	88.91
Seychelles	86.15	294	176.41	25.33	15.20	268	23.09
Somalia	17.85	701	420.34	12.51	7.50	144	2.57
South Africa	17.12	1,260	756.05	21.57	12.94	85	1.45
Tanzania	18.66	612	366.98	11.41	6.85	181	3.38
France	7.54	2,630	1,577.77	19.83	11.90	762	5.75
Regional total WIO Region	**445.69**			**404.82**	**242.89**	**-**	**146.69**
Non-WIO region	46.20			69.66	41.80		31.17
Total	**491.89**			**474.48**	**284.64**		**177.86**

Table 1-30 presents the estimates of resource rent, wages and normal profits earned by the fisheries of the WIO both by country within and outside the region. The fisheries of the WIO are estimated to generate a resource rent of just about US$68 per year currently, of which about US$59 million are generated by WIO countries and the reminder by countries outside of the region. The largest resource rent of US$ 42 million per annum is generated in Madagascar. The fisheries are estimated to support almost 2.7 million people generating wages of about US$366 million per year. The profits to the owners of fishing capital are estimated to be US$60 million per year (Sumaila *et al.* 2012). Table 1-31 presents the direct output impact, the output multiplier, and the economy-wide impacts of the activities dependent on the coastal and marine resources of the WIO region. While the direct output impact or landed value of catch from the WIO is about US$475 million a year, the total economic impact is more than 2 times the DOI estimated at about US$1,150 million a year (Sumaila *et al.* 2012).

Table 1-30: Estimates of economic indicators (Sumaila *et al.* 2012).

Country/entity	**Jobs ('000)**	**Wages to fishers (mill US$)**	**Earnings to fishing enterprise (mill US $)**	**Resource rent (mill US $)**
Comoros	160	4.14	1.59	1.09
Kenya	51	1.13	0.16	-0.26
Madagascar	630	114.03	15.38	42.40
Mauritius	23	6.25	0.15	2.39
Mozambique	900	108.23	14.43	0
Seychelles	7	18.24	7.22	0
South Africa	66	9.00	3.69	2.43
Somalia	480	14.24	2.13	7.17
Tanzania	190	12.55	2.18	1.19
France	1.85	22.41	0.93	2.19
Total ASCLME Countries	**2509**	**310.22**	**47.86**	**58.86**
Non-WIO region	233	55.47	12.31	8.84
Total	**2,742**	**365.69**	**60.16**	**67.70**

Table 1-31: Direct output, income and economic impacts

Country/entity	**Direct output (million US $)**	**Output multiplier**	**Economic impact (US $)**
Comoros	6	2.95	17
Kenya	2	2.95	5
Madagascar	148	2.34	347
Mauritius	12	1.62	20
Mozambique	146	1.83	268
Seychelles	25	2.95	75
South Africa	13	2.95	37
Somalia	22	3.13	68
Tanzania	11	2.72	31
France	20	4.11	82
WIO Regional total	**405**		**948**
Non-WIO region			
Non-WIO region	70		200
Total	**474**		**1,147**[(6)]

4.18.2 Economic wealth generation scenarios

Economic wealth captured by resource rent, wages and economic impact generated by the fisheries of the WIO region is estimated under two scenarios. In Scenario 1, the wealth generated currently by the fisheries operating in the WIO is computed. Fisheries around the world are known to be plagued by overcapacity (e.g., Porter 1998), and the fisheries of the WIO are no exception. This overcapacity results in overfishing and higher than necessary fishing costs. In Scenario 2 the wealth (resource rent, wages and economic impact) that could be generated if overcapacity is eliminated and the fisheries of the WIO are rebuild and sustainably managed thereafter (Table 1-32). The data reported in Table 18 shows that most of the gains from rebuilding fisheries of the WIO will come mostly from reducing cost and fishing the resources more efficiently, including eliminating or redirecting harmful subsidies currently provided by governments. Table 1-33 presents the gains in resource rent, income and economic impacts that could be expected if WIO fisheries are rebuilt and sustainable managed through time. Rebuilding and effectively managing WIO fisheries would result in annual gains in economic rent of US 221 million while wages and economic impact are likely to increase by US$10 million and $43 million per year, respectively. The latter two do not increase significantly because to rebuild, fishing capacity and therefore wages and normal profits need to be reduced.

Table 1-32: Estimated landed values, costs and subsidies under current and rebuilding scenarios (million USD) (Sumaila *et al.* 2012).

Country	**Current landed value**	**Rebuilt landed value**	**Current costs**	**Rebuilt costs**	**Current Subsidies**	**Rebuilt subsidies**
Comoros	5.75	5.66	3.45	1.73	1.21	0.90
Kenya	1.57	1.56	0.94	0.47	0.89	0.21
Madagascar	148.09	145.98	88.85	44.43	16.83	14.58
Mauritius	12.49	12.51	7.49	3.75	2.61	1.18
Mozambique	146.26	146.20	87.76	43.88	88.91	17.21
Seychelles	25.33	25.44	15.20	7.60	23.09	5.21
Somalia	12.51	15.42	7.50	3.75	2.57	2.39
South Africa	21.57	29.25	12.94	6.47	1.45	0.95
Tanzania	11.41	11.98	6.85	3.42	3.38	1.83
France	19.83	21.82	11.90	5.95	5.75	1.70
Total	**404.82**	**415.82**	**242.89**	**121.44**	**146.69**	**46.15**

Table 1-33: Gains in economic indicators from a rebuilt WIO LME (million US$) (Sumaila *et al.* 2012).

Country	**Gain in rent**	**Gain in income impact**	**Gain in economic impact**
Comoros	1.94	0	0
Kenya	1.13	0	0
Madagascar	44.57	0	0
Mauritius	5.20	0.01	0.03
Mozambique	115.52	0	0
Seychelles	25.59	0.08	0.34
Somalia	6.85	2.10	8.60
South Africa	14.66	5.07	24.06

Tanzania	5.54	0.63	1.55
France	0.77	2.24	8.15
Total	**221.77**	**10.13**	**42.73**

4.18.3 Distribution of benefits to WIO countries

The coastal and marine resources of the WIO are estimated to contribute about US$22.4 billion a year to the GDP of the countries of region. Coastal tourism contributes the largest share to the GDP at over US$11 billion a year, followed by coastal agriculture and forestry (Figure 1-30). The fisheries of the WIO contributes about US$68 million per year of which about US$59 million are generated by WIO countries and the reminder by countries outside of the region. The fisheries of the WIO are estimated to support about 2.7 million workers, generating wages of about US$366 million per year. On the other hand, owners of fishing capital earn normal profits of US$60 million per year. Rebuilding and effectively managing fisheries of the WIO could result in annual gains in economic rent of US$221 million while wages and economic impact are likely to increase by US$10 million and US$43 million per year, respectively. In terms of distribution and equity, most of the economic benefits from the coastal and marine resources of the WIO remain in the countries of the region. Also, workers in the sector capture a multiple of what owners of capital capture from the gross revenues generated from the resources of the WIO region.

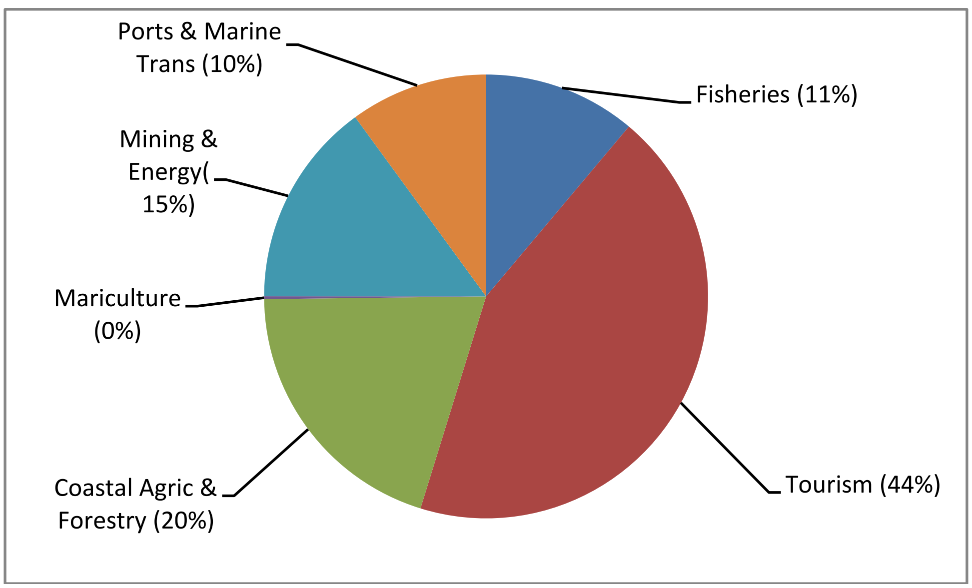


Figure 1-30: Relative Contribution of Goods and Services of Marine and Coastal Resources in WIO Region

5 Coastal - Marine Pollution

Deteriorating quality of the coastal waters of the WIO region poses a significant threat to public health as well as to the health of its living marine resources and ecosystems – and thus also to the economy. The sources of pollution which contribute to this deterioration include both land-based and marine and maritime related activities. While globally land-based activities are considered to contribute between 80–90% of the chronic pollution load to the marine environment, marine sources also make a significant contribution to localised and trans-boundary pollution, especially in terms of single-point impacts such as blow-outs or massive-scale oil spills from tanker strandings. The successful management of marine pollution requires an effective legal regime covering national, regional and international levels. Although the majority of WIO countries are party to most of the relevant international conventions – and are all members of the Nairobi Convention - there are a number of gaps and inconsistencies especially in their national legal and institutional frameworks which need to be addressed. For example:

There are many cases of overlapping jurisdictions, and a lack of communication across sectors;
Failure to domesticate the provisions of international conventions even when they have been ratified;
Weak implementation of legislation due to a lack of adequate financial, technical and human resources;
Surveillance activities split amongst various institutions which is neither cost-effective nor efficient;
Maritime borders between some of the countries have not yet been agreed and with the increasing interest in offshore resources, could lead to conflicts.

There is also a need to introduce and/or strengthen legislation on dredging – especially dredged material disposal – the environmental impacts of offshore oil and gas activities, liability and compensation related to offshore activities, and monitoring and standards. At the regional level, additional technical protocols should be developed under the Nairobi Convention to "operationalise" the relevant articles and promote regional harmonisation in the management of marine pollution. These could include:

- A Protocol on dredging/dumping; and
- A Protocol on the management of pollution from offshore activities. This could be broadened to cover all environmental impacts rather than just pollution and including discharge standards.

These could be supported by the development of a Regional Policy on Marine Pollution and a Regional Code of Practice for Environmental Management in Ports be developed in collaboration with PENAf and PMAESA. Consideration should also be given to the establishment of Special Areas and or Particularly Sensitive Sea Areas under MARPOL in the region. With respect to international conventions, efforts should be made to promote the ratification of Annexes IV (sewage) and V (garbage) of MARPOL, as well as the Anti-fouling Convention (2001) and the London Protocol (1996).

From a technical perspective, there is lack of detailed information available on marine sources of pollution in most countries due, at least in part, to the fact that the sources are not being adequately managed either because there is limited or no legislation or there is a lack of technical capacity – or both. While there is a limited amount of dumping (as defined in the London Convention/Protocol) taking place in the region, ports in all countries undertake dredging on a reasonably regular basis and that many of them are dumping the dredged material at sea. Moreover, although four of the countries are Party to the London Convention/Protocol, most of them do not appear to be implementing it. In addition, there have been reports of illegal dumping of toxic wastes off of the coast of Somalia. These represent a threat to the region as a whole.

There is minimal information on shipping incidents and associated pollution – although there is information on incidents involving piracy. Information on shipping traffic is outdated although it can be inferred from the port expansion plans that shipping activity in the region is increasing. Similarly, there is limited or no direct information on pollution in ports for most countries, although it is significant that the majority of the pollution hotspots identified by the WIO-LaB project are in or adjacent to ports. Efforts should be made to improve record-keeping and reporting for shipping and port activities.

Offshore oil and gas activities are expanding in most of the countries in the region and although there do not appear to have been any major pollution incidents to date, the risk of spills is increasing. Moreover, the growing number of platforms in the area increases the potential for conflicts with fisheries interests, not only due to pollution but as a consequence of habitat degradation and physical exclusion from drilling areas and abandoned rigs. At the same time, it is likely that the capacity to manage these activities is limited and since many of the companies involved are international, there may be problems of accountability.

Despite the general lack of data, the types of pollutant from marine sources likely to be of particular concern include:

- Litter from vessels, offshore rigs and port activities;
- Petroleum hydrocarbons from shipping, port operations and offshore oil and gas activities (including accidental and operational discharges);
- Tributyltins (TBTs) and other toxic constituents from anti-fouling coatings on vessels and submerged infrastructure;
- Heavy metals and other toxic contaminants (e.g. pesticide residues) which accumulate in port sediments and which may then be discharged into other coastal areas after dredging operations;
- Noise pollution associated with seismic surveys used in oil and gas exploration;
- Suspended solids, accumulated deposits, antibiotics, heavy metals and other toxic constituents associated with the drilling mud used and/or produced water arising from offshore oil and gas exploitation;
- Microbiological pollutants and organic matter arising from sewage and garbage discharges from vessels and drilling rigs/platforms, particularly if those located in shallow waters and/or semi-enclosed areas where water circulation is limited.

There is therefore, in addition to the legal and institutional reforms, a need to introduce and/or enhance the management of all marine sources of pollution through (i) setting of standards as appropriate; (2) implementing monitoring and assessment programmes; (3) development of environmental management plans (for example, for ports, offshore rigs etc); (4) development of Codes of Practice (for example, for ports) and (5) the provision of technical training, particularly for governmental officials. Much of this can be achieved through collaboration with existing programmes and organisational partners already active in the region.