Western Indian Ocean

Situation Assessment on Marine Pollution and Coastal & Marine Water Quality Management

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(Final Draft)

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EXECUTIVE SUMMARY

The Nairobi Convention is an important regional platform for addressing challenges facing coastal and marine ecosystems in the Western Indian Ocean (WIO) through catalytic interventions, dialogue, and partnerships. The Contracting Parties to the Nairobi Convention include Kenya, Mozambique, Somalia, South Africa, Tanzania and the island states of Comoros, Mauritius, Madagascar, Reunion (France) and Seychelles. The governments of these countries have agreed, through a highly consultative process, on a suite of national and regional collective actions that are required to address major stresses on the coastal and marine environment of the region, including:

- 'Implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities (WIOSAP)' - funded by the Global Environment Facility (GEF)
- "The Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy Harmonisation and Institutional Reforms (WIO LME SAPPHIRE)" - funded by the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP)
- "Enforcing Environmental Treaties in African, Caribbean and Pacific (ACP) Countries (ACP-MEA Phase III)" - funded by The European Union.

In terms of coastal and marine water quality management (C&MWQM), it is expected that through improved capacity and the implementation of appropriate strategic frameworks ecosystem integrity can be improved, leading to local socio-economic and environmental benefits, in addition to global environmental benefits. The development of a *regional Strategic Framework for C&MWQM* would, therefore, provide a basis for adopting and integrating this into national coastal and marine water quality frameworks, acknowledging that countries are at different stages of development. Two phases are envisaged, namely:

- Phase 1 - Development of a Strategic Framework for C&MWQM
- Phase 2 - Implementation of the Strategic Framework for C&MWQM at the national and sub-national levels.

This Situation Assessment forms part of Phase I and will inform:

- The development of the Strategic Framework for C&MWQM in the WIO region, as well as (see Strategic Framework Document)
- Revision of *Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas in the WIO region* (see WIO Guideline Document).

While there are numerous problems threatening coastal and marine ecosystems in the WIO region, such as global warming and climate change, destructive fishing practices and coastal degradation, this assessment focuses on key problems associated with marine pollution, constituting the primary need for coastal and marine water quality management (C&MWQM). At the core of C&MWQM is the protection of valuable natural resources, not only to protect biodiversity, but also to protect socio-economic ecosystem services (or benefits) to society.

Ironically, a number of root causes - situated in the social system itself - are significantly contributing to the deterioration and mismanagement of coastal and marine resources, also in the WIO region, including population growth, poverty and inequality, inappropriate governance, inadequate knowledge and awareness, and lack of financial resources. While root causes typically characterise the indirect, underpinning societal dynamics contributing to the deterioration of coastal and marine ecosystems, the major sectors found to contribute directly to marine pollution in the WIO region include urban development and tourism, agriculture and forestry, fisheries and aquaculture, industry and mining, marine transportation and energy production. These occur through various activities, contributing an array of pollutants as is illustrated in Table 1.

Table 1: Major sectors and key activities found to contribute to marine pollution in the WIO region, as well as typical associated pollutants

MAJOR SECTOR & KEY ACTIVITIES SOURCE	TYPICAL POLLUTANTS																
	Thermal pollution	Brine (high salinity)	Discolouration	Solid waste (e.g. litter)	pH	Biodegradable organic matter (affecting O^2)	Suspended/settable solids	Inorganic nutrients	Microbiological contaminants	Toxic inorganics (e.g. S, Cl CN^-, NH^3)	Metals	Petrochemicals	Agrochemicals	Pharmaceuticals	Other persistent organic pollutants	Radioactive matter	Harmful organisms
URBANISATION & TOURISM																	
Municipal wastewater (incl. faecal sludge)						●	●	●	●	●	●			●			
Solid waste disposal				●							●			●			
Diffuse urban runoff				●	●	●	●	●	●	●	●	●	●	●			
AGRICULTURE & FORESTRY																	
Return flows							●	●	●				●				
FISHERIES AND AQUACULTURE																	
Fishing fleet waste				●													
Aquaculture farming				●		●	●	●									●
INDUSTRY & MINING																	
Desalination	●	●								●					●		
Paper & Textile	●		●	●		●	●			●							
Chemical					●	●	●			●	●				●		
Food & Beverages	●		●		●	●	●										
Coastal mining							●										
TRANSPORTATION (SHIPPING, PORTS AND HARBOURS)																	
Oils spills							●					●				●	
Ballast water discharge																	●
Harbour activities				●	●	●	●	●	●		●	●					
Dredge dumping						●	●				●	●			●		
ENERGY PRODUCTION																	
Offshore oil & gas							●			●	●	●					
Oil refineries	●				●	●						●					

Key problems associated marine pollution in the WIO region have been grouped into microbiological contamination, nutrient enrichment (eutrophication), marine litter, suspended sediment loading and toxic pollution, contributing to an array of environmental impacts and socio-economic consequences, as illustrated below.

PROBLEM					ENVIRONMENTAL IMPACTS
Microbial contamination	Nutrient-enrichment	Marine litter	Suspended sediments	Toxic pollution	
	●		●	●	Modification in species composition in marine biological communities
	●		●		Smothering of benthic communities
		●	●		Entanglement/suffocation of marine organisms
			●	●	Chronic toxic effects on marine biota
	●		●	●	Mortality (acute toxic effects) on marine biota
	●				Opportunistic/nuisance/harmful/toxic algal blooms
	●		●	●	Discoloration of coastal waters
	●				Anoxic conditions/bad odours
					SOCIO-ECONOMIC CONSEQUENCES
	●	●	●		Loss of aesthetic value
●	●	●		●	Human health risk through contact recreation
●	●			●	Human health risk through ingestion of contaminated seafood
●	●		●	●	Loss in quality of seafood products
	●		●	●	Loss of fisheries resources and revenue

In 2009, an assessment of the severity of these pollution problems across the region concluded that microbiological contamination and suspended sediment loading contributed most to negative environmental impacts and socio-economic consequences in the WIO region (UNEP et al. 2009c), although marine litter (especially plastic pollution) is becoming a major concern in the region as many of the WIO countries relying on tourism. Also, with the rapid increase in coastal urbanisation (and associated generation of municipal waste) and a projected increase in commercial agricultural and industrial activities in the region, the risk of nutrient enrichment and toxic pollution can be expected to increase markedly in future. Based on the five key marine pollution problems a number of marine pollution hotspots were identified in the WIO region. Not surprisingly, pollution hotspots primarily coincide with the larger coastal cities and towns, where most of the key sources of marine pollution are concentrated. The lack of monitoring programmes at a national level and no linkages between any monitoring activities and management/policy decision making a key issue of concern for most WIO countries. The lack of effective development or implementation of initiatives is often a result of a silo-based, fragmented approach, instead of a more holistic, ecosystem-based approach that is critical for successful management of the environment – in this case the C&MWQM.

Reflecting on the status of C&MWQM at the regional level, Strategic objectives and Targets pertaining to C&MWQM in the WIO region have been defined as per the *Strategic Action Programme Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities* which has been adopted by Contracting Parties into a formal *Protocol on Land-Based Sources and Activities in support of the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region*. The *Strategic Action Programme Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities* set the following Strategic Objective for water quality in the WIO region: *'Water quality in the WIO region meets international standards by year 2035'*. In accordance with the Programme, this Strategic Objective will be achieved when (i.e. indicators of verification):

- Quality of coastal and marine waters in the WIO region meet regionally agreed standards
- Wastewater discharges adhere to agreed national and regional effluent standards

- Increased government budget allocations for pollution prevention.

The Programme further identified a number of specific targets towards achieving these outcomes, mainly focused on mitigating and preventing impacts from land-based sources and activities:

- Effluent discharge standards developed and regionally harmonized
- Marine water standards developed and regionally harmonized (also referred to as *Guidelines for the development of Environmental Quality Objectives and Targets*)
- Regional best practice framework models for municipal wastewater management developed and adopted
- Collection, treatment and disposal of effluents undertaken in accordance with regional standards
- Environmental management systems and cleaner production technologies encouraged
- Stakeholders' sensitized and political support harnessed in favour of pollution prevention.

In 2010, it was decided to also initiate a joint Transboundary Diagnostic Assessment and Strategic Programme of Action process under ASCLME and SWIOFP pertaining to all issues pertinent to the coastal and offshore areas of the LMEs that have not fallen under the SAP of the WIO-LaB initiative. The *Strategic Action Programme for the Sustainable Management of the Western Indian Ocean Large Marine Ecosystems* (SAP WIO-LME) was therefore published. To ensure a comprehensive ecosystem-based approach (watershed to outer offshore boundaries) the two SAPs need to be implemented in collaboration through a cooperative understanding, whilst recognising and respecting the mandates of the various management bodies and institutions. The SAP WIO-LME also identified water quality degradation as a key concern in the region, and posed the following ecosystem quality objectives that pertain to C&MWQM:

- Restore ground and surface water quality and prevent further degradation occurring in the future
- Reduce microbiological contamination in coastal waters
- Reduce solid waste (marine debris) from shipping and land-based sources in coastal water
- Develop the capacity to prevent and mitigate the effects of oil spills at regional and national level.

In response to the above, regional-level achievements in terms of C&MWQM to date include:

- WIO Action Plan on Marine Litter (UN Environment 2018)
- African Marine Litter Monitoring Manual (Barnardo and Ribbink 2020)
- WIO Marine Highway development and Coastal and Marine Contamination Prevention Project (2020)
- Regional oil spill preparedness in eastern Africa and WIO (UNEP et al. 2020a&b).

Reflecting on the status of C&MWQM at the national-level, most countries are signatories to the major international conventions and agreements pertaining to the combating of marine pollution, such as Regional Seas (Nairobi Convention), MARPOL and the Stockholm Convention. At a national level, all countries have some form of legislation in place to enable the control and management of marine water quality, some more advanced than others. However, dedicated management initiatives focusing on marine water quality management is limited, and where policies and plans have been put in place, implementation remains a major challenge. While numerous root causes, such as inappropriate governance, inadequate knowledge and awareness, and inadequate financial resources, will have to be addressed to ultimately achieving effective marine water quality management, there are a few, more direct, measures that could be undertaken to advance improvements in the region. The lack of effective development or implementation of initiatives is often a result of a silo-based, fragmented approach, instead of a more holistic, ecosystem-based approach that is critical for successful management of the environment – in this case the coastal marine environment. Because such programmes are largely lacking in countries of the region, and consequently there is no coordinated and consistent monitoring and reporting of marine pollution matters. This gravely impairs policy decision making, management and intervention to improving water quality.

Within this context the Contracting Parties to the Nairobi Convention urged the Secretariat to establish a Strategic Framework for C&MWQM for the region to fast-track implementation and which should build on refine previous initiatives on C&MWQM previously undertaken as part of the WIO-LaB Programme including:

- Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone of the WIO Region
- Towards a Protocol for long-term monitoring of marine environmental quality in the Western Indian Ocean.

The Strategic Framework should identify key components to be considered in C&MWQM, including monitoring. It is envisaged that a strategic (regional) framework would provide a basis for adopting and effectively integrating C&MWQM into national frameworks, acknowledging that countries are at different stages of development. The framework also should address mechanisms through which countries can contribute to regional reporting on global commitments and agreements, such as the SDGs and Aichi targets. Ultimately, it would also be desirable to develop a regional marine monitoring data repository (or data base) accessible to contracting parties and other interested stakeholders through, for example, the Nairobi Conventions Clearing House Mechanism platform.

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- Timothy Andrew – UNEP
- Theuri Mwangi – UNEP
- Jane Njeri Ndungu – UNEP.

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ACRONYMS

BCLME	Benguela Current Large Marine Ecosystem
CCME	Canadian Council of Ministers of the Environment
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DNE	National Directorate of Environment
DWAF	Department of Water Affairs and Forestry (South Africa)
EC	European Community
EEC	European Economic Community
EQT	Environmental Quality Target
EWURA	Energy and Water Utilities Regulatory Authority
GEF	Global Environmental Facility
GPA/LBA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
INRAPE	National Directorate of Fisheries, the National Institute of Applied Research Fisheries and Environment
ISO	International Organization for Standardization
KMFRI	Kenya Marine Fisheries Research Institute
LC_{50}	Concentration that is lethal to 50% of the test organisms
MARPOL	The International Convention for the Prevention of Pollution from Ships
NEMA	National Environment Management Authority
NEMC	National Environment Management Council
NZME	New Zealand Ministry of Environment
OLEP	Organe de Lutte contre les Evénements de Pollution marine
ONE	National Office of the Environment
OPRC	Oil Pollution Preparedness, Response and Co-operation
POLMAR	National Action Plan against Oil Spills at Sea
RSA	Republic of South Africa
SABS	South African Bureau of Standards
SAMSA	South African Maritime Safety Authority
SDG	Sustainable Development Goals
SMSA	Seychelles Maritime Safety Authority
SST	Sustainable Seas Trust
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Program
US-EPA	United States Environmental Protection Agency
US-FDA	United States Food and Drug Administration
WHO	World Health Organisation
WIO	West Indian Ocean
WIO LME SAPPHIRE	Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy Harmonisation and Institutional Reforms
WIO-Lab	Addressing Land-based Activities in the West Indian Ocean
WIOMSA	Western Indian Ocean Marine Science Association
WIOSAP	Western Indian Ocean Strategic Action Programme
WWTW	Wastewater treatment works

1. INTRODUCTION

1.1 Purpose

The Nairobi Convention is an important regional platform for addressing challenges facing coastal and marine ecosystems in the Western Indian Ocean (WIO) through catalytic interventions, dialogue, and partnerships. The Contracting Parties to the Nairobi Convention include Kenya, Mozambique, Somalia, South Africa, Tanzania, and the island states of Comoros, Mauritius, Madagascar, Reunion (France) and Seychelles. The governments of these countries have agreed, through a highly consultative process, on a suite of national and regional collective actions that are required to address major stresses on the coastal and marine environment of the region, including:

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1.2 Structure of This Report

This Situation Assessment provides a brief overview of the current situation in terms of coastal and marine water quality in countries of the WIO region, to set the scene for the development of a *Strategic Framework for Coastal and Marine Water Quality Management* (C&MWQM) and *the revision of Guidelines for the Development of Environmental Quality Objectives and Targets* (UNEP et al. 2009a). Information for this situation assessment was sourced through readily accessible information (published and grey literature) as well as inputs from country representatives.

This Introductory chapter (Chapter 1) is followed by an overview of the Coastal and Marine System of the WIO region (Chapter 2), highlighting some of the key social root causes hampering effective marine water quality management in the region. Chapter 2 also touches on characteristics of the natural environment, focusing on the most sensitive ecosystems, and on major marine pressures threatening coastal and marine ecosystems in the region.

Chapter 3 delves into issues pertaining to marine pollution in particular, focusing on key sources of marine pollution, organised into six main sectors: urban development and tourism, agriculture and forestry, fisheries and aquaculture, industry and mining, marine transportation, and energy production. Chapter 4 categorizes key forms of marine pollution that create the primary need for marine water quality management - including microbiological contamination, suspended sediment loading, nutrient enrichment (eutrophication), marine litter and toxic pollution. Chapter 5 identifies pollution hotspots in the region and Chapter 6 provides and overview of existing legislation and management interventions dealing with C&MWQM in the region and within each of the participating countries. Finally, Chapter 7 highlights key findings and recommendations for the way forward.

2. OVERVIEW OF COASTAL MARINE ENVIRONMENT

2.1 Social Environment

The Western Indian Ocean (WIO) region, with a combined coastline exceeding 15,000 km, spans the mainland countries of Kenya, Mozambique, South Africa and Tanzania, and the island states of Comoros, Madagascar, Mauritius, Seychelles, and Reunion (France) (UNEP et al. 2015).

Globally, at least 40% of the world's population lives in coastal areas and coastal cities have expanded rapidly over the past decade. The WIO region has been no exception. All countries in the region have experienced rapid population growth and urbanisation in coastal areas, particularly the larger coastal centres. Opportunities created by urbanisation, availability of ports and harbours, and various coast specific developments have attracted high concentrations of people. The countries in the WIO region (including Reunion) had a combined population of 212.6 million in 2014 (Table 2.1). Annual population growth rates in the region vary, with mainland states of Kenya, Tanzania, Mozambique (and Madagascar exhibiting growth rates of over 2% per year. For example, Madagascar's growth rate is an estimated at 3.01%. Kenya has a 2.3% growth rate in coastal areas (compared with the national rate of 3%) while South Africa, although the largest land mass, has the lowest growth rate. The high population density of the small island states has a significant impact on coastal ecosystems due to the movement of people into environmentally sensitive areas. It is predicted that by 2020, approximately 50% of the population in mainland countries, apart from Kenya, will live within the coastal zone (UNEP et al. 2015).

Table 2.1: Country size and total population size versus coastal populations in WIO countries (Gössling 2006; World Bank 2021a)

COUNTRY	SIZE OF LAND AREA (km^2)	POPULATION ($x10^6$) (2019)	ESTIMATED % LIVING NEAR COAST (2000)		
			<25 km	<75 km	<100 km
Comoros	2,170	0.85	100	100	100
Kenya	582,650	52.57	6.1	7.5	8
Madagascar	587,040	25.67	23.2	45	55
Mauritius	2,040	1.27	100	100	100
Mozambique	801,590	30.37	32.7	52.1	59
Reunion	2,517	0.86	100	100	100
Seychelles	455	0.98	100	100	100
Somalia	637,657	15.44	30.5	52.7	55
South Africa	1,219,912	58.56	23.4	35.9	39
Tanzania	945,087	58.00	13.6	17.3	21

The socio-economics of the WIO region are largely dictated by availability and patterns of natural resource utilisation, with significant proportions of the national population living along the coast. A significant proportion of coastal communities in the region depend on coastal and marine resources for their livelihood and income generation. They rely heavily on small scale fisheries as a source for livelihood together with agriculture, subsistence forestry, marine aquaculture, small-scale mining, localised trading, small livestock husbandry, trade in handicrafts, employment in services industries (including oil and gas production), and shipping and port related activities.

Extractive, construction and services sectors, including tourism, are significant drivers of growth. Mozambique has exhibited the highest growth in the region, with a 7% increase in GDP in 2013 and an estimated 8% for 2014-2015. Tanzania's growth rate of approximately 7% in 2013 was centred around the communications, transport, financial intermediation, construction, mining, agriculture and manufacturing sectors. Potential growth is predicted in investments in infrastructure, stabilisation of power generation, fiscal reforms and natural gas reserves (UNEP et al. 2015).

At the core of marine water quality management is the protection of valuable natural resources, not only to protect biodiversity, but also to protect socio-economic ecosystem services (or benefits) to society. Ironically, as is the case elsewhere in the world, a number of root causes - situated in the social system itself - contribute significantly to deterioration and mismanagement of coastal and marine resources (UNEP et al. 2009c):

- Population growth
- Poverty and inequality
- Inappropriate governance
- Inadequate knowledge and awareness
- Inadequate financial resources.

All of the countries in the WIO region have experienced rapid population growth and urbanisation in coastal areas. Demographic changes have been a significant factor in the increased demand for land for housing and associated infrastructure (e.g. sanitation and waste management). Rapidly changing lifestyles, increasing and changing consumption patterns, and rising expectations are a major root cause of pressure on ecosystems. Populations in coastal areas are not evenly distributed, most often concentrated in larger urban coastal centres. Specific issues related to population growth that pose potential risks to the natural environment are, amongst others, sanitation and solid waste management (Jones et al. 2002). If not provided for adequately these issues can result in severe pollution impacts

The WIO region is characterised by some of the highest levels of poverty in the world, demonstrated in low per capita income in the different countries (Table 2.2). Lack of adequate resources is one of the main reasons for insufficient or unsuitable sanitation and solid waste disposal facilities in many of the WIO countries. Alleviating poverty is a major challenge, requiring transparency, progressive development, management of land and water resources, education on effective technologies for both commercial and subsistence farming, and policies for food security. Education, healthcare and empowerment of the people are essential elements for poverty alleviation (UNEP et al. 2009c).

Governance concerns the values, policies, laws and institutions and sets the stage within which management occurs. Inefficiency in the level of governance of marine pollution issues varies from one country to another, and in many of the WIO countries some of these important building blocks for effective governance are not in place.

Knowledge is a key pillar for empowerment of people, empowering society and allowing them to play an active role. Not only is it an important factor in alleviating poverty, but also in combating marine pollution by creating awareness of the consequences of human activities on the marine environment. However, in the countries of the WIO region many people do not have access to appropriate knowledge pertaining to environmental impacts, the socio-economic consequences, or even existing policies and institutional structures that provide enforceable ways of preventing such impacts on the marine environment and the well-being of people. Also important is the value of indigenous knowledge, for examples the knowledge held by fishers on pollution and destruction of critical habitats on fish productivity and fisheries.

Table 2.2: Estimated GDP per capita income for countries of the WIO region (World Bank 2021b)

COUNTRY	GDP PER CAPITA INCOME (USD) PER YEAR (2019)
Comoros	1 370.1
Kenya	1 816.5
Madagascar	523.4
Mauritius	11 099.2
Mozambique	503.6
Seychelles	17 448.3
Somalia	126.9
South Africa	6 001.4
Tanzania	1 122.1

Several countries in the WIO region lack adequate resources to sustain suitable sanitation and solid waste disposal facilities. In some instances, the lack of political will to financially support environmental matters (including marine pollution) also is reflected in the low priority given to environmental budget allocations in countries in the region. The socio-economic consequences of such impacts are also not properly communicated to politicians, knowledge that could change such behaviour (UNEP et al. 2009b). However, industries which depend on clean and healthy environments, such as the tourism and hotel industries, are making efforts to control pollution and to preserve coastal biodiversity.

Root causes, are deeply 'rooted' in the characteristics and dynamics within the social system of any region, and usually take considerable commitment and effort over time to change. Their role in hampering effective marine water quality management can be significant, and it is therefore crucially important to acknowledge them to create awareness of the importance and urgency of tackling these for long-term sustainability.

2.2 Oceanographic Features

Ocean surface circulation in the WIO region (Figure 2.1) is primarily wind driven and is an important feature that strongly influences temperature and salinity distribution, availability of nutrients, distribution and abundance of phytoplankton, fisheries, and the transport and fate of pollutants. The prevailing wind regimes can be divided into two distinct systems; the monsoon regime that dominates the Somali Current Large Marine Ecosystem and the subtropical high-pressure system that dominates the southern region (the Agulhas Current Large Marine Ecosystem) (Beckley 1998; Okemwa 1998; UNEP et al. 2015). Large-scale climatic phenomena, such as the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), influence the meteorology of the WIO region (UNEP et al. 2015).

The Northeast Monsoon affects the climate of the Northwest Indian Ocean from November to March and is characterised by north-easterly winds over the tropics and northern subtropics (Ngusaru 1997). It 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 winds tend to be much stronger, with an intense wind stream developing along the high Eastern African highlands (e.g. Ethiopian highlands, Kenya highlands, highlands of northern and southern Tanzania) (Ngusaru 1997; Slingo et al. 2005).

During the Northeast Monsoon, the North Equatorial Current flows westward, turns south at the coast of Somalia, and returns east as the Equatorial Counter current between 2° and 10° S. 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 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 which originates from the South Equatorial Current (Okemwa 1998; Horrill et al. 2000; American Meteorological Society 2000).

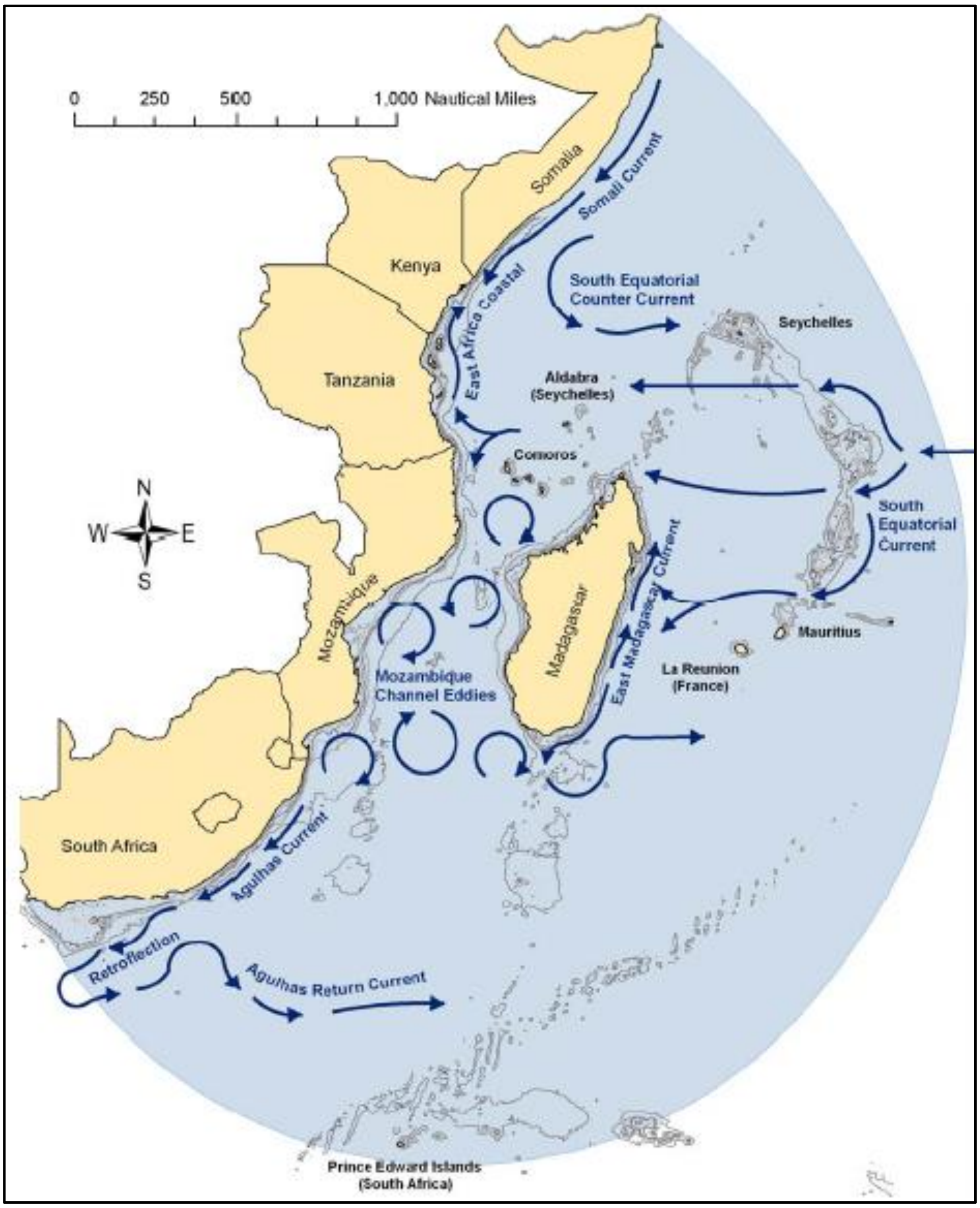

Figure 2.1 Schematic illustration of major surface current patterns in the Western Indian Ocean (Source: UNEP et al. 2009b)

The East African Coastal Current's geographical extent is 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 East African Coastal Current to the East Arabian Current (American Meteorological Society 2000). South of the monsoon region, there is a steady subtropical anti-cyclonic gyre, consisting of the west-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 and turns south as a series of slow-moving gyres or eddies that constitute the Mozambique Current between mainland Africa and Madagascar (Lutjeharms 2006). These drift southward along the shelf edge (Schouten et al. 2002) 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 this current and the Southwest Indian Ocean sub-gyre, with little inflow from the Mozambique Current (Lutjeharms 2006). The Agulhas Current flows along South Africa before turning east and joining the Antarctic Circumpolar Current south of 45° S. It generates periodic gyres between its western boundary and mainland which are responsible for minor upwelling (Lutjeharms 2006). The current system at the eastern boundary of the ocean is not as developed, but the West Australian Current flowing north from the South Indian Current closes the gyre to a certain extent. The Agulhas Current extends to a depth of about 1200 meters and the Somali Current to about 800 meters. Other currents do not penetrate farther than 300 meters. Below the influence of the surface currents, water movement is sluggish and irregular, and is derived from a number of oceanic sources apart from the Indian Ocean. These cold, dense layers, creep slowly northward from their source in the Antarctic Circumpolar region, becoming nearly anoxic (oxygen-deficient) en route.

The WIO region displays all three tidal types, namely diurnal, semi-diurnal and mixed, with semi-diurnal (i.e. twice daily) being most widespread. Semi-diurnal tides prevail on the coast of eastern Africa as far north as the Equator (Hamilton and Brakel 1984). Tides are mixed in the northern region, particularly towards the Arabian Sea (Sheppard 2000). Tidal ranges vary considerably. Mauritius, for example, has a spring tidal range of only 0.5 meters, while along the eastern Africa coast the spring tidal range is of the order of 3-4 meters (Alusa and Ogallo 1992; Hamilton and Brakel 1984; Kanagev et al. 2009).

Falling mostly within a tropical area, air temperature in the WIO region at sea level rarely falls below 20°C and seawater temperature is usually between 20-30°C. Upwelling is a seasonal phenomenon in some parts of the region. 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.

As a result of high seasonal and annual variability in rainfall and evaporation rates the region is subject to large variations in salinity. Sea surface salinity is also affected by anomalous anticyclonic winds blowing in the Southeast Indian Ocean, which prevent the export of saltier water from the WIO region. Overall, the salinity of WIO surface waters varies between 32 and 37, but with large local differences. High surface salinity (greater than 35) 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.

In general, the WIO region is considered to be oligotrophic, characterised by low nutrient concentrations and low phytoplankton biomass. For example, nutrients and primary productivity in surface waters of the Somali Current were found to be generally low except during seasonal upwelling (during the Southwest Monsoon), when colder nutrient rich waters are introduced to the Somali and Arabian coasts (McClanahan 1988; Mengesha et al. 1999). The flow of the South Equatorial Current also delivers higher concentrations of nutrients to the central and northern Mascarene Plateau, resulting in higher levels of productivity in these areas (New et al. 2005).

2.3 Sensitive Ecosystems and Key Threats

The WIO region supports over 11,000 species of plants and animals in numerous ecosystem types. Ecosystems that are particularly sensitive to marine pollution are mangrove forests, seagrass beds, coral reefs and salt marsh ecosystems (UNEP et al. 2009c). These highly productive ecosystems are vital to the ecology and socio-economy of the region, but are negatively impacted by human activity (UNEP et al. 2015).

2.3.1 Mangrove forests

Overview

Mangroves grow along sheltered shores of tropical and subtropical regions (UNEP et al. 2015), thriving in sedimentary lagoons, bays, estuaries and tidal creeks (Alongi 2002; UNEP et al. 2015). In the WIO region these ecosystems are found in all countries except Reunion (France), covering areas of about 1,000,000 ha (Table 2.3), However, 90% of the coverage occurs in estuaries and deltas in Mozambique, Madagascar, Tanzania and Kenya (UNEP et al. 2009c; 2015) (Figure 2.2). The most dominant species found throughout the region are *Bruguiera gymnorrhiza*, *Ceriops tagal* and *Rhizophora mucronata* (UNEP et al. 2004b), but others include *Avicennia marina*, *Avicennia officionalis*, *Heritiera littolaris*, *Lumnitzera racemosa*, *Sonneratia alba*, *Xylocarpus granatum* and *Xylocarpus moluccensis* (UNEP et al. 2015).

Table 2.3: Coverage of mangrove forests in the WIO region (Source: UNEP et al. 2015, unless otherwise indicated)

COUNTRY	AREA (ha)	LOCALITIES OF HIGHEST OCCURRENCES
Comoros	120	Moheli Island, especially in the region of Damou and Mapiachingo
Kenya	46,000 – 54,000	Lamu Archipelago, Tana Delta
Madagascar	279,078	West coast at Mahajanga bay, Nosy Be, and Mahavavy
Mauritius	120 - 145	Rodrigues, Agalega Islands
Mozambique	290,900 - 318,800	Save-Zambezi River complex
Seychelles	2,900	Mahé, Praslin, Silhouette and La Digue
Somalia	1,000	Juba/Shebele Estuary
South Africa	1,631	Warm temperate, sub-tropical and tropical areas along east coast (Adams et al. 2016)
Tanzania	115,500 (Main land) 18,000 (Zanzibar)	Rufiji Delta, Pangani, Wami, Ruvu, Ruvuma Rivers

Mangrove forests are extremely productive ecosystems that support complex food webs consisting of both terrestrial and aquatic organisms. They are vital spawning and nursery grounds for numerous invertebrates, fish, reptiles and birds and provide shoreline protection from storms (UNEP et al. 2015). Key taxa that typically associate with mangroves are bacteria, fungi, macro and micro-algae, polychaetes, bivalves, gastropods, crustaceans, fish, marine turtles and dugongs. These ecosystems also provide visual amenity and aesthetics, shoreline protection from severe wave action and erosion, trap sediment reducing turbidity of coastal waters, and fix, trap and turnover nutrients. Within the WIO region these habitats support major fisheries.

Despite their ecological value, mangrove ecosystems face severe degradation from various human activities such as inappropriate harvesting, clearing for forestation and agriculture, reduction in freshwater flows and marine pollution. Pest infestation, El Niño events and climate change also are impacting mangroves (UNEP et al. 2015).

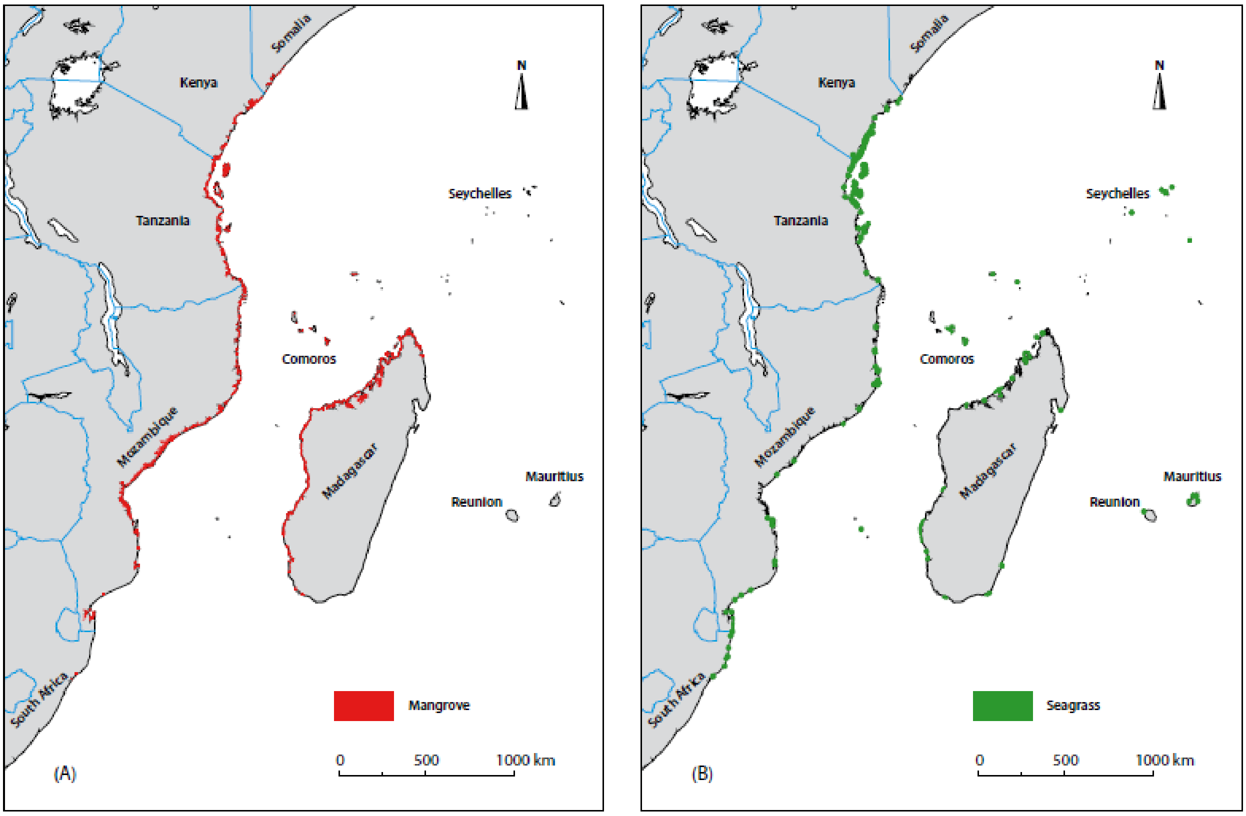

Figure 2.2 Distribution of mangrove forests and seagrass beds in the WIO region (Source: UNEP et al. 2015)

Key threats

Changes associated with climate change, such as sea level rise, increased storminess, and more excessive flooding are influencing the distribution patterns of mangrove ecosystems, through inundation and forced inland migration (Ellison and Farnsworth 1996). The removal of mangrove forests for development, aquaculture, salt production and timber has had cascading effects on these sensitive ecosystems (UNEP et al. 2015). Mangroves are traditionally harvested for wood for heating and building houses. In Tanzania, mangroves in the Rufiji Delta region have been removed to accommodate rice fields, while in Madagascar these ecosystems have been extensively cleared for the construction of shrimp farms (UNEP et al. 2015). Grand Bay in Mauritius is another example where large areas of mangrove swamps have also been removed to provide land for hotel, restaurant and shop construction in Grand Bay (UNEP et al. 2004a). Loss of mangroves has been a source of concern for many years. For example, mangrove forests in Mida and Lamu (Kenya) experienced such over-exploitation that an export ban was implemented as far back as 1975 (UNEP et al. 2004b). The trend nevertheless continues. These losses of mangroves not only affect ecosystem function, but also affect tidal flow and sediment loading in estuaries and shallow coastal waters (Alongi 2002; UNEP et al. 2015).

Destructive fishing methods, such trawling and seining in mangrove areas are known to be damaging to the root systems, as has been observed in Tanzania, Mauritius, Seychelles and Kenya. Dynamite fishing also damages and destroys mangrove trees, and the associated species richness and biodiversity within these ecosystems (McClanahan 2002; Richmond 2002). Increased sedimentation, as a result of catchment degradation, is also a key threat to mangrove ecosystems in the WIO region. For example, Tana and Sabaki rivers in Kenya deposit large volumes of sediment in estuarine and marine environments, negatively affecting mangrove habitats (UNEP et al. 2009c).

The effects of marine pollution on mangrove ecosystems stems from various activities, including inappropriate disposal of waste and wastewater and oils spills associated with harbour activities and shipping. Mangroves act as sinks for pollutants from municipal and industrial discharges, as well as agricultural return flows. Mangrove swamps are commonly targeted for sewage and industrial discharge as the trees filter nutrients and pollutants are absorbed by mangrove soils, algae and microbes (Wong et al., 1997). However, continuous increases in pollution eventually render a mangrove systems absorptive capacities and processes inefficient. Excess nutrients promote the over-growth of algae, smothering and destroying the aerial roots of mangroves. Excessive organic loading also contributes to disease outbreaks, retardation of growth, mangrove mortality and a decline in mangrove biodiversity (UNEP et al. 2009a). This is especially a concern in the larger coastal cities that do not have adequate wastewater treatment facilities, resulting in pollutants being discharged into estuarine waters and mangrove habitats (Richmond, 2002). Many countries still use pit latrines and septic tanks, which contaminate the groundwater that drains into mangrove ecosystems, causing localised eutrophication (Mmochi and Francis 2003). Toxic pollutants (e.g. from industrial discharges) also tend to accumulate in mangrove areas, becoming sources of pollutants to plants and soils, and affecting mangrove growth (Yim and Tam 1999). Herbicides and pesticides also leach into groundwater and surface water runoff causing mangrove defoliation and mangrove dieback (Mmochi and Francis 2003; Schaffelke et al. 2005). Oil spills can also be disastrous for mangrove forests (Munga 1993; Richmond 2002), smothering these sensitive ecosystems (Abuodha and Kairo 2001). For example, spillage from ships has caused considerable damage and destruction of mangrove forests in Mombasa (Kenya), resulting in mangrove dieback and the effects are still evident ten years after the last oil spill (Abuodha and Kairo 2001). Oiling causes mangrove defoliation, chlorophyll-deficient mutations, ands seedling and tree mortality. The recovery of mangrove ecosystems from impacts of hydrocarbons can take several years (Abuodha and Kairo 2001).

2.3.2 Seagrass beds

Overview

Seagrasses are highly productive ecosystems that cover approximately 0.1-0.2% of the global ocean (Duarte 2002), with at least 45 species that are distributed mainly in tropical and subtropical regions. Seagrass beds are a common feature in shallow waters of the WIO region (Table 2.4, Figure 2.2), with 12 species from three different families identified: *Cymodocea rotundata*, *C. serrulata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila ovalis*, *H. stipulacae*, *H. decipiens, H beccarii, Thalassia hemprichii*, *Thalassodendron ciliatum*, *Syringgodium isoetifolium* and *Zostera capensis*. The most dominant genera are *Thalassia*, *Halodule*, *Syringgodium*, *Halophila* and *Cymodocea* (UNEP et al. 2015; Adams et al. 2016).

Seagrass beds occur on soft substrates (sandy or muddy sediments), usually in estuarine and sheltered marine waters (den Hartog 1979; Richmond 2002). They fulfil important ecosystem functions. They are important habitats and nursery areas for numerous organisms, including crustaceans (crabs, shrimp and lobster), echinoderms (sea urchins and sea cucumbers), molluscs (bivalves and gastropods) and fish. Other organisms, such as macroalgae, epiphytes, fungi and a few sponge species, are often associated with seagrasses. These plants are a food source for invertebrates and fishes, as well as for dugongs and marine turtles (Orth 1984; Duarte 2002; UNEP et al 2015). In addition, these ecosystems provide oxygen to waters and sediments, stabilise sediment, protect shorelines, and trap and re-cycle nutrients (Duarte 2002; UNEP et al. 2015).

Seagrass ecosystems are continuously degraded either by direct removal or indirect impacts of land based activities. Globally, seagrass beds are listed as vulnerable, although in South Africa these ecosystems are already endangered due a marked reduction in extent (Van Niekerk et al. 2019). Key threats to seagrasses include climate change, sedimentation, physical destruction of beds (e.g. dredging, trampling and trawling), reduction in river flows (e.g. extended periods of mouth closure of inlets), sedimentation and marine pollution (UNEP et al. 2015).

Table 2.4: Occurrences of seagrass beds in the WIO region (Source: UNEP et al. 2015, unless otherwise indicated)

COUNTRY	LOCALITIES OF HIGHEST OCCURRENCES
Comoros	Mohéli Marine Park, Mitsamiouli, Malé and Ouroveni in Grande Comoro, and Bimbini and Ouani in Anjouan
Kenya	Kiunga, Malindi, Mombasa, Diani-Challe, Gazi Bay and Mida Creek
Madagascar	Shallow coast areas and lagoon throughout the island
Mauritius	Mauritius (55 ha), Rodrigues (649 ha)
Mozambique	Inhassoro and Bazaruto Island, Mecufi-Pemba, southern Quirimbas Archipelago, Inhaca Island
Reunion (France)	Reefal lagoons
Seychelles	Platte, Coetivy and Aldabra
Somalia	Adale to Ras Chiamboni, few beds along north coast
South Africa	Large permanently open estuaries (Adams et al. 2016)
Tanzania	Tanga coast, deltas of Ruvu, Wami and Rufiji rivers, Mafia Island, Songo Songo Archipelago, Kilwa and Chwaka Bay

Key threats

Global warming, associated with climate change, affects metabolic processes such as reproduction, growth, nutrient uptake and photosynthesis, while sea level rise is likely to influence the distribution of these beds as euphotic zones are altered (Duarte 2002; UNEP et al 2015). Activities such as land reclamation, land clearance, forest removal, aquaculture, salt production, mining, and tourism developments have markedly contributed to destruction of seagrass beds in the region. In Seychelles, land reclamation has been taking place since the 1970's, resulting in the destruction of seagrass beds (UNEP et al. 2004a; 2004b). Many tourist areas have had entire seagrass beds uprooted to make beaches more appealing to bathers. Many coastal anthropogenic activities contribute to increased sedimentation, resulting in mechanical abrasion of seagrass leaves and smother seagrass communities (UNEP et al. 2009c). Sedimentation from port activities, dredging and dredge spoil disposal impact on seagrass beds. Seagrass beds near ports in Zanzibar and Dar es Salaam have been completely destroyed due to increased ship traffic and high turbidity (UNEP et al. 2015).

Destructive fishing practices, clam digging, bottom-drag netting, boating and anchoring, have also contributed significantly to the degradation of seagrass beds in the WIO region (Duarte 2002; Richmond 2002; UNEP et al. 2015). Dynamite fishing, although banned in most countries, is still common throughout much of the region, particularly in Tanzania, Mauritius, Seychelles and Kenya (McClanahan 2002; Richmond 2002). Besides killing targeted and untargeted species, the explosions often create craters on the seabed, destroying entire seagrass communities. Even if not practised directly in seagrass habitats, this type of fishing increases turbidity that results in the smothering of these habitats (Richmond 2002).

Marine pollution as a result of inappropriate disposal of waste and wastewater, and oil pollution from harbour activities and shipping, is a major contributor to the decline of seagrass ecosystems. Excessive nutrient inputs from sewage and domestic wastewater discharge stimulate phytoplankton, epiphytes and macroalgae growth, decreasing light availability to seagrass beds (Lapointe and Clark 1992; Schaffelke et al. 2005; Duarte 2002). Seagrass sediments also trap and accumulate organic compounds, resulting in organic-rich sediments that promote microbial activity (Duarte 2002) leading to oxygen depletion and the release of toxic metabolic by-products like hydrogen sulphide and methane (Schaffelke et al. 2005). Agrochemicals, such as pesticides and herbicides, leaching into nearshore waters have been found to inhibit photosynthesis, reproduction and growth in seagrasses (Duarte 2002). Toxic pollutants, such as metals, have been shown to accumulate in seagrass tissue through foliar uptake (Schaffelke et al. 2005). The main consequence of oil pollution on seagrass beds is smothering (Abuodha and Kairo 2001), and to exacerbate problems, dispersants commonly used to clean up oil spills contain toxic solvents that penetrate the protective waxy cuticles of seagrass blades, causing plant loss and harmful effects on associated biota (Ellison and Farnsworth 1996; Abuodha and Kairo 2001).

2.3.3 Coral Reefs

Overview

Coral reefs are shallow subtidal ecosystems found in tropical and subtropical oceans and are among the most biodiverse and productive ecosystems in the world (McClanahan 2002; UNEP et al. 2015). These living structures thrive in shallow, nutrient limited waters up to depths of 20-30 meters (McClanahan 2002). Highly productive coral reefs fringe over 1,500 km of the WIO region coastline (Table 2.5). There are four main classes, with fringing reefs being the most common, generally associated with shallow lagoons. The other three classes include patch reefs, atolls and barrier reefs (UNEP et al. 2015).

Table 2.5: Coverage of coral reefs in the WIO region (Source: UNEP et al. 2015)

COUNTRY	AREA (km^2)	LOCALITIES OF HIGHEST OCCURRENCES
Comoros	430	Fringing and patch reefs around the island
Kenya	630	Northern and southern coasts of the country
Madagascar	2,230	Fringing and patch reefs around the island and the barrier reef, Grande Recife
Mauritius	870	Mahebourg barrier reef of Mauritius and patch reefs around the island
Mozambique	1,860	Quirimbas, Bazaruto, Inhaca, Inhambane
Reunion	<50	
Seychelles	1,690	Fringing and patch reefs around the island
Somalia	710	
South Africa	50	Fringing and patch reefs in Sodwana, St Lucia, Aliwal Shoal and Leadsman Shoal
Tanzania	3,580	Fringing reefs in Tanga, Pemba, Unguja, Mafia and patch reefs in the Zanzibar channel

Corals of the genus *Acropora* are the most abundant and diverse genus found in the WIO region, although since the 1998 bleaching event the geographic range of *Acropora* has become limited to southern Tanzania and northern Mozambique. *Millepora*, once dominant in shallow coral communities, has also experienced a decline in these waters and is now represented in some regions by dead skeletons only. Previously dominant genera are now being replaced by those that are less vulnerable to bleaching, such as *Porites* (Obura 2005). Other genera commonly found throughout the WIO region include *Astreopora*, *Alveopora*, *Cyphastrea*, *Echinopora*, *Favia*, *Favites*, *Galaxea*, *Goniastrea*, *Goniopora*, *Hydnophora*, *Leptoria*, *Montipora*, *Oxypora*, *Pavona*, *Platygyra* and *Pocillopora* (Fagoonee 1990; Obura 2005).

Coral ecosystems support an array of fauna and flora, including macro- and micro-algae, tunicates, sponges, polychaetes, bivalves, gastropods, echinoderms (urchins, star fish and sea cucumbers), crustaceans (prawns, crabs, lobsters, isopods, amphipods), fish, microbes and turtles (UNEP et al. 2015). Besides providing a unique habitat for biota, coral reefs protect the shoreline from strong wave action and erosion, provide construction materials and support local subsistence fisheries and tourism.

Key threats

As with most sensitive ecosystems in the WIO region, coral reefs are also seriously threatened by climate change and human pressures including over-exploitation, inappropriate fishing techniques (poison and dynamite), and marine pollution and litter. Corals in areas of high anthropogenic impacts are also prone to risk from diseases. The presence of the crown of thorns starfish (*Acanthaster planci*), which feeds on corals, and the invasive blue mussel also threaten coral reefs (UNEP et al. 2015).

Across the world climate change is considered one of the biggest threats to coral reefs due to the increase in sea surface temperature, ocean acidification, sea level rise and an increase in the severity of sea storms and floods. Global warming has already caused large scale coral bleaching and mortality to reefs around the world (Wilkinson 1999; McClanahan 2002). Bleaching in 1998 damaged 50-90% of the coral cover in parts of the WIO region, and brought some species to extinction (McClanahan 2002; UNEP et al. 2015). The increase in greenhouse gases, especially carbon dioxide, also alters the balance of carbonate and bicarbonate in the water column, causing ocean acidification that in turn affects calcification processes in reef growth and repair (Wilkinson 1999). Severe storms influence coral reef structure, while major floods result in an excessive flow of freshwater bearing high loads of sediment into shallow coastal areas, and cause reef stress and ecological damage (UNEP et al. 2015).

Destructive fishing methods commonly practiced in the WIO region are a major contributor to coral reef degradation and destruction. Dynamite fishing is the most destructive of these fishing practices and is especially common in Tanzania, Mauritius, Seychelles and Kenya (McClanahan 2002; Richmond 2002; UNEP et al. 2015). Mechanical damage to coral reefs is also caused by coral trampling, boating and anchoring activities (Richmond 2002). Excessive sedimentation smothers and scours coral reefs, and results in a decrease of light available for benthic macrophytes and photosynthetic coral reefs (Schaffelke et al. 2005). Suspended solids also reduce coral growth, recruitment, diversity and abundance (Wilkinson 1999). In addition to the physical destruction of coral reefs, coastal reclamation commonly practiced in the island states where land is at a premium, also results in increased sedimentation that smothers reef systems, as does port and harbour development (UNEP et al. 2004a; 2004b).

The impact of marine pollution is also evident in coral reef ecosystems. Numerous studies have reported high occurrences of diseases, blemishes and dead patches of coral reefs situated in close proximity to urban outfalls (McClanahan 2002). Nutrient loading from inappropriate disposal of sewage and domestic wastewater increases the productivity and biomass of phytoplankton and opportunistic algae, inhibiting light penetration and severely affecting coral growth and survival. Algae may overgrow and smother corals, promoting increased productivity of other opportunist organisms such as sponges and tunicates, which out-compete corals for habitat (Pastorok and Bilyard 1985; Ramessur 2002). Reef invertebrates and fish are vulnerable to toxic pollution (e.g. metals), accumulating these contaminants within soft body tissues and displaying distinct physiological and cytological responses to varying levels of pollutant exposure (Rainbow 1995). In addition, metals are easily absorbed by the tissue of coral skeletons, altering various chemically mediated processes such as reproduction and recruitment. Consequently, such pollutant exposure causes severe modifications to reef productivity and mortality rates (Peters et al. 1997). Studies have shown that corals exposed to oil pollution undergo a variety of negative impacts that include coral tissue death, bleaching and impairment of biological processes such as photosynthesis, reproduction and growth (McClanahan 2002). In addition, dispersants used to clean-up oil leaks contain toxic chemicals that exacerbate the effects of the oil spill and can prolong coral recovery by years (Peters et al. 1997).

2.3.4 Saltmarsh

Overview

Saltmarshes in the WIO region occur in the south and are found almost entirely in South Africa (UNEP et al. 2015; Adams 2020) (Figure 2.3). Here, intertidal and supratidal saltmarshes cover about 5,870 ha and 6,190 ha, respectively. Intertidal saltmarsh typically occurs in permanently open estuaries distributed along the entire coastline of South Africa, but predominantly in warm temperate regions. In turn, supratidal saltmarshes occur at elevations greater than 1.5 m above mean sea level and are dominant in the cool temperate region along the western and south-western coastlines (Adams 2020). Salt marshes also are important in mitigating threats from land, e.g. functioning as a trap for excessive sediments, nutrients and other pollutants to the marine environment.

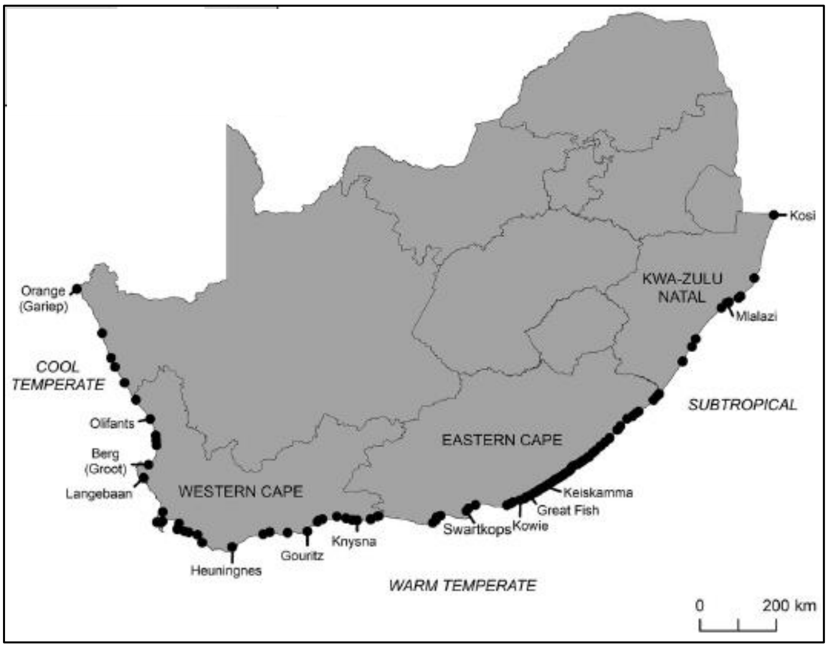

Figure 2.3 Distribution of saltmarsh along South African coastline (Source: Adams 2020)

Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. *Sarcocornia pillansii* is common in the supratidal zone (Adams et al. 2016). Saltmarshes are poorly studied elsewhere in the WIO but small patches are believed to be associated with mangroves and marshlands in the wider region (a small area of saltmarsh has been recorded in Maputo Bay) (UNEP et al. 2015).

Key threats

Saltmarsh ecosystems are threatened by climate change and various human activities, including changes in water abstraction (reduced river flows), flood plain development, and agriculture (resulting in nutrient enrichment through the introduction of fertilizers) (Adams 2020).

Vectors of climate change, such as sea level rise, increase in sea storms, changes in river discharge (droughts/floods), and higher temperatures are posing threats to saltmarsh systems. Sea level rise increases inundation and waterlogging, altering sediment biogeochemistry, while sea storms deposits sediment, closing estuary mouths, but also contribute to erosion in some systems. Climate related changes in rainfall, and consequent modification of river inflows to coastal systems, alters saltmarsh dynamics, with an increase in temperature stimulating plant growth, and possible expansion of mangroves into saltmarsh areas (Adams 2020).

Approximately 43% of saltmarsh habitat has been lost due to encroaching development and agriculture from the 1930s to 2018 (Adams 2020). Loss of intertidal saltmarsh habitat is usually due to inappropriate developments, such as causeways, bridges or encroaching housing and business developments. Agricultural impacts are largely responsible for the loss of supratidal salt marshes associated with crop production and cattle grazing.

Reduction in freshwater flows also impacts saltmarsh vegetation, causing salinisation and desiccation. In turn, extended periods of mouth closure of temporarily open/closed estuaries results in inundation and flooding of saltmarshes. Smothering of saltmarshes as a result of eutrophication (e.g. macroalgal blooms) caused by nutrient enriched sewage discharges and agriculture return flows is a growing concern (Adams 2020).

3. SECTORS CONTRIBUTING TO MARINE POLLUTION

While root causes typically characterise the indirect, underpinning societal dynamics contributing to the deterioration of coastal and marine ecosystems, the major sectors found to contribute directly to marine pollution in the WIO region include (UNEP et al 2009c):

- Urban development and tourism
- Agriculture and forestry
- Fisheries and aquaculture
- Industry and mining
- Marine transportation
- Energy production

Table 3.1 summarises the key activities contributing to marine pollution within these sectors, and the typical pollutants associated with each of these. A brief overview of the status within the WIO region is provided in the following sections.

3.1 Urban Development and Tourism

Of increasing concern in countries of the WIO region is the rapid and often uncontrolled coastal urbanisation and tourism development, as a result of inappropriate management and control of waste. Key activities that contribute to marine pollution include municipal wastewater disposal (including faecal sludge), diffuse urban runoff and solid waste disposal. In many cases, basic infrastructure cannot cope with the increased volume of sewage waste. Sewage from sanitary facilities (septic tanks, pit latrines and wastewater treatment plants) is a major source of marine pollution, with the level of treatment, and the type of treatment (or lack thereof) differing from country to country (UNEP et al. 2009c). Non-centralized sewer systems, such as pit latrines and septic tanks, produce significant quantities of fecal sludge. As a result of inadequate sludge management, this has become a major source of pollution in part of the region. While centralized wastewater treatment works (WWTWs) are found in some parts of the region, the rapid growth in coastal areas has led to a marked increase in effluent volumes, challenging infrastructure maintenance and upgrades. Microbial contaminants, nutrients, biodegradable organic matter and suspended solids are the main pollutants in untreated municipal sanitary wastewater. The highest concentrations of these pollutants are therefore found close to major cities in the region, although in many rural coastal areas low-level sewage contamination from defecation on beaches is common. Urban stormwater can also introduce toxicants, such as metals and petroleum hydrocarbons, associated with road runoff. Available information on the estimated volume of municipal wastewater that potentially enters coastal and marine environments in the WIO region is summarised in Table 3.2 (as updated from UNEP et al. 2009c). Recent studies have also shown inadequately treated wastewater is a major route by which microplastics enter water bodies (Ubomba-Jaswa and Kalebaila 2020). Municipal solid waste is a major source of marine litter in coastal areas (Table 3.1).

In the Comoros, the increase in the population and urbanisation has led to an increase in household waste production, untreated hospital waste and emissions associated with transport activity. There are no formal waste collection and processing structures in place. Garbage is disposed along roadways, into the sea or rivers, and in the vicinity of where people live. There is no sewerage, drainage and evacuation of wastewater treatment networks in the Comoros (ASCLME 2012a). In

Kenya, most urban centres, such as Mombasa, Kilifi, Lamu and Malindi, are not able to effectively dispose of sewage. Increased development in river basins has also contributed significantly to suspended sediment loading into the coastal environment (ASCLME 2012b).

Parts of Madagascar do not have sewage disposal facilities and wastes are discharged into estuarine and shallow waters (UNEP et al. 2009c; ASCLME 2012c). In Mozambique, the capital city Maputo is the only city with a sewage infrastructure, but which treats only about 50% of the city's sewage. Sewage contamination has also been recorded in Beira Bay and Nacala Bay, although levels were lower than those recorded for Maputo Bay. The rest of Mozambique mainly relies on pit latrines and septic tanks, which contaminate groundwater systems (ASCLME 2012d).

Table 3.1: Major sectors and key activities found to contribute to marine pollution in the WIO region, as well as typical associated pollutants

MAJOR SECTOR & KEY ACTIVITIES SOURCE	TYPICAL POLLUTANTS																
	Thermal pollution	Brine (high salinity)	Discolouration	Solid waste (e.g. litter)	pH	Biodegradable organic matter (affecting O^2)	Suspended/settable solids	Inorganic nutrients	Microbiological contaminants	Toxic inorganics (e.g. S, Cl CN^-; NH^3)	Metals	Petrochemicals	Agrochemicals	Pharmaceuticals	Other persistent organic pollutants	Radioactive matter	Harmful organisms
URBANISATION & TOURISM																	
Municipal wastewater (incl. faecal sludge)						●	●	●	●	●	●			●			
Solid waste disposal				●							●			●			
Diffuse urban runoff				●	●	●	●	●	●	●	●	●	●	●			
AGRICULTURE & FORESTRY																	
Return flows							●	●	●				●				
FISHERIES AND AQUACULTURE																	
Fishing fleet waste				●													
Aquaculture farming				●		●	●	●									●
INDUSTRY & MINING																	
Desalination	●	●								●					●		
Paper & Textile	●		●	●		●	●			●							
Chemical					●	●	●			●	●				●		
Food & Beverages	●		●		●	●	●										
Coastal mining							●										
TRANSPORTATION (SHIPPING, PORTS AND HARBOURS)																	
Oils spills							●					●				●	
Ballast water discharge																	●
Harbour activities				●	●	●	●	●	●		●	●					
Dredge dumping						●	●				●	●			●		
ENERGY PRODUCTION																	
Offshore oil & gas							●			●	●	●					
Oil refineries	●				●	●						●					

In the Seychelles, effluent from wastewater treatment works discharging directly to coastal waters was found to contain unacceptable levels of faecal contamination (Antoine et al. 2008). At Beau Vallon Bay, run-off from non-point sources, such as rivers and small streams, has been found to contribute to high microbial loads during the rainy season (Radegonde 1997; Antoine et al. 2008). Outbreaks of water borne diseases usually occur during the rainy season, associated with defective wastewater disposal systems. Septic tanks are the most common human waste disposal option in Somalia with only a small section of Mogadishu having sewage systems (ASCLME 2012f).

Since about 1985 the design of offshore sewage outfalls in South Africa has followed the receiving water quality objectives approach, where effluent quantities and composition must be within limits that meet receiving water quality objectives. Generally, long-term environmental monitoring programmes at these outfalls have indicated no marked or widespread detrimental impact on the marine environment or its beneficial uses (in terms of chemical and microbiological contamination). Of greater concern is the rapid increase in discharges to less dynamic and sensitive areas such as surf zones and estuaries, where effluents from malfunctioning or overloaded treatment facilities are adversely affecting the ecosystems and their beneficial uses (DEA 2016). Estuaries in particular are increasingly negatively impacted, to the extent that eutrophication and fish kills are now recurring problems in some urban systems (Van Niekerk et al. 2019). Many smaller coastal towns still rely on conservancy or septic tanks for sewage disposal. Overflows and seepage from these tanks can cause nutrient enrichment in estuaries and the coastal environment, while untreated sewage from bucket toilets, pit latrines and septic tanks also poses a risk to coastal water quality in rural areas (ASCLME 2012g).

Atmospheric Emissions:

Atmospheric pollutants potentially also contributing to marine pollution originate from several sources, such as:

- Fossil fuel fires: a large majority of coastal communities in the WIO region use fossil fuel for their domestic energy needs (this is therefore also an issue linked to the energy production sector)
- Traffic emissions: motor vehicles emissions can contribute significantly to atmospheric pollution
- Forest burning for land clearing: urban development adds pressure on land for growth
- Air emission from industries and energy production
- Solid waste dump sites and burning of waste.

However, data on the contribution of atmospheric emissions to marine pollution in the WIO region are limited, or even absent. This needs to be addressed by improved quantification and assessment.

In Tanzania, the growth in coastal populations has resulted in increased volumes of wastewater and solid waste (including faecal sludge), especially in cities such as Dar es Salaam, Tanga and Mtwara. In these cities the only means of sanitation for more than 90% of the population in pit latrine and septic tank producing large amounts of faecal sludge and where adequate sludge management has become a major challenge. In some areas damage to sewer pipes has led to discharge of untreated sewage onto sand- and mudflats near the harbour (ASCLME 2012h). On the island of Zanzibar sewage runoff from Zanzibar Town contributes to contamination (nutrients and microbiology) of adjacent coastal waters (Nyanda et al. 2016).

Litter patterns during COVID-19 pandemic lockdowns

In 2020 Ryan et al. (2020) used lockdowns during the COVID-19 pandemic to investigate the effect of human activity on street litter. Their study showed a three-fold reduction in street litter in two South Africa cities during a period of strict lockdown. However, as lockdowns were relaxed litter gradually increased again. While it may not be surprising, their study does re-emphasise that people are the primary cause of litter and that effective mitigating strategies need to focus on changing behaviours.

A feature common to all countries is that most land-based sources of solid waste are associated with urban centres, particularly informal settlements and industrial and commercial areas, and that runoff is the main distributor via rivers, streams and stormwater drains (Lane 2007). The major sources of solid waste contributing to marine litter in each of the countries of the WIO region are presented in Table 3.3.

Table 3.2: Summary of major sources of marine litter in the countries of the WIO region (Lane 2007, unless otherwise referenced)

COUNTRY	MAJOR SOURCES
Comoros	Of concern is waste from hospitals, including compresses, syringes, braiding, packaging, plastic, glass and human waste discharged in open dumpsites, usually in the vicinity of the hospitals (Abdallah et al. 2006). Direct dumping of garbage onto the beach or the sea, wrecked vehicles, ships, and appliances (UNEP and WIOMSA 2008; UN Environment 2018).
Kenya	The major sources of marine litter are reported to be beach recreation (66%), shipping (14%), dumping and surface runoff from urban areas.
Madagascar	Marine litter mostly comes from land-based sources such as discharge from stormwater drains and untreated municipal sewerage consisting mainly of plastic wrappers, bottles, bottle caps, plastic bags, cigarette butts and plastic containers.
Mauritius	Marine litter arises chiefly from beach recreation, surface runoff from urban areas and from rivers. The volume of ship-generated garbage is far smaller than land-generated volumes.
Mozambique	Beach users, garbage from shipping, fishing gear, road users and urban stormwater runoff are the major sources of litter.
Reunion	Major source of marine litter is residential, fishing “ghost net” and shipping. Waste from shipping arrives by ocean currents from countries such as Hawaii, Indonesia, Australia and Mauritius. Types of waste include; car shells, fridges, wheels, metallic tubes, pieces of glass, batteries and fishing nets. Plastic bottles and plastic bags dominate, and cause hazards to marine turtles (UN Environment 2018).
Seychelles	Most litter is from water runoff from rivers and storm drains (despite daily cleaning) from port wastes and particularly from public eating spots or picnic areas. Data are not available for litter generated by the fishing industry.
South Africa	The major source of marine litter is surface runoff from urban areas (via rivers and storm drains), confirmed by (a) litter deposition being greatest in the rainy season with higher levels close to urban areas; and (b) the high proportion of locally made articles (96%) in stranded litter. Commercial, industrial and low income residential areas produce most litter. Ship-generated waste is trivial compared to land-based litter sources. Some litter comes across the South Atlantic in the West Wind Drift from Argentina, Uruguay and Brazil. Marine litter on uninhabited oceanic islands derives from local and foreign fisheries, and distant continents. Litter mostly consists of single - use items and packaging such as paper and plastic food wrapping, cans, plastic bottles, cigarette packets and cigarette butts. These items accumulate in public places such as public parks and gardens, shopping centres, car parks, railway and bus stations, public bins, landfill sites and recycling depots. Despite its small proportion (~6%) compared to total land area, urban areas produce most solid debris found in river catchments (UN Environment 2018).
Tanzania	The major source of marine litter arises from uncontrolled disposal of solid wastes in unplanned settlements where, for example, about 70% of Dar es Salaam’s population live in unplanned areas. Most litter is from surface runoff, illegal dumping into river valleys and drainage from crude, open dump sites located near the beach and rivers. Marine litter also arises from fishing and shipping, as the important economic city of Dar es Salaam has a moderate-sized port and fishing is a major activity amongst the coastal communities. The latter are presumed to contribute a significant quantity of gear, boats, traps and plastic bottles in marine litter.

Mauritius has shown the ability to contain solid waste from the island. Mozambique, despite poverty and governance challenges, similarly contributes very little to the marine litter load. This is because it has a very poor transport infrastructure and the vast majority of the population lives in rural poverty with limited access to products with plastic packaging. Additionally, informal recycling of most salvageable products is commonplace. These factors have kept solid waste loads, that may contribute to marine litter, under control thus far but this situation may change (Lane 2007).

Marine litter has been researched in South Africa for over two decades and there is information on the abundance, distribution and trends of different types of litter found around the coast. Studies by the City of Cape Town have shown that the primary origin of waste was from informal settlements on the banks of canals. There seems to be an increase in plastic litter during rainy seasons (Verster and Bouwman 2020).

Seychelles has a good waste management system in place and has almost no marine litter generated from the island. There is relatively little information on the quantities, types and characteristics of solid waste that contribute to marine litter in Tanzania, Madagascar and Kenya. It is, however, known that large quantities of litter from urban areas reach the sea. The main reason for the littering is that none of these countries has an adequate solid waste management system (Lane 2007). Also a concern is that the vast majority of marine litter in the small island states comes from the eastern Indian Ocean, where the challenge is not only to reduce local pollution, but how to clean up litter from elsewhere. However, in Madagascar NGOs (e.g. Manaomanga) are taking initiatives to collect marine litter by sensitizing local community and to recycle plastic waste into furniture, contributing to blue economy initiatives.

3.2 Agriculture and Forestry

Agriculture is the backbone of the economies in most countries in the WIO region and central to the alleviation of poverty. Agriculture contributes to marine pollution primarily through return flows from agricultural areas in adjacent catchments, introducing pollutants such as suspended solids (the result of erosion due to inappropriate land-use practices), inorganic nutrients (excessive use of fertilisers), pesticides (persistent organic pollutants) and microbial contaminants (typically associated with runoff from livestock rearing areas). Slash and burn clearing for subsistence agriculture adds to the atmospheric pollution in some countries. Pollutants from agricultural activities usually enter the marine environment through river discharges, although agricultural activities adjacent to coastal areas can directly contaminate coastal waters through surface or sub-surface runoff (UNEP et al. 2009c).

In the Comoros, agricultural production occupies approximately 67% of land and accounts for 98% of export revenue. Vanilla, ylang-ylang and cloves are mainly grown for the export market, with cereals, rice, potatoes, fruits and legumes grown for local consumption. Steep slopes and continuous cultivation without provision of fallow fields has led to the impoverishment of the soil and incidents of serious soil erosion, and subsequent siltation of coral reefs. As a general rule, the use of pesticides and fertilisers for market gardening is limited. Almost all organic waste coming from agricultural practices is reintroduced into the soil to improve fertility (Abdallah et al. 2006).

Agricultural activities in Kenya's coastal region is mostly for subsistence, although commercial farming occurs in proximity of coastal areas near Mombasa, Kilifi, and Lamu, as well as inland from where agricultural pollutants are transported to the coast by rivers, particularly during the rainy season (Barasa et al. 2007). For example, the Tana and Athi rivers drain hinterland agricultural areas, carrying significant quantities of nutrients into their estuaries. Livestock rearing is another major source of pollution from agricultural activities in Kenya with some of the busiest slaughterhouses also being located on the farms (UNEP et al. 2009c). Siltation has been found to cause shadowing and/or smothering of coral reefs and seagrass beds along adjacent coasts (Munga et al. 2006). Coastal forest degradation also has contributed to increased erosion and sediment loading to coastal areas, for example in Malindi-Ungwana Bay (ASCLME 2012b) and Mwache Creek in Mombasa (Bosire et al. 2014) precipitating extensive mangrove die-back.

In Madagascar, agriculture contributes significantly to the GDP and employs more than 70% of working people, especially for the cultivation of rice and cattle rearing (ASCLME 2012c). Small areas of intensive production of sugar cane and cotton are located in the southwest and northwest of the country, where the greatest quantities of fertilisers and pesticides are applied. Bush-fires, harvesting of forests for production of charcoal, and clear-felling for agricultural purposes contribute to serious erosion and subsequent sediment loading to coastal and marine environments (UNEP et al. 2009c).

In Mauritius, cultivated land covers almost 50% of the island, mostly sugar cane, tea, tobacco and food crops. The island has a long history of pesticide use, importing significant amounts agrochemicals, which point to potential impacts on the coastal environment. The vast majority of the country's small scale farmers use hand sprayers, resulting in wastage and spillage of the pesticides. However, over the past decade there has been a systematic conversion of agricultural lands to land for industrial and urban development, and associated with this here has been a relative reduction in the utilisation of agro-chemicals (UNEP et al. 2009c). Most agricultural activity in Mozambique occurs along rivers, and these are the main pathways of agrochemicals to coastal areas. DDT is officially banned in Mozambique, but it is still being used in the country and neighbouring regions (ASCLME 2012d).

Pollution from agricultural activities has not been properly assessed in the Seychelles. However, as agriculture does not represent a significant proportion of land-use it is not considered to be a major source of marine pollution. Agriculture takes place on a local scale, often for own use only (UNEP et al. 2009c). In South Africa, river discharges draining intensive agricultural areas are considered a major pathway of pollution. Nutrient enrichment has resulted in large scale eutrophication in estuarine systems (Adams et al 2020). Of concern is the potential impact from agrochemical inputs that have not been properly monitored (Van Niekerk et al. 2019).

Most of the agricultural activities in Tanzania occur in river valleys and flood-plains where agrochemicals are known to be used to control pests and diseases and to improve yields (UNEP et al 2009c). In Zanzibar, agricultural activities are still artisanal in nature, dominated by the cultivation of food crops rather than cash crops, with sugarcane being cultivated in the northern district. The use of fertilisers and pesticides has remained relatively low, and are mainly used in rice and sugarcane cultivation. Poor management of livestock also contributes to coastal pollution. The destruction of coastal forests contributes to high suspend solid loading in coastal areas, although no quantitative data are available to confirm this (UNEP et al. 2009c).

Even without substantial scientific evidence of existing impacts, it can be expected that marine pollution associated with agricultural activities will increase in coming years and will require environmentally-sustainable interventions, especially in the large river basins discharging into coastal areas.

3.3 Fisheries and Aquaculture

Although aquaculture is still relatively poorly developed in the region it is an emerging sector that could have deleterious effects on marine water quality (UNEP et al. 2009c). Activities that are currently undertaken include the farming of crustaceans (e.g. shrimp, prawns and crabs) and seaweed in the Seychelles and Madagascar, crustaceans in Mozambique, and seaweed in Tanzania (WIOMSA 2007; ASCLME 2012d). There are a few marine aquaculture activities along the south coast of Kenya, including eight finfish farms, six crab farms and four prawn farms. These are all being produced for domestic consumption (ASCLME 2012b). Finfish, abalone, mussels and oysters are farmed in South Africa, with most aquaculture operations in the temperate regions. Typical pollutants associated with aquaculture include solid waste, nutrients, biodegradable organic matter (e.g. faeces), suspended solids, and harmful organisms (e.g. diseases) (Table 3.1).

Fishing fleets also contribute to marine litter, along with other vessels (UNEP and WIOMSA 2008). Marine litter found on isolated, inaccessible islands, far from urban cities suggest its origin to be from shipping and fisheries activities (Barnardo and Ribbink 2020). Marine-based sources of litter include ghost gear, dumping of garbage, and although not as significant as land-based sources, it is more difficult to control due to the heavy commercial and fishing vessel traffic in the region. In addition, ocean currents transport litter thousands of kilometers from where it originates, making this a transboundary issue in the WIO region (Lane 2007; UNEP and WIOMSA 2008).

The 'Southern South African waters' is classified as a Special Area under MARPOL Annex I, which prohibits the discharge of garbage anywhere south of 60°S. Along remote areas of northern Kenya and part of the Mozambican coast, litter from fishing and shipping dominates the beaches, with illegal foreign fishing vessels considered to be significant contributors to litter loads. Mozambique has reported increasing volumes of litter, including flares used in illegal night fishing (UNEP and WIOMSA 2008).

3.4 Industry and Mining

Industries and mining activities are becoming sources of marine pollution through, for example the inappropriate disposal of wastewater and solid waste. Most of the economies of WIO countries, in addition to depending on agriculture, also rely on food processing industries such as breweries, distilleries, fish processing plants and sugar mills. Other significant industries include textiles, tanning and paint manufacture. These industries dispose large amounts of toxic contaminants into estuaries and shallow coastal regions (UNEP et al. 2009c) (Table 3.1).

In the Comoros, industries are mainly associated with the processing of agricultural and livestock products (including food processing), although their contribution to coastal pollution (in terms of biodegradable organic matter, suspended solids and solid waste) has been considered to be small in comparison to waste from domestic sources. On the Kenyan coast, most industries are situated in Mombasa, Kilifi and Lamu districts. Few of these have been found to treat their wastewater, and either discharge effluents to municipal sewers or stormwater drains. Large quantities of solid waste are produced by cashew nut and sisal processing factories (Mwaguni and Munga 1997). The highly productive food processing, metal and textile industries in Kenya directly discharge untreated wastes into the Kilindini Harbour and Port Reitz, negatively affecting the health and productivity of sensitive ecosystems such as coral reefs (Mmochi and Francis 2003). Titanium mining along Kenya's south coast poses potential pollution threats to coastal ecosystems (Abuodha and Hayombe 2006).

In Madagascar, most industries are situated in coastal urban centres, mainly near the ports of Antsiranana, Ambilobe, Mahajanga, Tolagnaro and Toamasina, focusing mainly on seafood processing, sugar extraction, oil and soap production, breweries, tanneries and sisal production (ASCLME 2012c). The majority of these industries do not treat their waste, and where there is some treatment, it is limited to coagulation and decanting, or to decanting only prior to discharge into a treatment system or directly into the sea (UNEP et al. 2009c). While larger mining concerns in Madagascar are required to treat and monitor their effluents in accordance with agreed environmental management plans, the expansion of small scale mining, particularly gold mining using mercury, is becoming a much larger threat to pollution of rivers discharging into the sea.

Plaine Lauzun, Vacoas-Phoenix and Coromandel are the main industrial zones in Mauritius. Sugar processing plants (the largest contributor), textiles (e.g. dye houses), breweries and food processing plants mostly discharge to municipal treatment works (UNEP et al. 2009c). However, some sugar processing plants release waste products directly into rivers and canals that empty into shallow coastal areas (Mmochi and Francis 2003). Various other industries on the island, such as steel mills, galvanising, electroplating and battery factories, discharge their wastes directly into rivers (Grand River North West and St. Louis River) which empty into marine systems (Ramessur 2002).

Most industrial facilities in Mozambique are located in the coastal cities of Maputo, Matola and Beira and include textile, paper and tyre factories as well as a brewery. Most of those in Maputo discharge untreated wastewater into the Infulene River that drains into Maputo Bay (ASCLME 2012d).

Industries potentially contributing to marine pollution in the Seychelles mainly comprise food processing and chemical industries (Radegonde 1997). Industries such as canning and brewing also discharge considerable amounts of waste into estuarine waters of the island (Mmochi and Francis 2003; ASCLME 2012e).

In Somalia, untreated waste from tanneries, slaughterhouses and fish markets are discharged to sea (ASCLME 2012f). Toxic chemical and solid wastes are dumped at the sea on a regular basis. Contamination from dumpsite leachate is also a source of pollution, especially during the rainy season (ASCLME 2012f).

In South Africa, the disposal of industrial wastewater to sea occurs mainly in the larger urban coastal centres (e.g. Durban and Richards Bay) with an estimated 722,151 m^3 being discharged daily into marine or estuarine waters (DEA 2016; Van Niekerk et al. 2019). Most of this effluent is discharged to the offshore environment through properly designed marine outfalls that are subject to regular environmental monitoring and assessment studies. Mining of sand, diamonds and heavy minerals also occur along the South African coast, contributing to suspended and settleable matter, and other potential pollutants.

Most of the larger industries along the coast in Tanzania are located in Dar es Salaam, with some growth also occurring in Tanga around the country's second largest seaport. Industries include food processing industries (agro-industries), chemical factories, breweries, soap and steel manufacturing plants. Most of these industries discharge wastewater into the Msimbazi and Mzinga Creeks (Mgana and Mahongo 1997; 2002). Various other industries contribute to the untreated waste loads entering estuaries and shallow coastal environments (Mmochi and Francis 2003). Industrial activities in Zanzibar are mainly located in the Saateni, Maruhubi and Mtoni areas, and include food processing (slaughter houses, dairy products and beverages) and chemical (soap production) industries, generating significant biodegradable wastes and suspended solid loads.

3.5 Transportation

The WIO region serves as a major oil tanker route stretching along the east African coastline and ferrying millions of tons of oil each year. Major sources of marine pollution include oil spills and ballast water discharge (Table 3.1, UNEP et al. 2015). The region has experienced major oil spills, including those from the Cavalier in Mombasa (Kenya (1972), the Katina P. in Mozambique (1992), the Castillo De Bellver in South Africa (1983), and most recently the MV Wakashio along the Mauritian coast (2020). Such spillages result in major damage to coastal ecosystems and associated tourism industries, with detrimental impacts still evident years after the incident (Abuodha and Kairo 2001). The high volume of shipping, for example at Richards Bay and Durban, has resulted in the increased threat of alien species being introduced into the region (ASCLME 2012g).

Most of the large urban centres in the WIO region have large commercial ports and smaller harbours. Activities such ship maintenance and repair, disposal of garbage and dredging contribute to marine pollution. The major ports, as well as some of the key associated pollution issues are summarised in Table 3.4.

Table 3.3: Major ports in the countries of the WIO region and associated marine pollution issues (Source: UNEP et al. 2009c)

COUNTRY	MAJOR PORT/HARBOUR	MAJOR ISSUES
Comoros	Mutsamudu	Located near a river and is becoming shallower as a result of continued sedimentation, reducing its capacity to accommodate larger ships and vessels
Kenya	Kilindini (Mombasa)	The port area is subjected to environmental perturbation due to shipping and other marine and land-based activities. Periodic dredging in the port and approach channels for maintenance and expansion of facilities re-suspends considerable quantities of particulate material and associated pollutants (e.g. nutrients, heavy metals, persistent organic pollutants, etc.)
Madagascar	Numerous ports, e.g. Antsiranana, Mahajanga, Toamasina and Toliara	Spillage of pollutants during loading and offloading, lack of facilities to handle garbage, oil residues and wastewater from vessels and lack of facilities to remove wrecks
Mauritius	Port Louis	Dredging is undertaken on an ad hoc basis for maintenance of existing channels as well as for port development
Mozambique	Maputo, Beira and Nacala and several small ports e.g. Inhambane, Quelimane, Pebane, Angoche and Pemba	No specific issues have been listed, but major issues are most likely associated with dredging and spills. Waste management in Maputo harbour is a major issue (solid waste enters the port through streams/surface runoff during rainy seasons)
Seychelles	Port Victoria	Dredging, land-reclamation, waste from rivers and fishing vessels, food processing plants (cannery
South Africa	Richards Bay, Durban, East London, Port Elizabeth, Ngqura, Mossel Bay, Cape Town, Saldanha Bay	Contribute to marine pollution through poor operational practices and dredging activities
Tanzania	Dar es Salaam, Tanga, Mtwara and Zanzibar	Heavy metals and organophosphates levels in sediments are of concern, while other issues are mostly associated with dredging operations and chemical spills. There are also waste management problems

3.6 Energy Production

The energy production sector influences marine water quality mainly through thermal discharges of cooling water, oil spillage, and toxic pollutants (e.g. petrochemicals) (Table 3.1). Specific activities include oil and gas exploration, extraction and petroleum refineries.

Kenya, Madagascar and Seychelles are exploring for oil and gas due to the increase in energy demand. Tanzania has been producing natural gas for years. The Songosongo and Mtwara region and natural gas finds in Cabo Delgado, northern Mozambique, are the largest global finds in 20 years (UNEP et al. 2015).

In Kenya, a petroleum refinery at Changamwe use to produce hazardous sludge (containing toxic substances such as hydrocarbons and heavy metals) which is dispersed on agricultural land within the refinery grounds (UNEP et al. 2009c). However, the refinery ceased operation in September 2013 and the facility is currently being used as a terminal for imported petroleum products for the local market, and for crude oil (for export) extracted from the South Lokichar basin in Turkana, north Kenya.

4. KEY MARINE POLLUTION PROBLEMS

Key problems associated with marine pollution in the WIO region have been grouped into:

- Microbiological contamination
- Nutrient enrichment (eutrophication)
- Marine litter
- Suspended sediment loading
- Toxic pollution.

An overview of typical environmental impacts and socio-economic consequences of these problems is summarised in Table 4.1 (UNEP et al. 2009c).

Table 4.1: Overview of key impacts associated with the key problems linked to marine pollution in the WIO region (Source: UNEP et al. 2009c)

PROBLEM					ENVIRONMENTAL IMPACTS
Microbial contamination	Nutrient-enrichment	Marine litter	Suspended sediments	Toxic pollution	
	●		●	●	Modification in species composition in marine biological communities
	●		●		Smothering of benthic communities
		●	●		Entanglement/suffocation of marine organisms
			●	●	Chronic effects on marine biota
	●		●	●	Mortality (acute effects) on marine biota
	●				Opportunistic/nuisance/harmful/toxic algal blooms
	●		●	●	Discoloration of coastal waters
	●				Anoxic conditions/bad odours
					SOCIO-ECONOMIC CONSEQUENCES
	●	●	●		Loss of aesthetic value
●	●	●		●	Human health risk through contact recreation
●	●			●	Human health risk through ingestion of contaminated seafood
●	●		●	●	Loss in quality and value of seafood products
	●		●	●	Loss of fisheries resources and revenue

4.1 Microbiological Contamination

Microbial contamination refers to the presence of pathogenic organisms (protozoa, bacteria and viruses) of either human or animal origin in the aquatic environment that can pose health risks to humans. Many human diseases in coastal areas are water-borne and directly associated with poor water quality. These include diseases such as dysentery, cholera and diarrhoea. In coastal waters, infection during recreation activities, consumption of contaminated seafood and diseases in marine organisms are the main pathways of impacts from microbiological contamination.

In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater (including sewage), contaminated runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing, and industrial effluents (e.g.

from food processing industries). Loss, or potential loss, of the recreational value of coastal waters due to microbiological contamination is evident throughout the coastal zone of the WIO region. In many areas the situation is exacerbated by poor aesthetics and bad odours (UNEP et al 2009c).

Studies conducted around Taolagnaro (Madagascar) use to show high bacteriological contamination in coastal waters, which was attributed to defecation on the beaches as well as inappropriate treatment of municipal wastewater. Although untreated municipal wastewater associated with urban runoff still remains concern, an NGO sanitation initiative have led to the construction of public toilets and cleaning of beaches have been occurring, also sensitizing local populations to change behaviour. Human illnesses associated with the consumption of contaminated seafood such as molluscs have also been reported. Studies in Mahajanga and Nosy Be also confirmed microbial pollution in some waters along these parts of the coast (UNEP et al. 2009c). In Maputo Bay (Mozambique), microbial contamination has been recorded in shellfish and *Vibrio* spp. has been found to be the main cause of severe gastro-intestinal illnesses in Matola (Fernandes 1996). Areas in Maputo Bay in close proximity to sewage discharges, such as Miramar near the entrance of the Maputo Estuary, are not considered safe for swimming (ASCLME 2012d). Faecal contamination has also been reported in Beira Bay and Nacala Bay, although not as severe as in Maputo Bay (Fernandes 1995).

In Mauritius, microbiological parameters are monitored regularly (monthly) at several public beaches, including Flic en Flac, Albion, Pointe aux Sables, Trou aux Biches, Mon Choisy, Le Goulet, Grand Baie and Blue Bay. Most areas complied with Mauritius' guidelines for contact recreation, although exceptions have been recorded in Pointe aux Sables near Port Louis (UNEP et al. 2009c). Microbial pollution has been observed in urban areas along the Kenyan coast, e.g. Mombasa (Mwanguni 2002), as well as in the Kilindini/Port Reitz creek area and, to a lesser extent, the Sabaki estuary/Malindi Bay complex (UNEP et al. 2009c).

In the Seychelles, high microbial counts were recorded at Beau Vallon Bay during the rainy season in 2007. These were mostly associated with run-off from non-point sources such as rivers and small streams (Antoine et al. 2008). Outbreaks of water borne diseases usually occur during the rainy season and are mainly associated with defective wastewater disposal systems (UNEP et al. 2009c).

Microbiological contamination of recreational coastal water also is a concern in South Africa, especially along urban coasts. Regular (bi-weekly) monitoring of beach water quality in Cape Town revealed the impact of contaminated stormwater runoff and malfunctioning wastewater treatment facilities as the cause of microbiological contamination at some of its beaches (City of Cape Town, 2019), Studies conducted in urban centres on the east coast (Durban) also observed areas where microbiological contamination was evident, especially during the rainy season (Mardon and Stretch 2004). These patterns are also expected to occur along other urbanised coastal areas in South Africa which receive large volumes of wastewater or heavily contaminated urban runoff.

Along Tanzania's coast, including Zanzibar, some beaches in Dar es Salaam (e.g. Ocean Road and Banda beaches) have been closed for swimming and other recreational activities due to microbial contamination (ASCLME 2012h). Levels of microbial contamination were found to be especially high during the rainy season, showing the influence of urban run-off and sewage contamination on microbial pollution at urbanised coastal beaches (Lyimo 2009; Mwakalobo et al. 2013; Mushi 2020).

4.2 Suspended Sediment Loading

Inappropriate catchment and urban practices have contributed significantly to sediment loading to the coastal and marine environment in the WIO region, impacting on its sensitive ecosystems, as well as impacting on coastal development (e.g. port) and tourism. Excessive sedimentation smothers coral reefs, and results in a decrease of light available for benthic macrophytes and photosynthetic algae that support coral reefs (Schaffelke et al. 2005). Discolouration of coral reef waters also reduces their aesthetic value, rendering them less attractive for tourism.

In Kenya, increased development in river basins has caused sediment loading into the coastal environments affecting the depth of the photic zone and reducing primary production (ASCLME 2012b). The Tana and Sabaki rivers deposit large volumes of sediment in coastal and marine environments, increasing turbidity in coastal waters in Ungwana Bay and Malindi Bay (Kitheka et al. 2003a; b; Kitheka et al. 2005; Mmochi and Francis 2003). Sedimentation has also resulted in significant impacts on mangrove areas, smothering the root systems of trees and causing die-back of these forests (Kitheka et al. 2005), as well as in Lamu (Abuodha and Kairo 2001) and Mwache Estuary (Kitheka et al. 2003b). Sediment loading has been found to also affect the coral reefs in the Malindi National Marine Park and Reserve Kenya (McClanahan and Obura 1997; Kazungu et al. 2002; Kitheka et al. 2003a), as well as seagrass beds (Wakibia 1995; Kazungu et al. 2002).

Pollution as a result of suspended solids is a major issue for Madagascar, mainly as a result of soil erosion in catchments as a result of bush fires and deforestation. The Betsiboka River (also known as the Red River) owes its distinctive orange-red colour to the vast amount of silt that it carries and drains into the sea near Mahajanga. Coral reefs in the Toliara region receive large amounts of sediment carried by the Onilahy and Fiherenana rivers, reducing water transparency and smothering of the coral and mangrove areas. Sedimentation has also changed sandy beaches, impacting on sea turtle nesting grounds, e.g. in the Masoala region (ASCLME 2012c). In Mauritius, high sedimentation and associated high turbidity have been reported in the lagoon at Rodrigues and in Grand Baie, resulting in modification of these ecosystems. In Rodriques, this was mainly as a result of soil erosion from agricultural areas in the highlands, while in Grand Baie domestic wastewater discharge was found to be the major source of suspended solids. Sedimentation has also caused damage to the coral ecosystem (e.g. by smothering), thereby affecting artisanal fishing (UNEP et al. 2009c). In Mozambique, poor land-use practices, including deforestation of coastal and hinterland areas, are the main contributors to sedimentation in coastal environments (UNEP et al. 2009c).

In the Seychelles, sediment discharge has contributed significantly to coral losses around the main islands of Mahe, Praslin and La Digue, together with other factors such as global warming (Jones et al. 2002). Along the Tanzanian coast poor agricultural practices have been known to play a leading role in water quality deterioration due to sedimentation, resulting in smothering of coastal ecosystems (e.g. coral reefs), reducing the aesthetic value making it less attractive for tourism (Mohammed 2003).

4.3 Nutrient Enrichment

Nutrient enrichment of coastal waters typically stimulates algal production and may lead to eutrophication with detrimental effects on sensitive ecosystems (Lapointe and Clark 1992; Schaffelke et al. 2005). Excessive nutrient loading drastically increases the productivity and biomass of phytoplankton and opportunistic algae. Such algal growth tends to overgrow and smother corals and promote growth of other opportunist organisms such as sponges and tunicates (Pastorok and Bilyard, 1985). High concentrations of certain inorganic nutrients, such as nitrogen and phosphorus, also can inhibit coral calcification processes (Fabricius 2005, Schaffelke et al. 2005). Decaying excess algal matter can radically reduce dissolved oxygen levels, especially in sheltered coastal waters, often resulting in fish and invertebrate mass mortality (Forbes and Demetriades 2008). Nutrient loading in shallow waters, results in localised eutrophication, and in coral systems impacts coral health by causing diseases, blemishes and dead patches (McClanahan 2002). Nutrients were also found to reach elevated levels in sheltered environments, such as estuaries and creeks, compared with oceanic waters (e.g. Tudor Creek, Mombasa) (Okuku et al. 2019). In 2001 a harmful algal bloom (HAB) in the Kiunga National Marine Reserve (Kenya) lasted for 10 days and caused mortality of marine life associated with hypoxia. Studies near Mombasa showed that terrestrial nutrient loading from the city affected primary producers in onshore reefs at Nyali and Bamburi, especially during periods of low water exchange (Mwaura et al. 2017).

Rivers draining the Madagascan Highlands is an important source of nutrients to the coast. The use of fertilisers has been found to cause nutrient enrichment which can lead to eutrophication and harmful algal blooms (HABs) (ASCLME 2012c). In Mauritius, eutrophication, algal blooms and smothering of corals in shallow lagoons is common, particularly in Port Louis where coral mortality is prevalent (Ramessur 2002). Nuisance algal growth, affecting the recreational (aesthetic) value of coastal resources has been reported. For example, high nitrate concentrations introduced into lagoon systems through agricultural return flows have been associated with algal proliferation in the lagoons of Belle Mare/Palmar. As a result, many hotels have had to remove algal deposits from the shoreline on a weekly basis (Dulymamode et al. 2002). At Flic en Flac, black anoxic sands, smelling of hydrogen sulphide, have been observed at the low water mark and are associated with organic enrichment from wastewater discharges (Prayag et al. 1995). Algal blooms are observed annually at Trou aux Biches and isolated cases have been reported at Bain des Dames near Port Louis (Prayag et al. 1995, Botte 2001).

In Seychelles, high nutrient loading in areas such as Port Victoria leads to eutrophication and HABs during certain periods of the year, resulting in oxygen depletion and mortalities of fish and benthic crustaceans. Such losses can ultimately affect fisheries and livelihoods (ASCLME 2012e).

Along the South African coast, estuarine systems typically act as nutrient purifying systems where, nutrients from catchments are absorbed, resulting in cleaner water entering the sea (Adams et al. 2020). Urban estuaries on the KwaZulu-Natal coast are increasingly showing signs of excess nutrient and organic loading from surface drainage and, possibly malfunctioning sewage reticulation systems. This has contributed to fish kills in several estuaries in the eThekwini municipality and the Port of Durban (Forbes and Demetriades 2008).

In the Tanga area of Tanzania, proliferation of macroalgae has been reported in coastal waters due to nutrient loading from municipal wastewater and industrial discharges, particularly from a fertiliser factory. Excessive growth of *Ulva* spp. and *Enteromorpha* spp. could be associated with nutrient input from sewage pipes (ASCLME 2012h). A study along the Tanzanian coast also found that although seagrass beds themselves did not show major change as a result of nutrient enrichment, associated organisms were being affected (Daudi et al. 2012).

In Zanzibar, eutrophication, associated with the release of inorganic nutrients from domestic sewage, has been identified as one of the main causes for a decrease in coral-reef-building algae (Björk et al. 1995). Coralline algae are sensitive to phosphate and are disappearing from phosphate-rich areas

(Björk et al. 1996). Nutrient rich waters from Zanzibar town flowing in a south westerly direction during the NE monsoon season were found to stimulate phytoplankton production impacting areas around Bawe and Chumbe islands (Peter et al. 2018).

4.4 Marine Litter

Marine litter pollution refers to the introduction of solid waste material, manufactured or processed by humans, into coasts and oceans and their surroundings (where it either floats or sinks) (Barnardo and Ribbink 2020). Inappropriate disposal of solid waste is a serious problem in most of the coastal urban centers in the WIO region, although quantitative data are limited. Important land-based sources of litter are wastes from urban centers (particularly ports, industrial and commercial areas and informal settlements) and that discharged into marine environments via rivers (transporting solid waste from adjacent catchments).

With growing awareness of its detrimental effects, marine litter, especially plastics and microplastics, has become increasingly topical amongst scientists, members of the public and governments. However, data on litter production, litter loads, location and composition, flows from source, amounts entering the sea and waste mismanagement is not available for most African countries, making effective management of waste difficult (Barnardo and Ribbink 2020). Litter also travels large distances from its origin, increasing the risk of organisms attaching to the litter and invading new regions, with both biological and commercial impacts. Litter that sinks to the ocean floor can affect gas exchange in bottom sediments (UNEP and WIOMSA 2008). The economic impacts of litter result from decreased amenity value, costs of clean-up operations, increased flood risks and damage to fishing and recreational vessels. The economies of Seychelles and Mauritius rely on the tourism industry and, therefore, waste management in these countries is well resourced compared with other WIO countries (UNEP and WIOMSA 2008).

Impacts of marine litter have been observed across the region. In Kenya, animals have been found to be entangled in, or to have ingested marine litter resulting in serious cuts, suffocation, hampered mobility, drowning, strangulation and starvation (Ochiewo 2006). Increased development of villages in Madagascar has resulted in garbage and other waste being dumped in mangrove forests. In Mahajanga, turtles have been found to be feeding on plastic bags, presumably mistaken as jellyfish. Abandoned cast nets can trap and drown turtles while seabirds become entangled in nets and other discharged fishing gear. Levels of ingestion of marine litter by animals off South Africa are one of the highest in the world and several threatened species are affected (UNEP and WIOMSA 2008; ASCLME 2012c; ASCLME 2012g). A summary of key reported impacts in different countries are provided in Table 4.2.

In South Africa, studies have been conducted on the effect of marine litter on aesthetics and tourism, and costs of beach and harbour clean-ups, but economic impacts and impacts on ecosystem services such as fisheries, aquaculture, and shipping is lacking. Non-market costs of impacts on cultural and spiritual values are also lacking (Arabi and Nahman 2020). The most common waste type causing entanglement of sharks is plastic straps from bait boxes and other plastic packaging material (entanglement found with 53 sharks caught in shark nets between 1978 and 2000). In estuaries gill nets are a common source of litter, for example in the Mlalazi Estuary, 51 monofilament gill nets were removed in 2018/2019 (Naidoo et al, 2020). Reported entanglements have involved turtles, birds, Cape fur seals (usually caught in rope, string, fishing line and plastic straps) and whales (Naidoo et al 2020). On the remote island of Marion (a territory of South Africa) entanglements of 101 sub-Antarctic and Antarctic fur seals and 5 elephant seals were recorded over a 10-year period, likely associated with discarded tackle from the longline fishery. Some turtle and bird species have also been found ingesting plastics causing blockage of the gut and starvation. Studies have shown that seabirds ingest mesoplastics based on colour and their foraging strategies. Ingested fibers and fragments of rayon, polyester, nylon and polyvinylchloride have been recorded in brown mussels and juvenile fish collected from mangrove forests in KwaZulu-Natal. Plastic ingestion by seabirds in South Africa and the African sector of the Southern Ocean have been recorded in 36 species (Naidoo et al, 2020).

Table 4.2: Key reported impacts and proportion of plastic/synthetic litter in countries of the WIO region (Source: UNEP and WIOMSA, 2008; unless specified)

COUNTRY	REPORTED IMPACTS	PROPORTION OF PLASTIC/SYNTHETIC LITTER
Comoros	Impacts on coral reefs and associated ecosystems (seagrasses, mangroves, beaches), and on sea turtles and fish near urban areas.	In 1996 plastics were estimated to make up 3% by weight of household refuse (more than 60,000 tons of garbage was produced by households in 2000, excluding markets and commercial areas).
Kenya	Impacts on human health, tourism and marine mammals are inferred but not quantified especially along urban areas and in the northern-most coastal areas.	The percentage of plastics in the waste stream not specified. Appears that about 40% of items recovered on beaches are synthetics.
Madagascar	Impacts on human health particularly, and on aesthetics and tourism. Impacts on marine animals, particularly sea turtle (UN Environment 2018).	No quantification of marine litter has been made but there is evidence that 100 m^3 of plastics per day are collected in one coastal city's garbage stream.
Mauritius	Degradation of aesthetics and potential threat to public health. Solid waste in ports found to damage propellers. Litter blocks drainage systems and causes back-flooding. Lost anchors and fishing materials damage corals (UN Environment 2018).	About quantities of solid waste are collected daily from beach and port areas of which about 70% is plastics, mainly polyethylene terphthalate (PET) bottles.
Mozambique	Negative impacts on human health, aesthetics and tourism associated with popular beaches	Although no marine litter quantification has been done, plastics are reported to be one of the most common litter items observed on beaches.
Seychelles	Very little impact reported as litter are kept very low on islands	Approximately 56% of litter items in a waste analysis done at the Old Port were plastics.
South Africa	Threats to marine organisms and birdlife, with several threatened species affected, entanglement, and negative impacts on tourism.	Plastics comprise up to 89% of litter items (60% by mass) found on beaches; 80% of the litter items found on a sea bed survey were plastic.
Tanzania	Smothering of marine organisms, including coral, and negative influence on future tourism and fisheries developments.	Plastics make up 6% by weight of non-food wastes in Zanzibar, and 3.4% in Dar es Salaam.

Progress is being made to combat marine litter in the WIO region. For example, the Western Indian Ocean Marine Science Association (WIOMSA) is partnering with Sustainable Seas Trust (SST), through its African Marine Waste Network, initiating an observation and monitoring programme involving Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania planned to run from 2019-2021 and focusing on land-based sources of litter (WIOMSA 2020). To develop uniform ways of measuring marine litter the Sustainable Seas Trust and WIOMSA published the *African Marine Litter Monitoring Manual* in 2020 (Barnardo and Ribbink 2020).

The WIO Regional Marine Litter Action Plan (UN Environment 2018), prepared in response to UNEA Resolutions 1/6, 2/11 and 3/20, aims to address marine litter in a coordinated and collaborative manner across the region towards implementation of the Protocol on Land Based Sources and Activities (LBSA Protocol) as well as supporting achievement of Sustainable Development Goal 14. A Regional Technical Working Group on Marine Litter and microplastics has also been established by the Nairobi Convention and WIOMSA to promote shared learning across the region and to provide regional governments with appropriate technical support on interventions to combat this challenge.

4.5 Toxic Pollution

Toxic pollution refers to threats from chemical contaminants released in the coastal and marine environment that are toxic, persistent and/or bio-accumulating. For the purposes of this assessment these can be grouped into three broad categories, namely metals, petrochemicals (hydrocarbons) and other persistent organic compounds (e.g. pesticides).

4.5.1 Metals

Metal pollution originates from various sources and affects sensitive coastal ecosystems in varying ways. As metals are not bio-degradable they may accumulate in plant tissue, affecting growth. Mangroves act as pollution sinks (Wong et al. 1997; Yim and Tam 1999) and numerous countries utilise these ecosystems as secondary waste treatment facilities. However, with the increasing disturbance to mangrove ecosystems, mangrove soils reach their maximum absorptive capacity for binding toxic metals resulting in adverse effects on mangrove leaf numbers, stem basal diameter and biomass production (Wong et al. 1997; Yim and Tam 1999). Coral reef invertebrates and fish are vulnerable to metal contamination and accumulate these contaminants within soft body tissues and display distinct physiological and cytological responses to varying levels of pollutant exposure (Rainbow 1995). In addition, metals are easily absorbed by the tissue of coral skeletons, thereby altering various chemically mediated processes such as reproduction and recruitment. Consequently, such pollutant exposure causes severe modifications to reef productivity and mortality rates (Peters et al. 1997). The human health risks associated with the consumption of metal contaminated seafood are also well documented (e.g. Bosch 2015).

Signs of metal pollution have been recorded in various coastal areas in the WIO region. A serious case of lead poisoning in Mombasa (Kenya), associated with an emission from a lead smelter, also has been reported (CNN 2020). Elevated metal concentrations (cadmium, copper, lead and zinc) have also been observed previously in sediments of the Sabaki estuary/Malindi Bay complex and Kilindini/Port Reitz Creek (UNEP et al. 2009c). Studies conducted previously in Kilindini and Makupa Creeks in Mombasa did revealed elevated levels of metals (copper, cadmium, iron and zinc), although the levels were considered to be substantially lower than those recorded in other polluted coastal areas (Kamau 2001). Recent studies conducted along the estuarine areas of Ramisi-Vanga system, along Kenya's south coast, in peri-urban creeks of Mombasa, and in estuarine areas along the north coast showed metal concentrations were within acceptable limits, except in the Kilindini Harbour that had elevated chromium levels (Okuku et al. 2019).

In Madagascar, monitoring at Mahajanga and Nosy-Be provided evidence for elevated metal concentrations in sediments, generally in close proximity to sewage outfalls (UNEP et al. 2009c). Metals, particularly chromium (from dye factories), zinc and lead (from industrial effluent and land runoff) are prevalent in Mauritian coastal waters. Estuarine habitats, such as Tombeau Bay and Poudre d'Or Estuary, have been exposed to untreated industrial wastes since the 1980s. Metals, particularly chromium (from and textile industries), zinc and lead (from industrial effluent, sewage sludge and landfill leaches) are potentially problematic (Ramessur 2002; 2004). Studies conducted in Mozambique have shown the presence of metals, particularly lead, in the Port of Maputo from discharges of the Matola and Maputo Rivers, as well as in Nacala Bay (Fernandes 1995, UNEP et al. 2009c).

In South Africa, the sediment in estuaries and ports in many coastal cities is often severely contaminated by metals (e.g. Newman et al. 2015; Harris et al. 2019). However, in ports heavy contamination is usually limited to surface sediments in sheltered depositional areas due to frequent maintenance dredging (e.g. CSIR 2009b). A first report of metals in corals of the WIO region found higher concentrations of most metals in reefs close to urban areas, although less contaminated than in other parts of the world (e.g. the Red Sea). Nickel concentration in corals of the genus *Sinularia* (South Africa) was found to the highest ever reported (Van der Schyff et al. 2020), and co-occurred with concentrations of persistent chemicals such as polychlorinated biphenyls, whose production was banned decades ago because of toxicity concerns. These and other chemicals pose a toxic risk to aquatic fauna and flora (Vogt et al. 2018). In Tanzania, several studies on metals in coastal ecosystems have been undertaken. Mangrove sediments in close proximity to Dar es Salaam (Msimbazi, Mtoni and Mzinga Creek) showed elevated levels compared with more remote mangrove areas (Mbweni) (Mremi and Machiwa 2003; ASCLME 2012h). An analysis of metals in sediments in the inner area of Dar es Salaam harbour (Machiwa 2000) also revealed an accumulation of certain metals, notably chromium and copper. Some metal accumulation was also detected in mud crabs, and although levels did not pose a risk in terms of average per capita consumption in Tanzania, potential risks (from As and Cu) were flagged if average per capita consumption is exceeded (Rumisha et al. 2016; 2017a). Accumulation of some metals has also been observed in some invertebrates and in sediments in mangroves and off the coast of Dar e Salaam (Rumisha et al. 2012, Rumisha et al. 2016) while metals were also found to limit the gene flow in giant tiger prawns along the Tanzanian coast (Rumisha et al. 2017b). A first study reporting on metallic elements in dolphin tissue from Tanzania found concentrations to be low compared to other studies, but Cd increased significantly with age in kidneys and lungs (Mapunda et al. 2017).

4.5.2 Petrochemicals

Common sources of petrochemicals include urban runoff, shipping, port activities and illegal disposal and accidental spillage of oil. The impacts of oil and petrochemicals are numerous. The main consequence of oiling on seagrass beds is complete smothering of these benthic plants, as well as their associated organisms (Abuodha and Kairo 2001). To exacerbate the problem, dispersants which are commonly used to clean up oil spills contain toxic solvents which penetrate the protective waxy cuticles of seagrass blades. Studies have shown such actions affect the biological functioning of cellular membranes and chloroplasts, thereby causing plant loss as well as harmful effects in other benthic biota (Ellison and Farnsworth 1996; Abuodha and Kairo 2001). Oiling also smothers mangrove ecosystems and their organisms (Abuodha and Kairo 2001). Because petroleum compounds persist in mangrove soils, toxic derivatives of oil are continuously re-released into the environment, thereby causing sub-lethal effects to mangroves. Oiling causes massive mangrove defoliation, chlorophyll-deficient mutations as well as seedling and tree mortality. Further, the recovery of mangrove ecosystems from impacts of these hydrocarbons can take several years (Abuodha and Kairo 2001). Oil pollutants often float above coral reefs (Peters et al. 1997) and even if petroleum does not come into contact with the reef, the pollutant contains toxic substances that are water soluble and are taken up by corals. Studies have shown that corals exposed to oil undergo a variety of negative impacts that include tissue death, bleaching, and impairment of biological processes such as photosynthesis, reproduction and growth (McClanahan 2002). In addition, dispersants used to clean-up oil leaks contain toxic chemicals that exacerbate the effects of the oil spill and can prolong coral recovery by years (Peters et al. 1997).

Studies in Kenya have indicated cases of complete smothering of seagrass beds and their associated organisms as a result of oiling. This is also the case for beds in Maputo Bay (Mozambique) which have been destroyed by oiling (Munga 1993; Abuodha and Kairo 2001; Richmond 2002). Extensive mangrove forests in Mombasa and Maputo have been destroyed by such spills (Munga 1993, Richmond 2002). In Mida Creek in Kenya, effects of oil spills on mangroves were still evident ten years after the incidents (Abuodha and Kairo 2001). High level of poly-aromatic hydrocarbons in Kilindini Harbour (Kenya) was attributed to petroleum sources in the area (Okuku et la. 2019). Studies in Kenya also highlighted car wash facilities as sources of PAHs (Kwach and Lalah 2009). It was also found that pollution from oil spills tend to concentrate in areas within the Mozambique Channel due to eddy circulation from the north to the south (ASCLME 2012d). In South Africa, there is evidence of accumulation of polycyclic aromatic hydrocarbons (PAHs) in some commercial ports (e.g. Newman et al. 2015).

4.5.3 Persistent organic pollutants

Persistent organic pollutants (POPs) refer to an array of compounds that have the potential for long-range transport, persistence in the environment, and the ability to bio-magnify and bio-accumulate in ecosystems. The most commonly encountered POPs are agrochemicals such as organochlorine pesticides (e.g. DDT) and industrial chemicals and by-products (e.g. polychlorinated biphenyls [PCB], polychlorinated dibenzo-p-dioxins [PCDD]) and dibenzofurans [PCDF]).

POPs bio-magnify throughout the food chain and bio-accumulate in organisms, therefore the highest concentrations often are found in organisms at the top of the food web. Ultimately this poses risks to humans and manifests in increased risk of cancer, reproductive disorders, alteration of the immune system, neurobehavioural impairment, endocrine disruption, genotoxicity and increased birth defects (WHO 2020). Herbicides and pesticides leaching into coastal ecosystems are known to cause mangrove defoliation and mangrove dieback (Schaffelke et al. 2005). PCBs and pesticides are also extremely toxic to corals which have been shown to display decreases in photosynthesis of the symbiotic algae, changes in coral metabolism and growth retardation when exposed to such contaminants (Pastorok and Bilyard 1985).

The presence of POPs in Kenyan coastal waters was found to be due to the use of pesticides in agricultural areas. DDT is suspected to be used in upstream agricultural areas with significant concentrations of pesticides being found in the River Sabaki and Ramisi River. Fish samples from rivers and estuaries have also shown residue concentrations of pesticides and sediment has been found to contain POPs. Dioxins and furans, produced when insulation is removed from scrap wire cables through burning, metals and old tyres, also contribute to the presence of POPs (ASCLME 2012b). Effects on mangrove forests in Mombasa and Lamu (Kenya) as a result of the pesticide loading have also been observed (Mmochi and Francis 2003). Elevated levels of DDT in sediments of the Tana Estuary have also been recorded posing potential ecotoxicological risks to the benthic fauna in the system (Okuku et al. 2019). In Madagascar, DDT used to be used in the control of malaria but has been banned for more than a decade (ASCLME 2012c). Sugar cane farming in Mauritius uses large amounts of pesticides (Mmochi and Francis 2003) which have also contributed to mangrove decline on the island. Studies on spinner and bottlenose dolphins along the Réunion coast showed contrasted contaminant profiles for PCBs and PBDEs probably linked to different dietary and foraging habitat preferences (Dirtu et al. 2016).

Common pesticide residues identified in Mozambique were 2,4,5-TCB, p,p'-DDT, p,p'-DDE, p,p'-DDD, Lindane and HCB. Though DDT is officially banned in Mozambique, it is still used, as it is in neighbouring countries (Massinga and Hatton 1997). Analysis of pollutants adsorbed to plastic pellets however, indicates comparatively low concentrations of DDTs compared with elsewhere in the world, but showed very high concentrations of hexachlorocyclohexane (Lindane) (Ogata et al. 2009). Studies on DDTs and PFASs in swordfish and tunas suggested their similar feeding habitats resulted in similar presence of POPs, while tuna from the Mozambique Channel showed unique DDT profiles (Munschy et al. 2020a).

In the Seychelles, agricultural activities are the main sources of POPs. These activities are still relatively small in scale, but low concentrations of chlorinated pesticides such as Aldrin, Lindane, Dieldrin, pp'- DDT and the breakdown products of DDT (pp'-DDD and pp'-DDE) have been detected in sediments. Even though the use of DDT and Aldrin has been banned, risk remains from leachate from landfills (ASCLME 2012e). Investigation into the presence of POPs in swordfish along the Seychelles coast showed the major contaminants to be chlorinated (OCPs, PCBs) and fluorinated (PFASs) compounds, although at relatively low levels (Munschy et al. 2020b).

Current data on POPs levels in water, sediment and biological tissue in the coastal and marine environment of South Africa is limited (ACSLME 2012g). However, previous studies have shown POPs levels in coastal water further offshore were not significant, at least by international standards (e.g. Griffiths et al. 2004; CSIR 2009a&b), possibly as a result of the high-energy nature of the coast preventing significant settling of fine-grained sediment and organic matter with which most POPs preferentially associate. However, since most monitoring is restricted to about 3-4 km offshore and in small areas, there remains poor understanding of whether contaminants are accumulating further offshore (e.g. the Tugela Bank) (ASCLME 2012g). POPs have also been detected in the sediments of estuaries and ports in coastal cities. These include pesticides, and polychlorinated biphenyls whose production was banned decades ago (Newman et al. 2015). These chemicals pose a toxic risk to aquatic fauna and flora (Vogt et al. 2018) based on studies conducted on marine organisms, for example in fish (e.g. Grobler et al. 1996), seals (e.g. Stewardson et al. 1999) and dolphins (e.g. de Kock et al. 1994). A study on the levels of organochlorine pesticides (OCPs) in reef organisms from marginal coral reefs in Sodwana Bay (South Africa) showed significantly elevated levels, which were attributed to groundwater seepage (Porter et al. 2018).

In Tanzania, high levels of PCBs and OCP residues have been detected in Dar es Salaam harbour (Machiwa 1992; Mwevura et al. 2002), while chlorinated compounds associated with pesticides have also been reported in sediment and polychaetes in Chwaka Bay and near Stone Town, Zanzibar (Mmochi 2005, Mwevura et al. 2020) and in the Rufiji Delta, in Tanzania (Mwevura et al. 2021). Another study along the coast of Dar es Salaam found POPs accumulation in sediment and oysters mainly attributed to insufficient wastewater treatment (Machiwa 2010).

5. MARINE POLLUTION HOTSPOTS

Based on the five key problems associated with marine pollution in the WIO region, that is, microbial contamination, high suspended solids, chemical (toxic) pollution, marine litter and nutrient enrichment (eutrophication) (see Chapter 4), Figure 5.1 shows the location of marine pollution hotspots identified in the WIO region (UNEP et al. 2009c). Not surprisingly, hotspots are primarily located at the coastal cities and larger towns, where most of the key sources of marine pollution are concentrated.

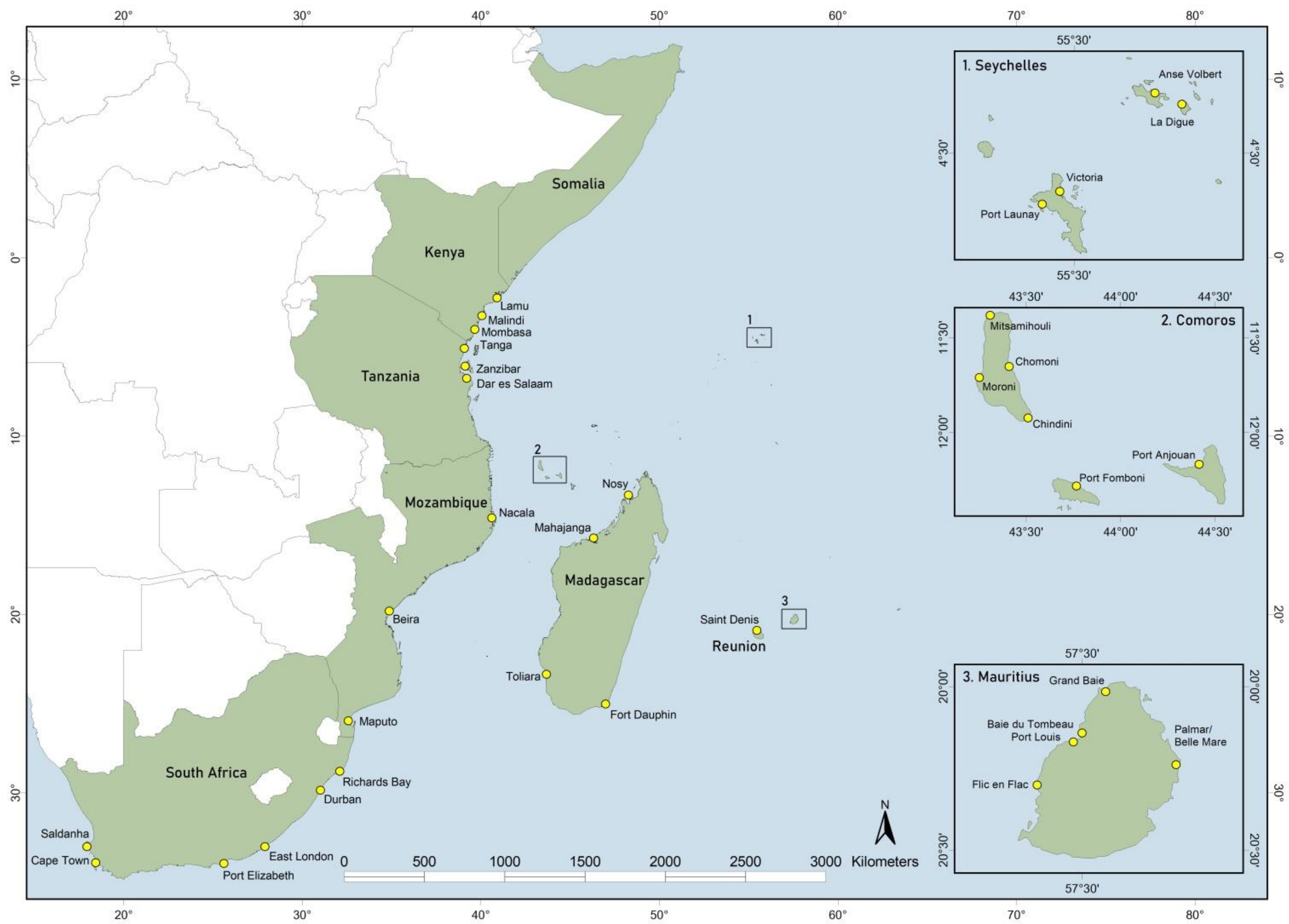

Figure 5.1 Marine pollution hotspots (major coastal urban cities) in the WIO region (UNEP et al. 2009c)

Using the following evaluation criteria, a Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment in the WIO region (UNEP et al. 2009c) rated hots spots in the region.

		SEVERITY OF POLLUTION		
		1: Frequent non-compliance EQTs	2: Seasonal non-compliance with EQT	3: Occasional non-compliance with EQTs
SIGNIFICANCE OF IMPACT	1 High	Category 1	Category 1	Category 2
	2 Medium	Category 1	Category 2	Category 3
	3 Low	Category 2	Category 3	Category 3
	Category 4: Emerging hotspot			

The results are presented in Table 5.1.

Table 5.1: Categories for marine pollution hotspots in the WIO region, based on estimated severity of pollution and significance of impact (UNEP et al. 2009c)

COUNTRY	LOCATION	SEVERITY	SIGNIFICANCE	HOTSPOT CATEGORY
Comoros	Port Famboni			4
	Chindini beach			4
	Chomoni beach			4
	Mitsamihouli	3	1	2
	Port Moroni	1	2	1
	Port International de Mustamudu	1	1	1
Kenya	Mombasa inshore waters	1	1	1
	Lamu inshore waters	1	2	1
	Malindi Bay and Sabaki Estuary	1	1-2	1
	Diani	2	2	2
Madagascar	Nosy Be	1	1	1
	Mahajanga	1	1	1
	Toliera	1	1	1
	Bay de Diego	2	1	1
	Port of Tamatave	2	2	2
	Port Dauphin	2	2	2
Mauritius	Palmar	2	1	1
	Pointe aux Sables to Baie du Tombeau	2	1	1
	Grand Baie	3	3	3
	Flic and Flac			4
Mozambique	Maputo Bay	1	1	1
	Beira			4
	Nacala Bay			4
	Pemba Bay			4
	Incomati Estuary			4
Seychelles	Port Victoria	2	2	2
	Anse Volbert		2	4
	La Digue		2	3
	Beau Vallon Bay	2	2	2
	Mahé East Coast,	3	2	3
South Africa	Richards Bay	3	3	3
	Durban	1	1	1
	East London			4
	Port Elizabeth			4
	Mossel Bay			4
	Cape Town	2	2	2
	Saldanha	2	2	2
Tanzania	Dar es Salaam	1	1	1
	Tanga	2	1	1
	Zanzibar	1	1	1

6. LEGISLATION AND MANAGEMENT INITIATIVES

6.1 Key International and Regional Conventions & Agreements

Several countries in the WIO region are signatories to international conventions or agreements linked to the combatting and prevention of marine pollution (Table 6.1). Most of these conventions and agreements relate to pollution from shipping, although, the United Nations Convention on the Law of the Sea (UNCLOS) (1982) addresses pollution of the marine environment more generally.

Table 6.1: Key International and regional conventions/agreements applicable to marine water quality (or marine pollution) management, indicating signatory countries

CONVENTION/ AGREEMENT	DECRIPTION	Comoros	Kenya	Madagascar	Mauritius	Mozambique	Reunion (France)	Seychelles	Somalia	South Africa	Tanzania
International Convention on Civil Liability for Oil Pollution Damage (CLC) (1969)	Ensures adequate compensation to persons who suffer oil pollution damage resulting from maritime casualties involving oil-carrying ships, placing the liability on owners of the ships (www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx)	●	●	●	●	●		●		●	●
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION) (1969)	The Convention affirms right of coastal states to take measures on high seas to prevent, mitigate or eliminate danger to its coastline or related interests from pollution by oil or the threat thereof, following upon a maritime casualty (www.imo.org/en/About/Conventions/Pages/International-Convention-Relating-to-Intervention-on-the-High-Seas-in-Cases-of-Oil-Pollution-Casualties.aspx)			●	●		●			●	●
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972) and London Protocol (1996)	Prohibiting the dumping of certain hazardous materials. In addition, a special permit is required prior to dumping of a number of other identified materials and a general permit for other wastes or matter. (www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx)		●			●		●		●	●
	In 1996, Parties adopted a Protocol to the Convention. It prohibits all dumping, except for possibly acceptable wastes on the so-called 'reverse list'		●							●	
International Convention for Prevention of Pollution from Ships (MARPOL) (1973)	Main international convention covering prevention of pollution by ships from operational or accidental causes www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx):										
	Annex I: Regulations for the Prevention of Pollution by Oil	●	●	●	●	●		●		●	●
	Annex II: Control of Pollution by Noxious Liquid Substances	●	●	●	●	●		●		●	●
	Annex III: Harmful Substances Carried by Sea in Packaged Form	●	●	●	●	●				●	●
	Annex IV: Sewage from Ships	●	●	●	●	●					●
	Annex V: Garbage from Ships	●	●	●	●	●				●	●
	Annex VI: Air Pollution from Ships										
United Nations Convention on the Law of the Sea (UNCLOS) (1982)	This convention is cornerstone of ocean governance at the national, regional and global levels. Section 5 addresses prevention of pollution of the marine environment (www.iucn.org/theme/marine-and-polar/our-work/international-ocean-governance/unclos)	●	●	●	●	●	●	●		●	●
Regional Seas Programme: Nairobi Convention (1985)	Partnership between governments, civil society and private sector, working towards a prosperous Western Indian Ocean Region. This Convention offers a regional legal framework and coordinates efforts of member states to plan and develop programmes that strengthen their capacity to protect, manage and develop their coastal and marine environment (including marine water quality management) (www.unenvironment.org/nairobiconvention/)	●	●	●	●	●	●	●	●	●	●
International	Require parties to establish measures for dealing with					●		●			

CONVENTION/ AGREEMENT	DECRIPTION	Comoros	Kenya	Madagascar	Mauritius	Mozambique	Reunion (France)	Seychelles	Somalia	South Africa	Tanzania
Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) (1990)	pollution incidents, either nationally or in co-operation with other countries (www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx)										
Convention on Biological Diversity (1993)	This convention has 3 main objectives (1) conservation of biological diversity, (2) sustainable use of the components of biological diversity, (3) fair and equitable sharing of the benefits arising out of the utilization of genetic resources (www.cbd.int/convention/)	●	●	●	●	●	●	●		●	●
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND) (1996)	Under this Convention, victims of oil pollution damage may be compensated beyond level of ship owners' liability (www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx).	●	●	●	●	●		●		●	●
International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER) (2001)	The Convention ensures adequate, prompt, and effective compensation availability to persons who suffer damage caused by spills of oil, when carried as fuel in ships' bunkers (www.imo.org/en/About/Conventions/Pages/International-Convention-on-Civil-Liability-for-Bunker-Oil-Pollution-Damage-(BUNKER).aspx)		●		●		●				
Stockholm Convention (2001)	Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods (www.pops.int/Home/tabid/2121/Default.aspx)	●	●	●	●	●	●	●	●	●	
International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM) (2004)	This Convention aims to prevent spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for management and control of ships' ballast water and sediments (www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx).									●	
2030 Agenda for Sustainable Development (2015)	Adopted by UN member states as an agenda for people, planet and prosperity. Seventeen Sustainable Development goals were identified of which some are relevant to marine pollution prevention (e.g. SDG 14) (www.un.org.za/sdgs/2030-agenda/).	●	●	●	●	●	●	●	●	●	●

Agenda 2030 and its Sustainable Development Goals (SDGs) have a central, overarching aim of ensuring environmentally sustainable and socially equitable development, including the marine environment. Specifically, SDG 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development* is relevant to marine pollution where Goal 14.1 is aimed at *preventing and significantly reducing marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution.*

The Convention of Biological Diversity (CBD) also sets overarching targets for environmental biodiversity protection (including the marine environment). Specifically, the Aichi Biodiversity targets aim to (https://www.cbd.int/sp/targets/):

- Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
- Reduce the direct pressures on biodiversity and promote sustainable use
- Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
- Enhance the benefits to all from biodiversity and ecosystem services

- Enhance implementation through participatory planning, knowledge management and capacity building.

Specifically, the Nairobi Convention aims to address the accelerating degradation of the oceans and coastal areas in the WIO region through sustainable management and use of these resources by those sharing these environments. Regional initiatives that have been established that also focuses on matter pertaining to C&MWQM, amongst others, include:

- Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities (WIOSAP)
- Protocol for the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-Based Sources and Activities (LBSA Protocol)
- Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy Harmonisation and Institutional Reforms (SAPPHIRE)
- African, Caribbean, and Pacific (ACP) Countries Capacity Building of Multilateral Environmental Agreements project (MEAS).

6.2 Existing Regional Strategies linked to C&MWQM

The Strategic objectives and Targets pertaining to C&MWQM in the WIO region have been defined as per the *Strategic Action Programme Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities* (UNEP/Nairobi Convention Secretariat 2009) which has been adopted by Contracting Parties into a formal *Protocol on Land-Based Sources and Activities in support of the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region* (UNEP 2010). The *Strategic Action Programme Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities* set the following Strategic Objective for water quality in the WIO region:

'Water quality in the WIO region meets international standards by year 2035'.

In accordance with the Programme, this Strategic Objective will be achieved when (i.e. indicators of verification):

- Quality of coastal and marine waters in the WIO region meet regionally agreed standards
- Wastewater discharges adhere to agreed national and regional effluent standards
- Increased government budget allocations for pollution prevention.

The Programme further identified a number of specific targets towards achieving these outcomes, mainly focused on mitigating and preventing impacts from land-based sources and activities:

- Effluent discharge standards developed and regionally harmonized
- Marine water standards developed and regionally harmonized (also referred to as *Guidelines for the development of Environmental Quality Objectives and Targets*)
- Regional best practice framework models for municipal wastewater management developed and adopted
- Collection, treatment and disposal of effluents undertaken in accordance with regional standards
- Environmental management systems and cleaner production technologies encouraged

- Stakeholders' sensitized and political support harnessed in favour of pollution prevention.

In 2010, it was decided to also initiate a joint Transboundary Diagnostic Assessment and Strategic Programme of Action process under ASCLME and SWIOFP pertaining to all issues pertinent to the coastal and offshore areas of the LMEs that have not fallen under the SAP of the WIO-LaB initiative. The *Strategic Action Programme for the Sustainable Management of the Western Indian Ocean Large Marine Ecosystems* (SAP WIO-LME) was therefore published (ASCLME et al. 2014). To ensure a comprehensive ecosystem-based approach (watershed to outer offshore boundaries) the two SAPs need to be implemented in collaboration through a cooperative understanding, whilst recognising and respecting the mandates of the various management bodies and institutions. The SAP WIO-LME also identified water quality degradation as a key concern in the region, and posed the following Ecosystem quality objectives (or Targets) that specifically pertain to C&MWQM:

- Restore ground and surface water quality and prevent further degradation occurring in the future
- Reduce microbiological contamination in coastal waters
- Reduce solid waste (marine debris) from shipping and land-based sources in coastal water
- Develop the capacity to prevent and mitigate the effects of oil spills at regional and national level.

In order to achieve these targets the SAP WIO-LME posed the following actions pertaining to mitigation of water quality deterioration in coastal and offshore areas:

- Develop and adopt a general programme for long-term water quality monitoring (biochemical and physical) with the partners of the WIOSEA and ensure that such water quality monitoring programmes target vulnerable areas as well as point-sources (e.g. coral reefs and other critical habitats as well as marine aquaculture facilities)
- Review current capacity and then design and implement improved monitoring and evaluation systems for microbial contamination and for solid and liquid waste discharges both coastal and offshore (ship-based and platform based)
- Review existing vulnerability assessments to oil and hazardous chemical spills and develop an effective monitoring mechanism with specific indicators
- Develop and adopt a monitoring system for exotic, non-native and nuisance species
- Monitoring and reporting of microbial contamination; solid waste; oil and hazardous chemicals; run-off from agriculture and sewage, etc.
- Design, construction and function of various forms of waste reception facilities including oil and hazardous chemicals handling, sewage systems, etc.
- Use of oil and hazardous chemical spill clean-up equipment, response measures and rapid response contingency plans
- Development and adoption of effective and standardised Environmental Impact Assessment criteria, standards and regulations for watershed, coastal and offshore activities that could contaminate/pollute the marine ecosystem (including marine aquaculture and impacts from contamination, waste and potential invasive species)
- Review existing national plans for waste management and develop new plans and programmes as necessary including:
  - Development of appropriate port facilities for recycling and reuse of ship-borne wastes and
  - Implementation of incentive measures/mechanism for use of such facilities and implement an awareness and educational campaign

- Ratify and adopt International Maritime Organisation (IMO) protocols into all domestic legislation and regulations throughout participating countries
- Review existing national and regional Oil and Hazardous Materials Spill Contingency Plans (OHMSCP) and Oil Spill Response measures
- Prepare, adopt or modify/improve regional guidelines for OHMSCP and Rapid Response including the development and/or support any on-going process to adopt a regional response facility and emergency centre for Oil and Hazardous Materials
- Collaborate closely with the oil, gas, chemical and shipping industry and IMO to develop appropriate responses, equipment stockpiles and response coordination centre(s).

In response to the above, regional-level achievements in terms of C&MWQM to date include:

- WIO Action Plan on Marine Litter (UN Environment 2018)
- African Marine Litter Monitoring Manual (Barnardo and Ribbink 2020)
- WIO Marine Highway development and Coastal and Marine Contamination Prevention Project (2020)
- Regional oil spill preparedness in eastern Africa and WIO (UNEP et al. 2020a&b).

6.3 Overview of Existing National Arrangements

Legislation pertaining marine pollution typically comprises that which deals with pollution from land (e.g. wastewater discharges), dumping at sea, shipping (maritime transport) and offshore exploration/mining. A brief overview of legal frameworks, policies and management structures pertaining to C&MWQM in WIO countries is provided below.

6.3.1 Comoros

The Constitution (2001) of the Union of the Comoros proclaims "the right to a healthy environment and the duty of all to safeguard that environment", with Article 18 of its Environmental Code (1994) stipulating that the State must ensure the protection of the soil and subsoil, water resources and the marine environment, the atmosphere and biological diversity (ASCLME 2012a).

The Framework Law on the Environment (No. 94-018/AF) was proclaimed in 1994. This Law (as emended in 1995) provides general principles on all the aspects of environmental protection such as pollution, impact studies, terrestrial and marine environment protection and protected areas. Under this framework law other decrees and orders were established, including the decree on impact studies and the decree on coastal zone monitoring as well as orders on the protection of the mangroves, the harvesting of sea cucumbers, the protected areas and the extraction of sea sand and corals.

The Comoros has developed several operational plans to deal with disasters, including a National Action Plan against Oil Spills at Sea (POLMAR) (2010) that defines administrative organisation and intervention techniques at sea and along the coast as well as the identification of responsibilities of the parties involved and their respective companies (ASCLME 2012a; UNEP/OCHA 2013).

At national level, issues concerning the environment are managed by the National Directorate of Environment (DNE), the National Directorate of Fisheries, the National Institute of Applied Research Fisheries and Environment (INRAPE) and almost all the Ministries (e.g. Public Finance, Budget, Economy and Planning, Transport and Tourism, Urban planning and Housing, Public Health and Population, Education and Justice). At the island level, responsibilities of regional departments of the environment ministry include the enforcement of regulations for protecting the natural environment (ASCLME 2012a). As far as could be established the Comoros does not have a national marine pollution monitoring programme (Jackson 2011).

6.3.2 Kenya

Kenya's Environmental Management and Coordination Act (No 8 of 1999, as amended 2015) (EMCA) explicitly addresses the management and control of the pollution in the coastal and marine environment. For example, Section 55 stipulates that the Minister responsible for environmental matters shall, in consultation with the relevant lead agencies, issue appropriate regulations to prevent, reduce and control pollution or other forms of environmental damage in the coastal zone. Also, that such regulations shall provide for the control and prevention of pollution of the marine environment from land based sources (ASCLME 2012b). Relevant regulations under EMCA include:

- Environmental Management and Co-Ordination (Waste Management) Regulations 2006
- Environmental Management and Co-Ordination (Water Quality) Regulations, 2006.

The Merchant Shipping Act (2009) consolidates ship-related legislation and provides for the prevention of pollution. For example, Section 410 allows for regulations on marine pollution, including giving effect to relevant international conventions (Jackson 2011).

Under the ECMA, the Ministry of Environment and Forestry has a wide range of powers regarding pollution control. The National Environment Management Authority (NEMA) was established under this act and has general powers with respect to enforcing other government agencies to fulfil their environmental responsibilities, including management of pollution. Other departments and institutions that also fulfil key roles on marine pollution management and control include (Jackson 2011):

- Ministry of Local Government (local authorities responsible for garbage collection and effluent treatment and disposal)
- Ministry of Transport and Communication (Kenya Ports Authority is responsible for ports and stores oil spill response equipment)
- Ministry of Health (Mombasa laboratories conduct marine pollution monitoring)
- Kenya Marine Fisheries Research Institute (KMFRI) (research, monitoring and advice on marine pollution).

6.3.3 Madagascar

In Madagascar the concept of sustainable development underpins environmental legislation and policy, for example the Decree relating to ensuring the environmental suitability of investments (MECIE) (No. 2004-167). In 2008 the National Office of the Environment (ONE) was established specifically to administer this Decree to ensure that economic activities and development are not detrimental to the environment. The ONE achieves this through the development and implementation of environmental management plans in order to manage and prevent pollution, and to monitor the marine environment. The Regulations of integrated management of coastal and marine areas in Madagascar (Decree 2010-137) also address aspects of coastal and marine pollution control and management (ASCLME 2012c).

In terms of Law No. 99-021 pertaining to the management policy for the control of industrial pollution, all industrial developments require authorisation prior to commissioning. Effluent quality standards that must be adhered to before discharge into surface waters are set out in Decree 2003/464, as well as minimum standards for metals in sewage sludge (Walmsley and Patel 2012). Also, in terms of the Corporate Social Responsibility practice industries are being encouraged to be implemented positive measures to advance society, and respect and preserve the environment.

The Organe de Lutte contre les Evénements de Pollution marine (OLEP) has been mandated to oversee the management and control of oil pollution in the marine environment (Decree 2004-994) (ASCLME 2012c). Since 2009, the Centre National de Recherches sur l'Environnement has undertaken monitoring at three hot spots (Mahajanga, Toliara and the Port of Toamasina) as part of their research activities. These initiatives have been found to also provide useful data to the Ministry in charge of the Environment.

6.3.4 Mauritius

The Environment Protection Act (No 19 of 2002, as amended) provides the policy framework for the preservation and conservation of the coastal zone in an integrated manner through the enforcement of environmental standards, particularly those pertaining to the control and prevention of pollution. The Guidelines on Coastal Water Quality (Government Notice No 620 of 1999) form part of the secondary legislation issued under the Environmental Protection Act of 2002. Other regulations under the Environmental Protection Act of 2002 include Standards for effluent discharge into the Ocean (Government Notice No 45 of 2003). The Pollution Prevention & Control Division of the Ministry responsible for the Environment carries out regular monitoring of environmental hotspots to prevent environmental pollution and degradation. Advice is also given on measures to prevent air, noise and water pollution and appropriate solid waste management systems (https://environment.govmu.org/).

Pollution from ships is dealt with under the Merchant Shipping Act (No 26 of 2007) and the Merchant Shipping Regulations (2019) and promulgated under the Act by the Ministry responsible for shipping (https://blueconomy.govmu.org/). Mauritius has prepared both a National Oil Spill Contingency Plan and the Port Louis Harbour Oil Spill Response Plan, providing frameworks for oil spill preparedness and response in the country (Mauritius Government 2011).

The Laboratories Division of the Ministry responsible for Fisheries conducts long-term monitoring of coastal water quality to ensure compliance with the Coastal Water Quality Guidelines. Long-term monitoring of coliform bacteria at public beaches is conducted while fish samples are also tested for the presence of ciguatoxin and ciguatera fish poisoning. Long-term monitoring of harmful marine microalgae are also conducted. The division comprises three laboratories, namely the Marine Chemistry, Marine Microbiology and Fish Toxicity laboratories (https://blueconomy.govmu.org/).

6.3.5 Mozambique

The Constitution of the Republic of Mozambique (2004) addresses matters relating to the environment and quality of life including the preventing and controlling of pollution. The Environment Law (No. 20/97), administered by the Ministry for Environmental for Coordination of Environmental Affairs (MICOA), is an umbrella law for environmental matters and an important instrument for the enactment of specific regulations (Wamsley and Patel 2012). With specific reference to coastal and marine pollution these include:

- Regulation on Standards for Environmental Quality and Effluent Discharges (Decree no. 18/2004, Decree no. 67/2010)
- Regulation for the Management of Solid Municipal Waste (Decree no. 94/2014), revoked (Decree no. 13/2006)
- Regulation for the Management of Hazardous Waste (Decree no. 83/2014)

Shipping and harbour operations are dealt with under the Sea Act (Law no. 4/1996) administered by Mozambican Dredging Company Mozambique Ports & Railways Company (Wamsley and Patel 2012). Specific regulations pertaining to pollution control include:

- Regulations for Harbour Operations (Portaria no. 18630/1965)
- Regulation for the Prevention of Pollution and Marine and Coastal Environmental Protection (Decree no. 45/2006).

Management and control of petroleum operations are dealt with under the Petroleum Law (Law no. 3/2001), including Environmental Regulations for Petroleum Operations (Decree no. 56/2010) and administered by Ministry of Mineral Resources and National Petroleum Institute (INP) (Wamsley and Patel 2012).

6.3.6 Reunion (France)

Reunion is a department of France and part of the Eurozone. It is therefore understood that France's legislation pertaining to marine pollution management and control apply. In 2000, France adopted its Environmental Code to reorganise the country's environmental legislation, including those pertaining to pollution prevention (Alogna 2018).

With specific reference to pollution prevention and control, the Law on water and aquatic environments (Law 2006-1772) are important, reflecting European requirements such as the Water Framework Directive (Directive 2000/60/EC). The legal regime to protect the marine environment from industrial pollution (or any other type of pollution) includes the Law of on installations classified for the purposes of environmental protection (Law 76-663) (Alogna 2018).

6.3.7 Seychelles

In the Seychelles the Environmental Protection Act (No 9 of 1994) is the framework environmental law providing for the protection, preservation and improvement of the environment and for the control of hazards to human beings, other living organisms and property. It also provides for the coordination, implementation and enforcement of policies pursuant to the national objectives on environment protection. For example, it prohibits the discharge of any effluent, or throwing, depositing or placing any polluting, or hazardous substance or waste in any watercourse or in the territorial waters without authorisation. This Act is administered by the Ministry responsible for the Environment. Specifically, the Standards and Enforcement Section is responsible to ensure that no harmful chemicals are discharged into the environment and are disposed of as permitted, while the Landscape and Waste Management Agency are responsible for monitoring the disposal of waste in all forms (www.meecc.gov.sc/).

The Merchant Shipping Act (No 13 of 1992, as amended) deals with a wide variety of matters relating to shipping in Seychelles waters including marine pollution. Regulations pertaining to pollution from shipping include:

- Merchant Shipping (Oil Pollution Preparedness and Response) Regulations (2001) giving legal status to Oil Pollution Preparedness, Response and Co-operation (OPRC), the Convention on Civil Liability (CLC) the Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND)
- Maritime Zones (Marine Pollution) Regulations (1981) provide for the protection and preservation of the marine environment and the prevention and control of marine pollution.

The Seychelles Maritime Safety Authority (SMSA) is the regulatory and supervisory authority within the current Ministry of Tourism, Civil Aviation, Ports and Marine that has been delegated responsibility to deal with shipping activities (http://www.seymaritimesafety.com/).

The Seychelles Ports Authority, a parastatal organisation under the current Ministry of Tourism, Civil Aviation, Ports & Marine, is responsible for administration, regulation and control of the country's commercial ports. Activities are regulated by the Harbour Act and Regulations (1932 & 1933, amended in 1988) which cover traffic movements, pollution, waste management and ballast water discharge (https://www.pemc.sc/seychelles-port-authority-spa).

6.3.8 Somalia

In Somalia, the Ministry of Fisheries and Marine Resources has jurisdiction to control pollution of marine (fishing) waters under the Fisheries Law (No 23 1985, as reviewed in 2016). Article 35 prohibits any intentionally or unintentionally dumping of any polluting substances or wastes into the fishing waters that may affect marine resources, birds, the environment and human beings, disrupt fishing activities or pose a threat to sea navigation (https://mfmr.gov.so/en/legislations/).

The Ministry of Ports and Marine Transport promotes stainable development of the maritime transportation sector and to ensure maritime safety and protection of the marine environment, amongst other responsibilities supported by two agencies, namely the Somali Port Authority Agency and the Somali Shipping Line Agency (https://mpmt.gov.so/).

The Petroleum Environmental Regulations (2017) promulgated under the Petroleum Law (No. XGB/712/08) set out requirements for oil and gas exploration to prevent and control pollution. Until the Somalia Petroleum Authority is established, the Ministry of Petroleum and Mineral Resources will administer these regulations (https://mopmr.gov.so/resources/petroleum/). The Ministry of Petroleum and Mineral Resources also is in the process of a Mining policy that will pave the way for regulatory frameworks pertaining to mining (https://mopmr.gov.so/resources/mining/mining-policy/).

6.3.9 South Africa

Environmental provisions are included in the Bill of Rights in the Constitution of South Africa Act (No. 108 of 1996) giving everyone the right an environment that is not harmful to their health or well-being and to have the environment protected, for the benefit of present and future generations (Walmsley and Patel 2012).

Coastal and marine water quality (or pollution) is governed under a number of key pieces of legislation (Taljaard et al. 2019). Land-based pollution is controlled under the National Environmental Management: Integrated Coastal Management Act (No 24 of 2008) (ICM Act) by the Department responsible for the Environment (Branch: Oceans and Coasts). A number of policies, guidelines and regulations pertaining to the management and control of coastal pollution have been published under the ICM Act including:

- National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment (DEA 2014b)
- Coastal Waters Discharge Permit Regulations (DEA 2019)
- Recreational water quality guidelines for coastal waters (DEA 2012a)
- Coastal water quality guidelines for natural environment and marine aquaculture (under revision).

Land-derived effluent discharges to coastal waters are subject to permitting and mandated operators to perform routine monitoring. Wastewater discharges to estuaries are also controlled under the National Water Act (No 36 of 1998) (classified as water resources under this Act).

Monitoring of environmental quality pertaining to human health (beach water quality) is delegated to metropolitan and district municipalities under the National Heath Act (No 61 of 2003). However, only a few of the larger local authorities have resources to perform routine monitoring (DEA 2014b).

The ICM Act also controls dumping of waste at sea under the jurisdiction of the Department for the Environment (Branch: Oceans & Coasts), giving legal status to the London Convention and its 1996 Protocol. A National Action List: Screening of dredged material proposed for marine disposal (DEA 2012b) provides guidance on the quality limits for dumping of dredge spoil to sea.

To assist with the implementation of integrated coastal management (including coastal water quality), coastal management programmes and coastal committees are mandated under the ICM Act. The first national coastal programme was published in 2014 (DEA 2014a), followed by several provincial and municipal coastal management programmes. A national ministerial working group acts as the national coastal committee, with several provincial and municipal committees also in operation, although some challenges remain (Sowman and Malan 2018).

To build capacity in coastal pollution monitoring the Government of South Africa established a National Pollution Laboratory in 2018, hosted by the Walter Sisulu University (Eastern Cape Province). Currently pilot testing is undertaken at designated sites along South Africa's coast (www.wsu.ac.za/waltersisulu/index.php/wsu-hosts-national-pollution-lab/).

Pollution from shipping is regulated through the Marine Pollution (Prevention of Pollution from Ships) Act (No 2 of 1986) which, together with regulations, gives legal status to the MARPOL Convention and the Annexes which South Africa has ratified. Accidental pollution from ships is dealt with under the Marine Pollution (Intervention) Act (No 64 of 1987) and the Marine Pollution (Control and Civil Liability) Act (No 6 of 1981, as amended). The responsibility of shipping falls with the Department responsible for Transport. However, responsibilities for day-to-day management of shipping activities has been delegated to the South African Maritime Safety Authority (SAMSA) and includes ensuring the safety of life and property at sea and the prevention and combating of pollution of the marine environment by ships (Jackson 2011). While SAMSA is responsible for the implementation of shipping legislation, the responsibility for matters relating to the combating of pollution is assigned to the Department responsibility for the Environment (Branch: Oceans and Coasts). The National Ports Act (No. 12 of 2005) addresses pollution matters in ports through the National Ports Authority.

Environmental matters pertaining of offshore exploration and mining activities are regulated by the Department responsible for Minerals under the Mineral and Petroleum Resources Development Act (No. 28 of 2002) which requires holders of exploration and mining permits to manage and remedy environmental impacts (including pollution) in accordance with the National Environmental Management legislation and in consultation with relevant government agencies (DEA 2014a).

6.3.10 Tanzania

The Constitution of the United Republic of Tanzania (1977) links a healthy environment with the wellbeing of its citizens and call on the public to ensure that natural resources of the country are managed properly obliging every person to safeguard and protect the natural resources, to combat all forms of misappropriation and wastage, amongst other matters (Walmsley and Patel 2012).

The Environmental Management Act (2004) provides a framework for the regulation of environmental issues in general, including Pollution Prevention and Control and Waste Management. A number of regulations relevant to pollution control have been issued under this Act, including (Jackson 2011):

- Environmental Management (Water Quality Standards) Regulations (2007)
- Environmental Management (Solid Waste Management) Regulations (2009)
- Environmental Management (Hazardous Waste Control) Regulations (2009)
- Environmental Management (Hazardous Waste Control and Management) Regulations (2019)
- Environmental Management (Environmental Impact Assessment and Audit) (Amendment) Regulations (2018)

The primary responsibility for marine pollution on mainland Tanzania lies with the National Environment Management Council (NEMC) (www.nemc.or.tz/). The NEMC has sole responsibility for control of land-based sources of pollution, and shares responsibilities on other matters pertaining to pollution of the marine environment.

Other pieces of legislation that also address aspects coastal and marine water quality include:

- Tanzania National Park Act (2002)
- Fisheries Act (2003), as well as Fisheries Regulations (2009)
- Tourism Act (2008).
- Public Health Act (2009)
- Water Resources Management Act (2009)
- Tanzania Fisheries Research Institute Act (2016)
- Water Supply and Sanitation Act (2019).

Together with the NEMC the Tanzania Ports Authority (established under the Tanzania Ports Act – 2004) controls pollution in ports and harbours on mainland Tanzania, while the Zanzibar Ports Corporation fulfils this function in Zanzibar's main ports (Jackson 2011).

The Merchant Shipping Act (No.21 of 2003) provides for pollution prevention and protection of the marine environment and marine security (Guromo 2017). Regulations under this Act include:

- Merchant Shipping (Prevention of Oil Pollution) Regulations (2012), providing technical and detailed guidelines for prevention of marine oil pollution
- Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations (2012) prescribing requirements for harbours, oil handling facilities, and offshore installations.

Also relevant is the The Tanzania Shipping Agencies Act (2017). The National Marine Oil Spill Response Contingency Plan (2016) is the national response to OPRC (1990) requirements, executed under the National Marine Oil Spill Coordinating Committee. The plan covers oil pollution response to the lakes and rivers but does not cover response to oil pollution originating from land based sources (Guromo 2017).

Petroleum exploration and development in Tanzania is governed under the Petroleum Act (No 21 of 2015). Part vii of the Act addresses environmental principles and liability towards pollution prevention. The Energy and Water Utilities Regulatory Authority (EWURA) is an autonomous multi-sectoral regulatory Authority that are obliged to comply and enforce the Petroleum Act (2015) (https://www.ewura.go.tz/home/).

7. KEY FINDINGS FOR WAY FORWARD

This overview of the status of marine pollution and C&MWQM in the countries of the WIO region underlines the threats posed to its sensitive and important coastal and marine ecosystems. Sources of marine pollution span several sectors; urban development and tourism, agriculture and forestry, fisheries and aquaculture, industry and mining, marine transportation and energy production. These sectors contribute to marine pollution problems through a number of key vectors, namely microbiological contamination, suspended sediment loading, nutrient enrichment, marine litter and toxic substances. In 2009, an assessment of the severity of these pollution problems across the region concluded that microbiological contamination and suspended sediment loading contributed mostly to negative environmental impacts and socio-economic consequences in the WIO region (UNEP et al. 2009c). Marine litter (particularly plastic) is becoming a major concern in the region with many countries rely on tourism. Also, with the rapid increase in coastal urbanisation (and associated generation of municipal waste) as well as a projected increase in commercial agricultural and industrial activities in the region, the risk of nutrient enrichment and toxic pollution can be expected to increase over the next years. The lack of monitoring programmes at the national-level and no linkages between any monitoring activities and management/policy decision making is a key concern in most WIO countries.

Reflecting on the status of C&MWQM, at the regional level Strategic objectives and Targets pertaining to C&MWQM in the WIO region have been defined as per the *Strategic Action Programme Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities* stating the following Strategic Objective for water quality in the WIO region: *'Water quality in the WIO region meets international standards by year 2035'.* In accordance with the Programme, this will be achieved when (i.e. indicators of verification):

- Quality of coastal and marine waters in the WIO region meet regionally agreed standards
- Wastewater discharges adhere to agreed national and regional effluent standards
- Increased government budget allocations for pollution prevention.

The Programme further identified a number of specific targets towards achieving these outcomes, mainly focused on mitigating and preventing impacts from land-based sources and activities:

- Effluent discharge standards developed and regionally harmonized
- Marine water standards developed and regionally harmonized (also referred to as *Guidelines for the development of Environmental Quality Objectives and Targets*)
- Regional best practice framework models for municipal wastewater management developed and adopted
- Collection, treatment and disposal of effluents undertaken in accordance with regional standards
- Environmental management systems and cleaner production technologies encouraged
- Stakeholders' sensitized and political support harnessed in favour of pollution prevention.

The *Strategic Action Programme for the Sustainable Management of the Western Indian Ocean Large Marine Ecosystems* also identified water quality degradation as a key concern in the region, and posed the following ecosystem quality objectives that pertain to C&MWQM:

- Restore ground and surface water quality and prevent further degradation occurring in the future

- Reduce microbiological contamination in coastal waters
- Reduce solid waste (marine debris) from shipping and land-based sources in coastal water
- Develop the capacity to prevent and mitigate the effects of oil spills at regional and national level.

Reflecting on the status of marine water quality policy and management at the national-level, most countries are signatories to the major international conventions and agreements pertaining to the combating of marine pollution, such as Regional Seas (Nairobi Convention), MARPOL and the Stockholm Convention. At a national level, all countries have some form of legislation in place to enable the control and management of marine water quality, some more advanced than others. However, dedicated management initiatives focusing on marine water quality management is limited, and where policies and plans have been put in place, implementation remains a major challenge. While numerous root causes, such as inappropriate governance, inadequate knowledge and awareness, and inadequate financial resources, will have to be addressed to ultimately achieving effective marine water quality management, there are a few, more direct, measures that could be undertaken to advance improvements in the region. The lack of effective development or implementation of initiatives is often a result of a silo-based, fragmented approach, instead of a more holistic, ecosystem-based approach that is critical for successful management of the environment – in this case the coastal marine environment. Because such programmes are largely lacking in countries of the region, and consequently there is no coordinated and consistent monitoring and reporting of marine pollution matters. This gravely impairs policy decision making, management and intervention to improving water quality.

Within this context the Contracting Parties to the Nairobi Convention urged the Secretariat to establish a Strategic Framework for C&MWQM for the region to fast-track implementation and which should build on refine previous initiatives on C&MWQM previously undertaken as part of the WIO-LaB Programme including:

- Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone of the Western Indian Ocean (WIO) Region (UNEP et al. 2009a)
- Towards a Protocol for long-term monitoring of marine environmental quality in the Western Indian Ocean (UNEP et al. 2009b).

The Strategic Framework should identify key components to be considered in C&MWQM, including monitoring. It is envisaged that a strategic (regional) framework would provide a basis for adopting and effectively integrating C&MWQM into national frameworks, acknowledging that countries are at different stages of development. The framework also should address mechanisms through which countries can contribute to regional reporting on global commitments and agreements, such as the SDGs and Aichi targets. Ultimately, it would also be desirable to develop a regional marine monitoring data repository (or data base) accessible to contracting parties and other interested stakeholders through, for example, the Nairobi Conventions Clearing House Mechanism platform.

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