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REGIONAL SEAS

Overview of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the Eastern African Region

UNEP Regional Seas Reports and Studies No. 167

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UNITED NATIONS ENVIRONMENT PROGRAMME
1998

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Contents

Preface

The Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities (UNEP(OCA)/LBA/IG.2/7) was adopted by an intergovernmental conferences held in Washington, DC, USA, from 23 October to 3 November 1995. The goal of the Global Programme of Action is to prevent degradation of the marine environment from land-based activities, by facilitating the realization by States of their duty to preserve and protect the marine environment.

The Washington Conference designated the United Nations Environment Programme (UNEP) as secretariat of the Global Programme of Action and requested that, as coordinator and catalyst of environmental activities within the United Nations system and beyond, it should through its programmes and secretariat role:

(a) Promote and facilitate implementation of the Programme of Action at the national level;

(b) Promote and facilitate implementation at the regional, including subregional, level through, in particular a revitalization of the UNEP regional seas programme; and

(c) Play a catalytic role in the implementation at the international level with other organizations and institutions.

The project for the Protection and Management of the Marine and Coastal Areas in the Eastern African Region (EAF/5) of the Food and Agriculture Organization of the United Nations (FAO) was launched in 1993 by the Eastern African Governments in collaboration with UNEP's Regional Seas Programme, with the main objective of developing, in collaboration with FAO and other United Nations agencies and multilateral and bilateral donors, national self-reliance in matters related to the integrated development and management of the environment of the coastal areas. The project is part of the ongoing broader concept within the framework of the Regional Seas Programme's Eastern African Action Plan aimed at enhancing the quality of the marine and coastal environments in partnership with coastal communities and their Governments in the Eastern African region.

To facilitate implementation of the Global Programme of Action around the world, UNEP is organizing, during the period 1996-1998, in cooperation with relevant regional and international organizations, a series of technical workshops of Government-designated experts, as well as representatives of relevant international organizations, the private sector and experts from non-governmental organizations. The purpose is to strength national capabilities for protection of the aquatic environment from land-based activities, and to promote regional and subregional cooperation. More specifically, the workshops are being convened with the following aims:

(a) To review the general objectives of the Global Programme of Action and its implications;

(b) To identify possible elements of regional framework strategies, with special reference to recommended approaches by source-categories;

(c) To consider the requirements for development and implementation of national programmes, including the assistance required and available for this purpose through the organizations supporting the Global Programme of Action; and

(d) To design and agree on general outlines for preparation of regional programmes of action to address land-based activities.

The present overview of land-based sources and activities affecting the marine, coastal and associated freshwater environment in the Eastern African region was prepared as a main background document for the workshop on implementation of the Global Programme of Action in the Eastern African region, held in Zanzibar, United Republic of Tanzania, 6 to 9 October 1997, organized by UNEP, FAO and the Institute of Marine Sciences of the University of Dar es Salaam, Tanzania. Funding for the workshop was provided by the Swedish International Development Cooperation Agency (SIDA), UNEP and FAO. SIDA also funded, through FAO, a previous related meeting of national experts from the region.

The objective of the overview is to present information that will assist Governments of the region, both individually and collectively, in their efforts to protect the marine environment and achieve the sustainable development of their coastal and marine areas through integrated coastal-management initiatives. The overview identifies and assesses the problems related to land-based activities for each country and the region as a whole. This information is intended to serve as the basis for establishing the priorities for remedial actions. In addition, management objectives and approaches have been defined, and criteria proposed for the evaluation of their effectiveness.

UNEP and FAO commissioned to the Institute of Marine Sciences of the University of Dar es Salaam to prepare the overview, which is based on national reports from the following countries: Kenya, United Republic of Tanzania, the Zanzibar state of the United Republic of Tanzania, Mozambique, Madagascar, Mauritius, Seychelles and Comoros. The draft document was submitted to the above-mentioned workshop and was reviewed and finalized based on discussions and recommendations provided by the government-designated experts participating, as well as recommendations by the UNEP Global Programme of Action Coordination Office and the Coordinator of the FAO EAF/5 project. The assistance of B. Rawlins and J. Arthurton (British Geological Society) in preparing the document is acknowledged.

The overview has three main objectives, namely:

(a) To review relevant information and activities of the individual countries comprising the region;

(b) To identify the priorities and formulate recommendations for the problems arising from land-based activities in each country, and the region as a whole; and

(c) To provide a basis for the formulation of a regional programme of action to address land-based activities in Eastern Africa.

The overview follows the approach recommended by the Global Programme of Action, as well as the layout prepared by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) for a global review on land-based sources and activities affecting the quality and uses of the marine, coastal and freshwater environment (GESAMP, 1997), and will also be used to provide data and information for the global review, currently being prepared (under the leadership of UNEP) by the GESAMP Working Group on Marine Environmental Assessments, which is expected to be ready by 1999.

Executive Summary

This document provides a regional overview of land-based sources and activities and their impacts on the marine, coastal and associated freshwater environments in the East African region. The overview covers three coastal States [Kenya, United Republic of Tanzania (Tanzania) and Mozambique] and five island States [Madagascar, Mauritius, the Islamic Federal Republic of Comoros (Comoros), the Zanzibar state of the United Republic of Tanzania and the Seychelles]. The rapidly expanding coastal populations of the region exert ever-increasing pressure on coastal habitats and resources. Land-based anthropogenic activities such as agriculture and industry, coastal urbanization, tourism and rock/mineral extraction, disturb natural conditions and processes, degrading coastal resources and habitats. The effects can have serious social and economic implications. The objective of the overview is to present information that will assist Governments of the region in their efforts to protect the marine environment and achieve the sustainable development of their coastal and marine areas through integrated coastal management initiatives.

There is a large degree of uncertainty associated with the source-inventory method for the estimation of pollution loads from industrial and domestic sources, on which all the national assessments were based. Very few scientific studies have been conducted to determine the concentration of specific pollutants in fresh, ground, or coastal waters. Therefore, the interpretations made in this report are tentative.

The lack of infrastructure and treatment facilities for the large quantities of domestic sewage generated by expanding coastal urban populations, and an increasing number of visiting tourists, represents the greatest threat to public health, coastal habitats and economic development in each State of the region. Other priorities requiring action include the effects of siltation related to agricultural activity and the dumping of solid domestic waste leading to the degradation of coastal habitats, with implications for fish stocks and catches. Although eutrophication and algal blooms associated with agricultural, industrial or domestic sewage pollution have been identified as a threat to coastal habitats, further scientific research is required to link the causes and effects.

Strategies and measures are suggested to address the priority issues identified, including the improvement of sewage infrastructures and more detailed assessment of the effects of pollution on coastal habitats using remote-sensing.

I. Introduction

A. Natural conditions and processes

The East African region comprises 10 States, four coastal States (Kenya, United Republic of Tanzania, Mozambique and Somalia) and six island States (Madagascar, Mauritius, Zanzibar state of the United Republic of Tanzania, Comoros, the Seychelles and Reunion) (Figure 1). They cover a wide range of both political and economical development. The coastal region between Somalia and Mozambique is home to 19 million people with an average population growth rate of 6 per cent in the main urban centres. In the mainland continental States, 20 per cent of the population reside on 12 per cent of the land area, exerting intense pressure on limited coastal resources. All the States of the region are heavily dependent on their coastal environments as sources of food, income and employment. Rapidly expanding coastal populations, as well as increasing industrial and agricultural activities, are potential sources of land-based pollution that threaten the sustainability of coastal and marine ecosystems and their associated non-living resources.

This report considers land-based sources and activities affecting the aquatic environment in Kenya, the United Republic of Tanzania, Mozambique, Madagascar, Mauritius, the Zanzibar state of the United Republic of Tanzania, Comoros, and the Seychelles. Although relevant reports were requested from Somalia and Reunion, they were not submitted for incorporation into this regional assessment. The land areas and the lengths of coastlines of all the countries are shown in table 1.

Table 1. Physical characteristics of the countries considered in the overview

Country	Area (km^2)	Length of coastline (km)
Comoros[a]	1,660	350
Kenya[b]	588,045	500
Madagascar[c]	592,797	5,100
Mauritius[d]	2,040	320
Mozambique[e]	800,000	2,770
Seychelles[f]	445	600
Tanzania[g]	942,654	800
Zanzibar State of the United Republic of Tanzania[h]	1,666	-

[a]Abdoulhalik (1997), [b]Odido (1997), [c]Rainaivoson (1997), [d]Baissac (1997), [e]Lundin and Linden (1997), [f]Shah (1997), [g]Francis (1997)

1. Climate and oceanography

The climate of the region is generally tropical humid to sub-humid. The monsoons are the dominant influence on wind direction and strength, temperature and rainfall. They also affect the major coastal currents. There are two monsoon seasons: the north-east monsoon (November to February) is characterized by higher air temperatures and weaker winds compared with the south-west monsoon (April to September) with lower air temperatures and stronger winds. The names of the monsoons may vary according to location within the region. The inter-monsoonal periods, the months of March/April and October/November, are typically calm.

The South Equatorial Current and the East African Coastal Current are strongest during the south-west monsoon; the East Madagascar and the Mozambique current systems are strongest during the north-east monsoon (Figure 2). The Somali Current shows reversals in direction reflecting the alternating monsoons. Tidal ranges vary greatly within the region (Alusa and Ogallo 1992). Along the mainland coasts, the average Spring tidal range varies from 2 m to 6 m, with Beira (Mozambique) having one of the largest ranges and the greatest flushing of coastal waters and inlets. Mauritius and Reunion experience negligible tides with minimal flushing.

2. Geology and geomorphology

Many types of geological formation are found in the region, with ages ranging from 200 million years to recent. For instance, the coastal sediments of the United Republic of Tanzania vary in age from Jurassic through Cretaceous to Tertiary and Quaternary and are composed of both marine and terrestrial sedimentary rocks (Kent *et al.* 1971). The islands of Reunion, Comoros and Mauritius are essentially volcanic while those of the Seychelles are granitic.

In terms of its geological structure, the coastline of Eastern Africa represents a passive continental margin, from which through geological time continental fragments, large and small, have separated and migrated across the adjoining oceanic crust. Some of these detached continental fragments remain within the region, notably the Seychelles Bank and Madagascar. This structural history has left the mainland States with generally narrow continental shelves. Exceptions include the coasts of southern Mozambique and central Tanzania in the vicinity of Unguja and Mafia islands. In the island States, wider shelves feature in western Madagascar and the Seychelles. Pleistocene coral limestones overlap older rocks along much of the mainland coastline and on some of the islands (Arthurton 1992). These limestones form extensive coastal terraces, cliffs and intertidal platforms (Arthurton 1992).

Fringing, largely intertidal platforms, eroded mostly in these Pleistocene limestones, dominate the coastal geomorphology in much of the region. Commonly cliff-bounded to landwards, these platforms extend seawards from a few tens of metres to more than two kilometres from the back shore, their seaward edges forming breaker zones for ocean swell. Terraces and platforms alike are incised by major creeks draining the hinterland, as at Dar es Salaam and Mombasa. Holocene and recent beach-ridge and bar deposits overlie the platform rocks in many places. Mangrove forests are developed in many of the sheltered sedimentary embayments including those in deltaic areas, such as the outflow of the Rufiji River in Tanzania. Coastal sand dunes are associated with river mouths where there is a high discharge of terrigenous sediment, as from the Sabaki River in Kenya (Arthurton 1992). Water resources, including potable water supplies, are dominated by groundwater in coastal areas of highly permeable Pleistocene limestone.

3. Ecosystems

The coastal ecosystems of the region are generally both rich in natural resources and highly productive. Especially important habitats include mangrove forests, coral reefs and seagrass meadows. Of the 38 designated marine and coastal habitats, at least one third are found within each country of the region; the greatest known diversity was reported in Mozambique where 87 per cent of all habitat types are recorded (UNEP 1984). These ecosystems sustain a great diversity of marine life and are an important food source for most coastal communities. The conditions within each ecosystem are influenced by those in adjacent ecosystems. For example, mangrove ecosystems are a nursery ground for a variety of fish, some of which mature in coral reefs and seagrass meadows. There is also nutrient, sediment and organic matter interchange between the ecosystems. The destruction of mangrove forest deprives many fish species of spawning and nursery areas, with the consequent deleterious effects on fish populations and biodiversity in adjoining offshore areas.

Coral reefs are among the most biologically diverse ecosystems on Earth. They occur at the margins of the fringing platforms, mostly on the outer, seaward-facing slopes and in adjoining lagoons; also, on shallow sub-tidal patches isolated from extensive platforms. The reefs support inshore fisheries, and in some cases protect shorelines and ecosystems such as mangrove forests and seagrass meadows from extreme wave action. Coral reefs occur in all countries of the region, with Mozambique, Madagascar and

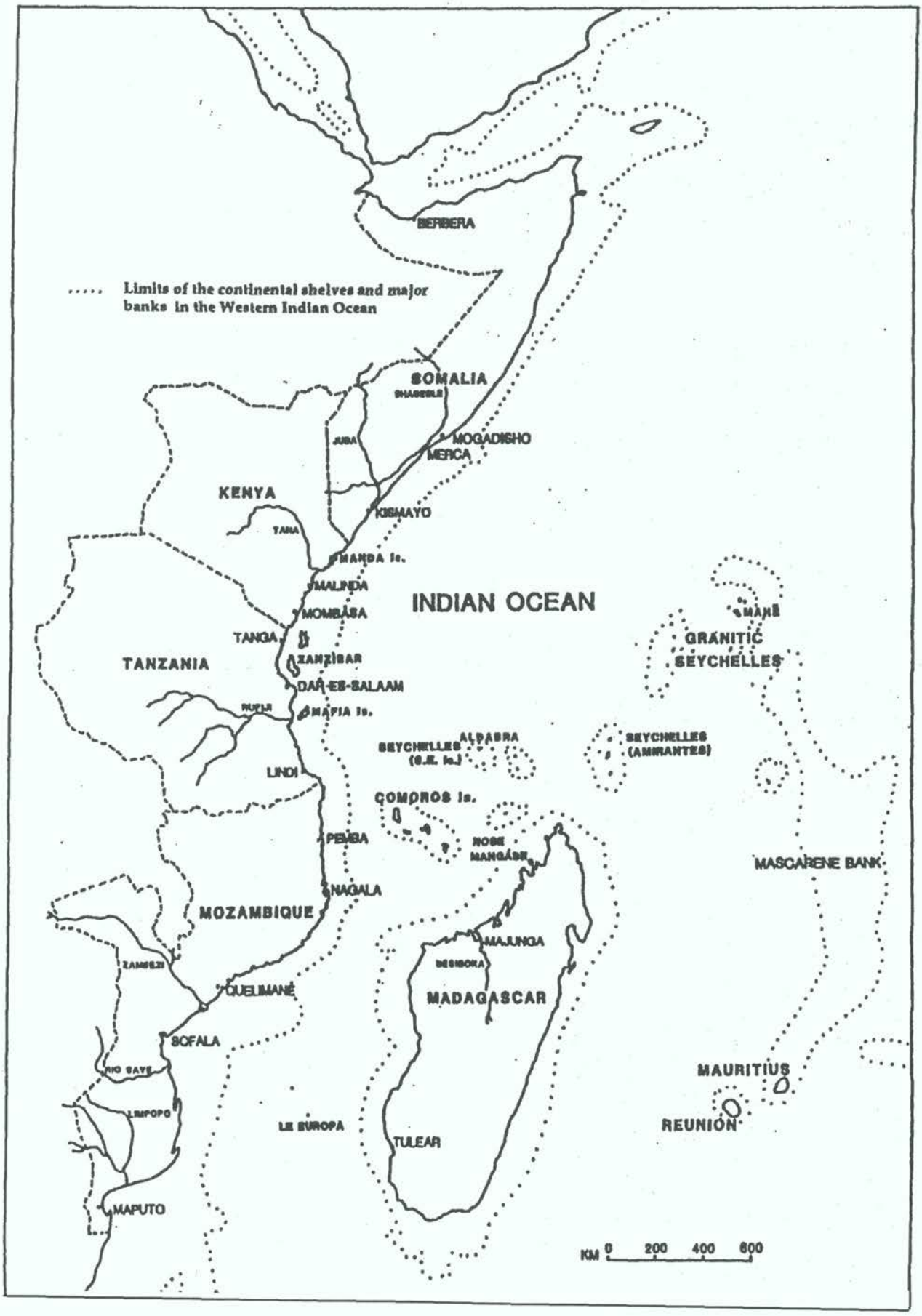

Figure 1. The Eastern African region showing major towns, coastal settlements and rivers (Ambio 12(6), 1983, IUCN)

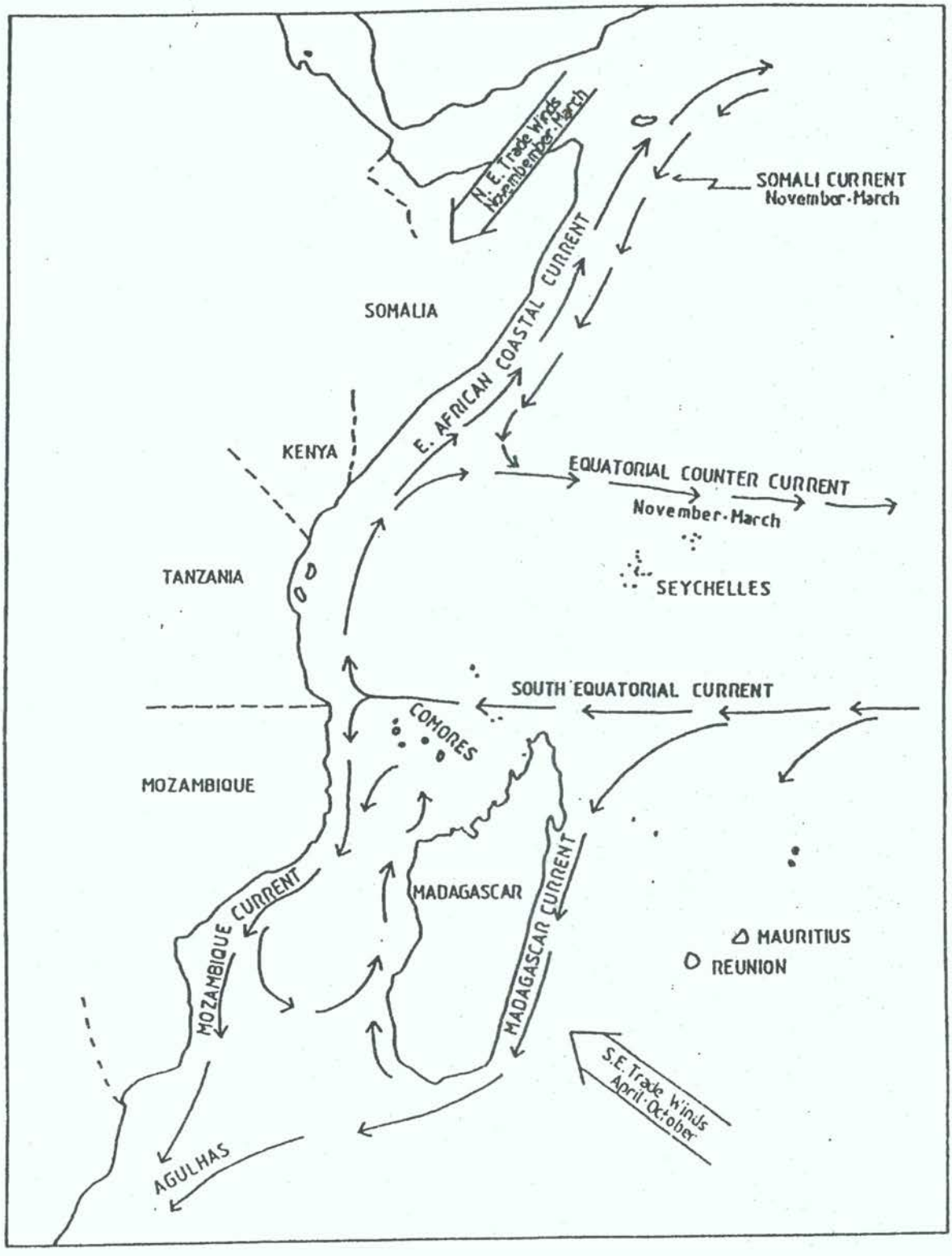

Figure 2. Ocean currents and winds in the Eastern African Region (After IUCN/UNEP 1982)

Tanzania having the largest coverage by area. The economies of all the countries benefit from reef fisheries, as well as reef-related tourism. Artisanal fisheries typically represent more than 95 per cent of the total marine fish catch, these activities being mostly in reef, seagrass and associated platform environments, thus providing employment and income in most coastal communities. For example, more than 60 per cent of the fish species caught in Tanzanian waters are caught in or around the reef environment (Francis and Muhando 1996). Coral grows in clear water and is extremely sensitive to pollution, whether due to chemical contaminants or suspended sediments. The rapid expansion of coastal populations and the consequent increased loads of domestic sewage, agricultural run-off and industrial effluent to the marine environment represents a significant threat to the coral-reef habitat.

Mangrove forests are biologically rich ecosystems and an important form of coastal vegetation. Their extensive root systems stabilize sediments and they provide shelter for an array of birds and marine animals, in particular the juveniles of commercially important fish and crustaceans. In addition, the decomposition of mangrove litter provides a source of food for both mangroves and, for example, shrimp communities in adjacent habitats. For many coastal communities, mangroves are the primary source of timber, firewood, charcoal and a variety of other forest products. Some mangroves are also used for medicinal purposes. Molluscs, crabs, fishes and shrimps caught from the mangrove ecosystems are direct sources of food and income. Consequently, mangroves are under increasing pressure from the expanding coastal population. Mozambique has the largest total area of mangrove in the region with 396,080 hectares (Fernandes and Hauengue 1997). Madagascar and Tanzania have 327,000 (Rajonson 1995) and 115,475 ha (Semesi 1991), respectively.

Coastal wetlands are ecologically sensitive areas that provide inter-linkages between coastal habitats and help to maintain their biological diversity. Sedimentation in wetland areas reduces turbidity of coastal waters by trapping terrigenous sediment that would otherwise be transported offshore. Coastal habitats provide food, shelter, breeding and nursery grounds for a range of marine species including birds, crabs and shrimps. Seagrass meadows for example, are at the important primary producers on which all levels of the food chain depend. They act as nurseries for many species of fish and are feeding grounds for turtles and dugongs.

B. Anthropogenic impacts on natural conditions and processes

1. Coastal urbanization

Large, rapidly expanding coastal urban populations produce large quantities of domestic sewage, which pose a threat to potable water supplies and to the clarity and quality of both freshwater and near-shore coastal waters. Storm-water run-off from impermeable urban surfaces and sub-surface sewers represents an alteration to the natural hydrological regime and the salinity of near-shore coastal waters. Storm-water run-off in urban areas is also a significant source of land-based pollution to coastal waters contributing to both the biochemical oxygen demand (BOD) and suspended solid loads. Expanding coastal populations also imply an increase in solid wastes. Because of the low efficiency in collection and treatment of solid wastes, the garbage is a threat to wetlands and near-shore marine ecosystems. In addition, the expanding coastal population also increases the pressure on marine fisheries for increased catches, resulting in diminishing fish stocks. In 1994, the combined population of the nine countries residing within coastal regions was estimated at 19 million, of which Kenya, Mozambique, Tanzania and Madagascar constituted over 95 per cent of the total (Table 2). The population growth rates of the mainland States, the Comoros and Madagascar are generally high, particularly in Kenya (3.3 per cent), Tanzania (2.8 per cent) and Mozambique (2.8 per cent). Growth rates in the large coastal cities, such as Dar es Salaam (7.8 per cent per annum (Ministry of Finance and Planning 1988), Maputo and Mombasa, are even higher due to rural-urban migration. In addition to the local population, the number of coastal tourists visiting the region has increased significantly in recent years, which has increased the load of domestic sewage.

The exploitation of water resources by expanding coastal urban populations can lead to the degradation of groundwater and freshwater resources through sewage pollution and/or saline intrusion. Much of the coastal urban population relies on septic tanks and pit latrines resulting in faecal contamination of groundwater. Increased abstraction of groundwater to meet the demand of expanding local and tourist populations can lead to saline intrusion along coastal margins.

Table 2. Population and population density statistics for States considered in this overview

Country	Total population (M)	Coastal population (M)	Population in coastal zone (%)	Population growth rate (%) (a-f)
Comoros	0.54[a]	0.54	100	2.70
Kenya	26.80	2.30	8.10	3.30[b]
Madagascar	12.10[c]	4.80	36.60	3.00
Mauritius	1.10	1.10	100	1.20
Mozambique	18.53[d]	6.50	39.30	2.80[d]
Seychelles	0.07	0.07	100	1.50[e]
Tanzania	28.90	4.61	16.20	2.80[f]
TOTAL	85.60	19.04		

Sources: [a]Abdoulhalik (1997), [b]Government of Kenya (1989), [c]Ranaivoson (1997), [d]National Institute for Statistics (1996), [e]Government Management and Information System (1996), [f]Bureau of Statistics, Ministry of Finance, Economic Affairs and Planning (1991).

2. Industrial activity, ports and harbours

Harbours and ports located along coastlines, creeks, estuaries and rivers are the focus of industrial activity representing point sources of pollution to the marine environment. While the level of industrial development in the region is still relatively low, the rate of industrialization around large coastal cities is accelerating. Furthermore, regulations on the treatment and disposal of wastes are either lacking or poorly enforced. Pollutants include the discharge of industrial chemicals, heavy metals, food and beverage processing waste and inadvertent oil spills. Salt production in coastal areas often depends on the use of salines, flooded areas on which salt is collected following the evaporation of sea water. Mangroves are often clear-cut for the provision of saline areas.

The marine waters off the coast of East Africa are used as one of the main transportation routes for petroleum from the Middle East en route to Europe and the United States of America. Recorded incidents of major oil spills have had devastating, long-term effects on coastal habitats. A major oil-spill, either within ports or in near-shore coastal waters of the region represent a significant potential threat to coastal habitats.

3. Agricultural activity

Agricultural pollution is associated with elevated concentrations of nutrients and pesticides in freshwater and near-shore coastal waters. The increased use of agricultural fertilizers can lead to elevated concentrations of nutrients, particularly nitrate, in drainage waters and, depending on the local hydrogeology, the contamination of surface and groundwater. Elevated concentrations of both nitrate and phosphorous in agricultural run-off can lead to eutrophication of freshwater and near-shore coastal waters. The problems associated with eutrophication include rapid increases in phytoplankton (algal) biomass leading to changes in the physical and chemical composition of water, including a decline in dissolved oxygen concentrations. Increases in nutrient concentrations and reductions in water clarity can have deleterious effects on coral health. In addition, algal blooms release toxins that poison shellfish. Pesticides in agricultural run-off have resulted in the destruction of mangrove ecosystems. Intensive use of agricultural land leads to the mobilization of sediment, which reduces water clarity and damages sensitive coral habitats.

4. Mineral development and quarrying

The mining of mineral sands in coastal environments leads to short term, site specific, but

often catastrophic effects due to the mobilisation of sediment and damage to coral reefs.

C. Socio-economic implications anthropogenic alterations on natural conditions

The GDP of the seven countries considered in this overview indicates large differences in economic development, from US$ 700 in the Comoros and Mozambique to US$ 9,600 in Mauritius. The majority of the countries in the region are classified as 'poor' according to the World Bank criteria (annual per capita GNP of less than US$ 580). The social and economic implications of land-based activities concern to water pollution, public health and the sustainability of coastal resources.

Domestic sewage and garbage in coastal urban centres and diffuse sources of agricultural pollution represent significant threats to the quality of drinking water, in both the short and long term, for surface and groundwater, respectively. Health problems are often associated with limited treatment of sewage in areas of poorly developed sewerage infrastructures, particularly where local populations rely on groundwater as a source of potable water.

The degradation of groundwater resources through saline intrusion has both social and economic implications for the entire population of the coastal region. Although the degradation of water quality generally occurs slowly, the reversal of the process can only be achieved over a prolonged period. Therefore, prevention through long-term planning is imperative to avoid expensive treatment of the problem over many years.

The destruction of coastal habitats by an expanding coastal population leads to the degradation of interdependent habitats and reduced fish catches. For example, a reduction in seagrass or mangrove cover can reduce fish spawning, leading to reduced catches, which has both social and economic implications, particularly for artisanal fisheries, the income from which represents a significant proportion of GNP. The perception of a pristine environment and unpolluted water along beaches is crucial in maintaining ecosystem health and ensuring the continued success of beach hotels in attracting tourists, and the associated income. The importance of coastal tourism throughout the region is highlighted by Kenya where 60-70 per cent of national tourism is coastal (Mwaguni and Munga, 1997) and the island States of Comoros, Mauritius and Seychelles where it accounts for all tourism.

II. Identification and assessment of problems

This section considers how significant land-based sources and activities affect both the local population and the marine, coastal and associated freshwater environments. Where appropriate, assessments are made of their effects on: (i) food security, poverty alleviation, and public health; and (ii) marine and coastal resources, ecosystem health and biological diversity.

The national assessment of sources of water and air pollution for each State of the region were compiled using either the World Health Organization (WHO) Management and Control of the Environment Manual (WHO 1989) or the rapid inventory techniques in environmental pollution (WHO 1993a). Estimates of land-based sources of pollution in the national reports, which were used to compile this regional overview, generally refer only to the largest coastal urban centres.

A. Agricultural activities

Agriculture is the backbone of the economy of most countries in the region and is central to the alleviation of poverty. In 1982, 90 per cent of the population in the region depended on agriculture. For example, it is the mainstay of the Kenyan economy, providing employment for 75 per cent of the labour force and accounting for 30 per cent of gross domestic product (Odido 1997). For the remaining mainland countries and Madagascar, agriculture currently forms the basis of the economy, accounts for most of the foreign exchange earnings, employs between 76 per cent and 86 per cent of the work force and represents between 28 per cent and 66 per cent of GDP (Rainaivoson 1997; Lundin and Linden 1997; Francis 1997).

Only tentative interpretations concerning the significance of agricultural pollution can be made, because concentrations of nutrients or pesticides have not been determined for fresh waters, ground waters or coastal waters in the majority of the States of the region. Data concerning the sale or application of agricultural fertilizers and pesticides have been included in several of the national reports. However, in the case of the mainland States these often do not refer to the whole coastal region, but to specific coastal districts, generally around large urban centres. A table showing the types of pesticide used in each of the States of the region is provided in annex II below.

In Kenya approximately 56,000 kg of fertilizers and 24,000 kg of pesticides are applied annually in

the districts of Mombasa and Lamu. The only district in which agricultural run-off contributes significantly to the pollution load is Kilifi. Sediment cores collected in the creek systems of Mombasa as part of the Department for International Development (DFID)-funded Land Ocean Contamination Study (LOCS) indicated that the influx and/or retention of organochlorine pesticides, including persistent forms such as DDT, were negligible (Williams *et al.* 1996). It is unlikely that much of the input is incorporated into the sediments due to the short water-residence time, and much of the dissolved or very fine particulate load is discharged and dispersed in the Indian Ocean. The detrimental effects of sedimentation are considered to be more significant than agrochemical and pesticide pollution. The Tana and Sabaki rivers discharge large quantities of sediment into coastal waters, partly as a result of tillage in their respective catchments (Munga *et al.* 1993; Mwaguni and Munga 1997) which has been associated with marine degradation due to soil erosion (van Katwijk *et al.* 1993). However, a study of the effects of siltation conducted between 1985 and 1993 found no evidence for decreased diversity or ecological health of sediment-influenced reefs in the Watamu and Malindi National Marine Parks (McClanaham and Obura 1997). In addition, the port of Mombasa requires frequent dredging due to siltation representing a significant economic cost to the port authorities.

In Tanzania, there has been an increase in the use of pesticides from 0.33 to 0.5 and 1 kg per capita between 1977 and 1988 and 1994, respectively (Ak' habuhaya 1989; Meena and Lema 1994). However, intensive agricultural production on the mainland is confined to the highlands, from which pollution effects in the coastal zone are likely to be limited. Although monitoring data are not available, it has been reported that the intensive uses of fertilizers and pesticides for rice production may be causing pollution in the Rufiji Delta and the Rufiji Delta Mafia Island complex. A comparatively small total of 57,814 litres and 16,143 kg of pesticide were imported into Zanzibar state of The United Republic of Tanzania between 1985 and 1990, used mainly on rice farms and sugar-cane plantations. There has been a gradual change over the last decade from the use of more persistent/toxic pesticides to less harmful forms (Mmochi 1997; Head, Plant Protection, Department, Zanzibar, personal communication). In the Zingwezingwe River and Makoba Bay, which drain sugar-cane plantations and rice farms around the Mahonda sugar factory, there have been reports of occasional fish mortality, which may be associated with pesticide pollution (Mohammed 1990).

Sugar cane dominates agricultural production in Mauritius accounting for 98 per cent of agricultural land and representing 57 per cent of agricultural production in terms of its contribution to GDP. The average total annual import of fertilizer and pesticides between 1979 and 1989 was 57,500 and 1,153 tonnes, respectively. Reported estimates suggest that the application of nitrogen for sugar-cane production is approximately 126 kg/ha, among the highest figures worldwide. Increases in the nitrate concentrations of ground waters in certain areas have been reported for several years (Jootun *et al.* 1997) and have reached recommended upper limits for drinking water of 50 mg /l (WHO 1993b). Evidence of ecological damage due to the application of pesticides in riparian zones has also been reported, suggesting that pesticides may be transported via freshwater to coastal waters.

Agricultural production occupies approximately 67 per cent of land on the Comoros, employs between 70 per cent and 80 per cent of the total population, and accounts for 98 per cent of export revenue. The main export crops include vanilla, ylang-ylang and cloves. Cereals, rice, potatoes, fruits and legumes are also grown for local consumption. As a general rule, the use of pesticides and fertilizers for market gardening is limited; the total quantity of pesticides used between 1991 and 1993 was approximately 70,000 kg (Kouassi 1994). Steep slopes and continuous cultivation without the provision of fallow fields have led to the impoverishment of the soil and serious incidents of soil erosion, siltation of the coral reefs with deleterious effects on fisheries. Agricultural run-off is also considered to have led to the pollution of groundwater although no data have been reported on which an assessment of the problem can be based.

Most of the agricultural activities in Mozambique take place along or close to the main river basins. Laboratory analysis has shown presence of 2,4,5 TCB, pp DDT, pp DDE, lindane and HCB residues in Monapo, Pungoe Maputo and Incomati river mouths (Fernandes and Hauengue 1997). Poor farming practices, deforestation and other bad land-use practices cause sedimentation in the coastal and marine environments. Amounts of 1,200,000 and 2,500,000 m^3 of sediments dredged in Maputo and Beira bays, respectively, are thought to be a consequence of bad land use practices.

Agricultural production does not represent a significant proportion of GDP or land use (4 per cent of the total area) in the Seychelles. Consequently, the nutrient load derived from agricultural run off was reported as less than 1 per cent of that from refuse heaps, which would indicate that the former is not a significant source. Approximately 820 kg of pesticides were sold between October 1989 and March 1990, a small amount in comparison with other States of the region. These figures would suggest that soil

erosion and agrochemicals do not currently represent significant sources of pollution to the water environment.

Cattle-rearing and rice production are the main agricultural activities in Madagascar, although small areas of intensive production of sugar cane and cotton are located in the south-west and north-west of the country, where the greatest quantities of fertilizers and pesticides are applied. The application of fertilizers in intensive agricultural areas was reported to be as high as 163 kg/ha in 1990, and has been linked to localized algal blooms and reduced fish catches in lagoons (Vasseur *et al.* 1987), particularly around the reef at Toliara. However, no research has been reported to date to prove cause and effect. The clearing of forests in Madagascar, resulting in sediment mobilization, siltation and the destruction of coral-reef habitats has been identified as a major problem (Linden and Lundin 1997), particularly along the western coastline (Neuvy 1982). The causes include bush-fires, harvesting of forests for production of charcoal and clear-felling for agriculture purposes. Little is being done in the way of reafforestation to reduce soil erosion.

Regional assessment of problems associated with agricultural activity

With the exception of Mauritius, the physical effects of siltation resulting from agricultural activities, most notably along the coasts of Kenya, Madagascar and the Comoros, are currently of greater concern throughout the region than agrochemical pollution. Further work is required to quantify these physical effects, such as the extent of destruction of coastal habitats, and their economic implications, including reduced fish catches and the need to dredge harbour areas.

The lack of monitoring data concerning the concentrations of agricultural nutrients and pesticides in the coastal and fresh waters of the region makes any assessment of associated pollution problems very tentative. Ecological damage and the nitrate contamination of ground waters have been linked to intensive agricultural production in Mauritius. The absence of significant concentrations of persistent organochlorine pesticides in the creek sediments of Mombasa could indicate that fresh waters draining into the creek systems are not severely polluted. However, this finding may be explained by the lack of intensive agricultural activity bordering this area or the short residence times of the creek waters. Therefore, there is insufficient evidence to indicate whether pesticide pollution in the more intensively farmed coastal areas of the region poses a significant threat to drinking water supplies, or to coastal habitats receiving elevated nutrient loads in agricultural run-off. The trend in increased use of both fertilizers and pesticides in intensive agricultural production is likely to lead to elevated concentrations of nutrients in agricultural run-off and ground waters.

Although algal blooms have been observed in coastal waters of the region, an assessment cannot be made regarding the importance of agricultural run-off for their occurrence, because of a general lack of monitoring of nutrient concentrations and research into the process of eutrophication. To date, algal blooms around coastal urban centres have generally been associated with inorganic nutrients derived from domestic-sewage pollution.

B. Industrial activity, ports and harbours

Overall, industrial development in the region remains relatively low. Industrial activity is focused on the ports and harbours of both the mainland and island States. The number and type of manufacturing industries have changed considerably since 1982 (see annex III below). The number of recorded manufacturing industries in Mombasa and Maputo increased by 250 per cent between 1982 and 1992. The increase over the same period was less pronounced in Dar es Salaam (132 per cent), while the numbers of manufacturing industries in Seychelles and Tanga fell significantly. Mombasa, the largest port in the region, handles over 8 million metric tonnes of cargo per year. Other major ports include Dar es Salaam (Tanzania), Maputo (Mozambique), Beira (Mozambique), Toamasina and Mahajanga (Madagascar), Victoria (Seychelles) and Port Louis (Mauritius). Refineries receiving crude oil in the region are located in Mombasa, Dar es Salaam, Maputo and Tamatare (Madagascar). Few industries in the region have waste-treatment plants and/or recycling facilities. Many industries empty effluents directly into creeks, rivers or coastal waters.

In Kenya, the increase in industrial activity in Mombasa was largely a result of an expansion in the food processing, metal and textile industries. Although industries generally discharge their waste directly into Kilindini harbour and Port Reitz, the more hazardous waste is disposed at the Kibarani dumpsite, leachate which enters the creek system. Monitoring data for the concentrations of metals and organic contaminants associated with pollution from industrial activity are limited to those reported in the British Geological Society (BGS) LOCS study for waters and sediments around Mombasa. No substantial increases in metals concentrations attributable to anthropogenic activities have been reported, with the exception of localized lead, zinc, and copper contamination in the vicinities of Makupa Creek and Mombasa harbour. However, it is important to note that the hydrodynamic setting of Mombasa, in which the

average residence time of contaminated water was shown to be less than one week (Rees *et al.* 1996), may result in the rapid attenuation of contaminant concentrations. The LOCS study reported elevated concentrations of lead, zinc and copper in waters and suspended particulate matter along the reef front between Nyali and Mtwapa. Although this could not be explained by an anthropogenic influence, it has been suggested that the source of such contamination may be ships which flush their tanks in near-shore waters.

The annual total BOD load in Mombasa was estimated to be 25,800 tonnes, 72 per cent of which comes from industrial effluent (Munga *et al.* 1993), with 94 per cent of that amount attributed to the food and beverage industry. Practically all the BOD loads derived from industry around Mombasa enters the creek system. The rapid mixing of oxygenated marine water and contaminated creek water will rapidly attenuate the high levels of BOD resulting from the release of industrial effluent, limiting its impact on coastal habitats. Industrial sources account for 62 per cent of the annual suspended solid load (more than 20,000 tonnes per year) entering the creek systems of Mombasa. The remainder is derived from storm-water run-off and domestic sewage. Despite two significant oil spills in the last decade, the concentration of hydrocarbon derivatives in the inshore waters of Mombasa is low (Williams *et al.* 1996).

In Tanzania, the total number of industrial units in Dar es Salaam increased from 49 in 1982 to 74 in 1992; in Tanga it fell from 14 to 5. The cumulative BOD of the waste from industries in Dar es Salaam was estimated to be 405g/l in 1982, 29g/l of which was from breweries. It has been reported that the Msimbazi River is practically devoid of life due to the anoxic conditions resulting from the pollution load of the brewing industry (Kimolo 1989). Elevated concentrations of the metals lead, cadmium, chromium and copper have been detected in shellfish at the mouth of the Msimbazi River where it enters the Indian Ocean (cited in Mashauri and Mayo 1989). The majority of industrial waste generated in Dar es Salaam was reported to be either disposed of on site, or at Vingunguti disposal site. Except for paper, sugar and cement industries that recycle part of their waste, the remainder discharge their wastes directly without treatment. The average chemical oxygen demand of five sea-water samples collected around Dar es Salaam and Zanzibar Town was reported as 602 mg/l and 1235 mg/1, respectively. However, the variability of chemical oxygen demand among the five samples on which the average figure is based suggests that this value may not accurately reflect the organic load to coastal waters. No significant increases in metal concentrations or hydrocarbon derivatives could be related to industrial/ anthropogenic activity throughout the creek systems of Dar es Salaam (unpublished LOCS data). In addition, an analysis of coral tissues conducted under the LOCS project showed that metal contamination of corals adjoining Dar es Salaam was not significant. Industrial activities associated with the exploitation of natural gas on Songo Songo Island is also a significant potential source of pollution.

The total number of industrial units listed for Maputo (Mozambique) has increased from 11 in 1982 to 29 in 1992 to 137 in 1996. The industries produced a total of 79,388 tonnes of BOD in 1996, including an unquantified amount of wastes containing heavy metals such as mercury, lead, chromium, manganese, nickel and zinc.

Sugar-cane processing produces the largest quantities of industrial waste effluent in Mauritius. There are 18 sugar mills, which discharge large quantities of a variety of effluents with high BOD values to canals and rivulets during the harvest season. They include hot condensed water, carbon-column workings, fly ash and organic solvents. On the basis of figures for the sugar cane harvest of 1994 (500,209 tonnes) and average pollution loading for selected streams per tonne of sugar cane processed, the total load of BOD_5 and total suspended solids to streams were 358 tonnes and 683 tonnes, respectively. Although a variety of waste-water treatments, including sedimentation, anaerobic and aerobic lagoons, have been used to reduce the pollutant load of waste effluent, their relative success has been varied. The release of effluent containing black soot ash from sugar mills to coastal waters at Bel Ombre leads to high turbidity of water on the beach, although this has not been linked directly to ecological damage. The release of effluents with high BOD into streams has resulted in oxygen depletion and the death of fauna. The designing process in the textile industry also produces waste effluent with a high BOD and suspended particulate content, but represents only a small proportion of the total BOD loads to fresh and coastal waters.

Little information was available concerning chemical pollution of water resources from industrial sources in the Comoros. Industries are under an obligation to respect the environment and not to release untreated chemical wastes. Processing industries associated with agricultural and pastoral production account for 85 per cent (14.41 tonnes per annum) and 92 per cent of the BOD and total suspended solid load derived from industrial sources. The loads of BOD, total suspended substances (TSS) and solid waste produced by industrial sources are small in comparison to domestic-waste loads.

Calculations of BOD loads to the water environment derived from industrial activities in the Seychelles indicated that agricultural and livestock production accounts for 71.6 and 88.7 per cent of the BOD and TSS loads, respectively (Radegonde 1997). The other major contribution is from the fish processing and canning industries, which account for 17.7 per cent of total BOD, 6.7 per cent of TSS and 95.9 per cent of the total oil load (130.5 tonnes per annum), although details of disposal (for example, direct to coastal /fresh waters, refuse sites, etc.) were not reported. Artisanal fishing in the Seychelles provides employment for the local population, while industrial fishing of tuna, principally by European vessels, accounts for 90 per cent of exports. The brewing and tuna-canning industries are reported to contribute 65 and 18 per cent respectively, to the total BOD load derived from industrial effluent (UNEP 1995b). However, this accounts for only 17.5 per cent of the total BOD load, of which 72 per cent is derived from storm run-off and sewage treatment. Industrial waste was reported to constitute 56 per cent of the total suspended solid load discharged into coastal waters of the Seychelles, the remainder being derived from domestic sources.

With the exception of the oil refinery in Toamasina, most of the industrial activity in Madagascar concerns the processing of agricultural and farmed animal products. Industrial activity around the coast is focused in the ports of Antsiranana, Ambilbe, Mahajanga, Tolagnaro and Toamasina, where the majority of the factories do not treat their waste but discharge it directly to the water environment. Detrimental effects have been reported in mangrove swamps in the north and north-west of Madagascar where industrial effluents have been released (Rakotoarinjanahary *et al.* 1994). One notable exception is the oil refinery where an efficient waste water treatment system is reported to operate. Industrial effluents in the capital city Antananarivo are discharged into the river Ikopa, although this is considered to be sufficiently far from the coast to have little impact on coastal habitats. In comparison to domestic effluent, the pollution load from industry is relatively small. Industrial activity was reported to account for only 21.1 and 15.4 per cent of the total BOD and TSS loads, respectively; domestic sewage accounted for the majority in each case.

Regional assessment of problems associated with industrial activity, ports and harbours

Although monitoring data on industrial pollution of the water environment throughout the region are sparse, that reported to date, with the possible exception of Mauritius, suggest that currently such sources do not have any serious social or economic implications. For example, heavy-metal and petroleum-hydrocarbon concentrations in waters and sediments for Mombasa and Dar es Salaam, two of the most industrialized areas of the region, indicate that pollution derived from this source is not currently a major threat to either food security, public health or marine and coastal resources, ecosystem health and biological diversity. However, this is no justification for not introducing stricter control measures before widespread damage commences. Although such pollution derived from industrial activity in ports and harbours of the other States is likely to be less significant than is the case for Mombasa, Dar es Salaam and Maputo, no assessment can be made because of the lack of available monitoring data. However, the data collected in the LOCS provide a valuable baseline to which subsequent monitoring can be compared.

The high seasonal BOD load associated with the release of effluent to rivers from sugar-cane processing factories on Mauritius, and its subsequent transfer to longer-residence-time lagoonal waters, may lead to degradation of coastal habitats. A large proportion of the BOD load to the coastal waters of the Seychelles is derived from industrial activity, in particular agricultural and livestock production and oil from the tuna canning industry. Further information is required concerning the disposal of this effluent before a more thorough assessment can be made of its socio-economic implications. However, it should be noted that such point sources may result in deterioration of water quality such as reduced dissolved oxygen concentrations, and the localized degradation of coastal habitats. With the exception of Mombasa, more information is required on the residence time and mixing of industrial effluents in coastal waters of the region to assess the significance of the BOD load for habitat degradation.

Oil spills associated with the transportation of oil by tankers is not considered in the context of this overview to be a land-based source of pollution. However, tanker oil-spills remain a significant threat to the coastal waters of the region. A notable example was the complete destruction of the mangrove forest in Makupa Creek (Mombasa) following an oil spill of 5,000 metric tonnes in 1988. Approximately 470 million tonnes of oil are transported annually through the waters of the region by 1,200 very large crude carriers (VLCCs) and 4,000 medium-sized tankers.

C. Coastal urbanization

The urban population of coastal towns in the mainland States is rising at a greater rate than the average population growth rate, for example 5.7 per cent in Mombasa and 7.8 per cent in Dar es Salaam (Ministry of Finance and Planning

1988), partly due to rural-urban migration. There is a direct relationship between population growth and waste generation. In the case of most large urban centres the solid waste and sewerage facilities have remained the same while the population has increased, leading to decline in percentage population served by the facilities. Only a small proportion of dwellings throughout many of the large urban centres of the mainland States are connected to a sewage system (see annex IV below). The sewage which is collected is often pumped directly into coastal waters without any treatment.

The majority of the population in the region use septic tanks and pit latrines. There is large degree of uncertainty concerning the BOD and TSS loads that reach the water environment from on-site domestic-sewage disposal systems. Calculations using the rapid assessment estimate loads are based on the FAO factor of 0.7/kg/head per day (WHO 1989). However, only a fraction of the BOD and solids actually reach the water environment depending on the efficacy of septic tanks/pit latrines and the local hydrogeological conditions. Such data should be treated with caution and only tentative interpretations will be made of the significance of its effects on the water environment.

In Kenya, domestic sewage and storm-water run-off in Mombasa were reported to account for 18 per cent (4,588 tonnes per year) and 37 per cent (12,802 tonnes per year) of the total BOD and suspended solid loads, respectively. Currently no sewage-treatment facilities are operational in Mombasa (Mwaguni and Munga 1997) resulting in the release of untreated domestic sewage and microbial contamination of waters in Kilindini, Port Reitz and Tudor Creek. Analyses of water samples from wells and bore-holes indicate that microbial contamination (total and faecal coliform) of groundwater has occurred in the Mombasa district. Only 3 of the 23 wells sampled passed drinking water standards, while none of the 11 bore-hole water samples was classified as potable (data cited in Mwaguni and Munga 1997). Although municipal solid waste is dumped at the Kibarani dumpsite (Makupa Creek), only 53 per cent of the 103,000 tonnes of annual solid waste production in Mombasa is collected. The dumping of domestic waste on mangrove shores has been reported around Makupa Creek (Linden and Lundin 1997) and Lamu.

In Tanzania, sewage in Dar es Salaam was reported to account for 55 per cent (11,312 tonnes per year) and 42 per cent (18,418 tonnes per year) of the BOD and suspended solid load respectively. Analyses of the same figures for Tanga were reported as 83 per cent (2,287 tonnes per year) and 99 per cent (3,258 tonnes per year). Conflicting evidence has been reported concerning the sewage outfall in Dar es Salaam. It was reported to be effective in dispersing sewage away from the local shoreline (Meghji and Merinyo 1990). However, the same authors attributed elevated concentrations of cadmium, chromium and copper in oysters to a break-point in the main sewer pipeline, suggesting that a fraction of sewage is discharged onto the intertidal platform, with attendant implications for public health and habitat degradation. Domestic-sewage infrastructures are poorly developed in Zanzibar (Baur 1993) and this is considered the major source of pollution to near-shore coastal waters. The greater part of the drinking water in and around Zanzibar Town was reported to be unsuitable for human consumption according to WHO guidelines due to the presence of coliform bacteria (Kivaisi and Van Bruggen 1990). Eutrophication associated with the release of inorganic nutrients (phosphate, nitrate and ammonia) into coastal waters from domestic sewage around Zanzibar was identified as the possible cause of the decreased cover of coral-reef-building algae (Bjork *et al.* 1995). Saline intrusion to ground water around Zanzibar Town is a natural phenomenon and perched aquifers are relied upon as the main source of potable water. During dry periods, the perched aquifer is separated from supply wells which intersect the deeper, contaminated aquifer. Increased water abstraction by the expanding and, in particular, the tourist population has led to reports by the Ministry of Water of increased salinity in water supplies. There have also been reports of domestic waste being dumped on mangroves around Zanzibar (Dorsch Consult and Ministry of Water, Construction, Energy, Lands and Environment 1992)

In Mozambique, Maputo is the only city with a central sewage system for collection and treatment of domestic sewage. However, it is estimated that only 50 per cent of Maputo's sewage is treated. The majority of the population use septic tanks and pit latrines. The Maputo area produces 71 per cent of the total domestic sewage (Baquaete and Hauengue 1993). The sewage is emptied into rivers that flow into Maputo Bay. Studies in the bay have revealed that faecal coliforms, faecal streptococci and Escherichia coli were detected in marine water and shellfish tissues. Pathogens causing severe gastro-intestinal illness were also isolated from clams collected in different areas of the bay. An increase on the levels of total and faecal coliforms was reported from 1968 to 1996 in the Maputo Bay (Fernandes 1995). As a result, some areas are not safe for swimming. Maputo city produces about 4.3 million tonnes of solid waste per year.

In contrast to the other states of the region, high population densities are not confined to the large urban centres on Mauritius (Port Louis and Plaines

Wilhems), but occur in rural areas where 55.5 per cent of the total population resides according to the 1990 census. The two large urban centres have sewerage systems, although the system in Plaines Wilhems constructed in 1960 is inadequate to deal with peak flows during heavy rainfall, resulting in frequent discharges of raw sewage to surface watercourses. The remainder of the population generally use pit latrines, soakage pits or septic tanks. No data were available in the national report concerning the microbial contamination of ground water by domestic sewage. A risk assessment based on a 20-year period indicated that unacceptable pollution would only result in four areas following the failure of on-site sanitation systems. However, there remains a need for monitoring of contamination of ground waters from on-site disposal systems. The release of domestic sewage to coastal waters from urban areas and poorly planned housing developments on reclaimed wetlands is recognized as a cause of eutrophication resulting in growth of algae and the choking of coral. Algal blooms are observed annually at Trou aux Biches, and isolated cases have been reported at the sewer outfall at Bain des Dames near Port Louis.

There are no centralized systems for the collection and treatment of domestic sewage and solid waste in the Comoros, which are considered to cause pollution of the water environment. The majority of the population use septic tanks or soakage pits (79 per cent), and the remainder pit latrines. Domestic sewage represents the majority of the BOD (3,248 tonnes per annum) and TSS load (7,533 tonnes per annum). The total BOD load of domestic sewage from hotels is small by comparison (2.23 tonnes per annum). Organic pollution from domestic sewage represents a significant threat to marine, fresh and ground-water resources. The occurrence of eutrophication at Trou du Prophete (Grand Comoros) has been attributed to domestic waste pollution. Faecal contamination of waters in the Comoros include drinking water on Anjouan and Moheli and ground water on Grand Comoros. Solid-waste litter from domestic sources consists of organic waste (57 per cent), paper cartons (3.5 per cent), plastics (3 per cent), metals and textiles. It represents a serious threat to public health through the proliferation of flies, bacteria and pathogens. Rainwater infiltrating through such littered waste is reported to lead to the contamination of ground water with serious implications for public health.

Based on figures from the 1987 census, the majority of the local population of the Seychelles use septic tanks (82 per cent), the remainder being connected to a sewage treatment system. The contribution of domestic sewage to the total BOD (19.4 per cent) and TSS loads is small in comparison to waste from industrial sources (Radegonde 1997). No information concerning the quality of water discharged from the sewage treatment works has been provided.

Few of the larger coastal towns in Madagascar have extensive sewerage systems. These systems were established in the period 1958-1960. They have not been renovated except for Antiranana, which serves 40 per cent of the population. However, the sewers empty waste directly into coastal waters and are poorly maintained, resulting in a blockage and the stagnation of effluents in surface canals. Both this and the large quantities of faeces deposited on beaches represent a significant threat to human health through microbial contamination. Ancestral customs prevent the storage of human excreta even in septic tanks. An inventory of sanitary installations in Madagascar made in 1993 indicated that 66 per cent of the population does not have any such installation. Pit latrines are utilized by between 2 and 40 per cent of the population in the larger coastal towns. Domestic sewage accounts for the majority of the total BOD and TSS loads to the coastal zone in Madagascar: 79.9 per cent (10,368 tonnes/year) and 84.6 per cent (15,068 tonnes/year), respectively. However, no reports of algal blooms have been linked to increased inorganic nutrient concentrations in coastal waters associated with domestic sewage. Solid domestic waste such as organic matter, paper and plastics is collected in some of the larger coastal towns, but the majority is not disposed of in dumps and represents a hazard to public health when it accumulates in urban areas.

Regional assessment of problems associated with coastal urbanization

Rapid population growth in the countries in the region and particularly in the coastal areas have lead to rapid changes in land-use patterns. Natural ecosytems are being destroyed or replaced by agricultural crops. The large population is also putting pressure on the marine and coastal resources. Lack of infrastructure and treatment facilities for the large quantities of domestic sewage generated by expanding coastal urban populations, and an increasing number of visiting tourists, represents the greatest threat to public health, coastal habitats and economic development in each State of the region. Faecal-coliform contamination of surface and ground water resulting from on-site disposal of domestic waste (septic tanks and pit latrines) has been reported in wells and bore-holes in Maputo and Mombasa. High faecal coliform and bacteria counts have been reported in Influene River in Mozambique. Faecal coliform have also been observed in Maputo Bay, both in marine waters and shellfish tissues. The concentrations at the bay have been increasing over the years. Consequently, some areas of the bay are not safe for swimming. Furthermore, the levels of in

ground waters around Maputo are positively correlated with distance to latrines, depth of the wells and population density. Some bore-holes are contaminated by biological pollutants. Although monitoring data are not available, there is a perceived link between domestic sewage and the occurrence of gastro-enteritis in the Comoros and Zanzibar State of The United Republic of Tanzania. There is an urgent need for monitoring of microbial contamination of ground waters in coastal areas of all States of the region to assess the scale of the problem.

As was the case for industrial effluents, the importance of the organic (BOD) load to coastal waters from domestic sewage cannot be assessed more completely without detailed data concerning the residence times and mixing rates in coastal areas.

Degradation of coastal habitats caused by the dumping of domestic and industrial waste in coastal areas, and its transport via near-shore waters, represents a serious threat to the ecological health, biological diversity of coastal habitats and, in the long term, the economic prosperity of commercial and artisanal fishing. Domestic waste also represents a hazard to public health when it is allowed to accumulate in urban areas.

The release of untreated domestic sewage has been associated with the occurrence of eutrophication in near-shore coastal waters, phytoplankton blooms and the subsequent degradation of coastal habitats and reduced fish catches. However, it is not possible to assess the scale of the problem without adequate monitoring data and detailed scientific research.

D. Mineral development and quarrying

Mineral extraction and/or quarrying occurs in the coastal zone of each of the States of the region (see annex V below). The mineral deposits which are currently worked along the Kenyan coast include iron ore, lead, baryte, apatite and rock salt. Quarrying is carried out on a large scale at Bamburi and Kaloleni to supply the respective cement factories. There is also significant rock-salt extraction at Gongoni in Malindi.

Limestone and clay are also quarried for building and cement manufacture in Tanzania at Wazo Hill. Other extractive industries include rock salt (Lindi) and kaolin (Pugu Hills).

The main mineral extraction/quarrying activities on Mauritius include sand mining and rock quarrying, the latter used primarily for the construction industry and road building. Currently there is an annual demand for 1.5 million tonnes of fine aggregates (National Physical Development Plan 1995). The mineral resources extracted from the sea and the littoral zone consist primarily of sand, including aeolian deposits. Sand is exploited from the terrestrial quarries, lagoons and beaches and undeclared sand dunes. The annual mining of approximately 800,000 tonnes of sand in lagoonal areas (Ministry of Fisheries and Marine Resources 1995) was reported as one of the major factors contributing to ecological damage as the entrapment of fine particulate matter into the water column leads to death of coral.

There are currently no economic mineral deposits in and around the Comoros. The extraction of sand and gravel for construction, particularly on Moheli and Anjouan, has resulted in the destruction of part of the coral reef and represents a continued threat to coastal areas. Although no quantitative details are available, the mining of heavy mineral sands in coastal areas of Zambesia (Mozambique) was identified as a threat to coastal habitats by Linden and Lundin (1996). Dredging for minerals is conducted along the south coast of Madagascar around Tolagnaro, although it is considered to be at the experimental stage. Granite is mined in the Seychelles for aggregate. Artisanal quarrying of coral-bearing limestone occurs in coastal zones of all the mainland States and Zanzibar State of The United Republic of Tanzania, although by the small scale nature of the workings, the effects on coastal habitats are minor and localised.

Regional assessment of problems associated with mineral development and quarrying

Mineral extraction and quarrying activities have the potential to damage coastal habitats, and coral reefs in particular, by increasing the suspended solid load (turbidity) of coastal waters. Few interpretations can be made of the threat of mining operations to coastal habitats due to the lack of information concerning the scale of disturbance caused by specific activities. Although significant damage to coastal habitats related to mining and quarrying have been reported in Mozambique and Mauritius, little analysis has been done on the likely impacts of current mineral development or quarrying activities. Detailed appraisals at the national levels are required prior to a regional assessment.

E. Atmospheric emissions

Out of 79 major industries surveyed in Dar es Salaam, 43 per cent have been found to cause air pollution. Among these, the cement industry of Wazo Hill is the principal polluter, emitting approximately 2,831 tonnes of total suspended particles per year. If Wazo Hill is a representative model, the same levels of pollution may be expected

from the cement factories in Maputo, Bamburi (Mombasa) and Kaloleni (Kilifi). Other significant sources of air pollution, in order of importance are charcoal manufacture and domestic combustion, agricultural activities, and traffic (mobile sources). With increases in development, communication and tourism, atmospheric emissions from traffic, particularly of lead, are increasing. The Kibo Paper Mill also releases significant quantities of hydrogen sulphide. In Zanzibar Town, burning of waste at the Mwanakwerekwe dump site causes significant pollution to the densely populated urban area. The other significant sources in Mombasa include road traffic and the burning of domestic and industrial waste at the Kibarani dump site, although no data on loads are available.

Particulate matter released from bagasse fired boilers is the most significant atmospheric pollutant emitted during the processing of sugar cane on Mauritius. However, no assessment was made of the quantities of suspended particulates released or their impact on the surrounding area. In Madagascar, atmospheric pollution is mainly caused by dense fumes and gases emanating from large factories, refineries and textile industries. Old motor vehicles, which are numerous, also contribute to air pollution. No significant sources of atmospheric emissions were reported for the Comoros.

Regional assessment of problems associated with atmospheric pollution

In the absence of detailed assessments for atmospheric emissions for the entire region, the generally low level of industrial development would suggest that socio-economic problems associated with such sources are likely to be limited. Indeed, the national reports contained very few references to issues of public health, food security, ecosystem health or biological diversity associated with atmospheric pollution. However, in those areas identified as causing the greatest pollution, most notably around cement factories, further monitoring of pollution plumes and their impact on their local environment is required.

III. Emerging and foreseeable problems

A. Agricultural activities

There are two emerging problems relating to non-point sources: one, the increasing uses of agrochemicals as fertilizers and pesticides within catchments, and the other, changes in agricultural practice through increasing large-scale mechanization in ploughing. Leaching and run-off of persistent organic chemicals can be expected to have a long-term negative impact on coastal and associated freshwater habitats. The increase in soil erosion that can be expected as a result of the increasing agricultural mechanization will lead to increased sediment loads in streams and rivers, and increased seasonal discharges of silt to estuarine and coastal waters. Such discharges will have a damaging effect on the growth of coral in waters adjoining the outflows.

Emerging aquaculture activities in the region may pose some environmental problems in the future. Some of the developments include seaweed, oyster and shrimp cultures.

B. Coastal urbanization

Problems associated with coastal urbanization relate to increasing populations, including overall national population growth and continued preferential resettlement of populations in coastal regions, especially migration to coastal urban centres. These changes will have significant consequences for waste management and the threat of degradation of water supplies.

C. Industrial activity and domestic sewage

Urban and associated industrial growth in coastal regions can be expected to produce potential new point sources of pollution impacting directly or indirectly on coastal waters and inlets. Such growth will lead to an increase in the scale of trading and associated shipping movements and there will be a need to monitor port-related pollution. With increases in shipping movements, it may be necessary to expand the present harbours and ports or develop new ones. The dredging in the vicinity of the near-shore and coastal environment may affect the delicate marine and associated wetland ecosystems. Hydrocarbon development is another growth area, for example at the Songo Songo gas field in Tanzania, and this may present potential pollution hazards which could have extensive consequences for the health of coastal habitats. Even without urban growth, there are existing point emissions which are producing significant degradation of platform environments, for example at Dar es Salaam in Tanzania. Some of the coastal urban centres, such as Zanzibar Town, have poorly developed sewerage systems and increasing population pressures without remedial action may lead to serious problems. Much of the coastal population relies on underground sources for water supply. There are serious risks of groundwater contamination if more effective sewage management is not introduced as a priority. Effluents from industrial growth in non-coastal parts of catchments will need to be monitored.

With the increase in population the demand for hydroelectric power is rising. The general tendency in the region will be to continue impounding river basins. This may change the river flow and siltation patterns with negative consequences to the environment. Predicted sealevel rises as a consequence of global warming may exacerbate the problem of groundwater quality due to saline intrusion, particularly around Mombasa and Zanzibar Town.

D. Tourism

The management of waste and the discharge of chlorinated swimming pool waters from hotel developments on coastal waterfronts is seen as a growing problem, particularly in locations without significant tidal flushing and unpredictable expansion in the tourist population. Although individually small, there are many of these sources on some coastal regions, and their combined long-term impacts on the health of platform and reef habitats could be considerable. Other tourism-related activities which are growing and possible sources of direct pollution in sensitive habitats include the use of power boats and jet skis. The power boats and skis may cause physical habitat degradation through accidental running aground in the shallow waters, through anchors and oil spills.

Atmospheric emissions

The problems of increasing road traffic and cement production have been mentioned in the previous section.

E. Mineral exploitation and quarrying

The proposed mining of an economic deposit of titanium mineral sands in the Kilifi district is likely to cause localized degradation of coastal habitats.

The availability of baseline data on the concentration of metals, selected pesticides and petroleum-hydrocarbon derivatives should be followed with continued monitoring.

IV. Priorities for action

Annex VI provides a summary of the main land-based activities which have socio-economic implications for each State of the region and classifies them as either low, medium or high priority. However, it should be stressed that the assessments of problems relating to pollution of the water environment were often based on limited scientific data or observations. For example, the scales of coastal-habitat degradation due to either physical effects or chemical pollution require detailed assessments of the scale of each problem. Links between chemical pollution and the degradation of coastal habitats are often more complex than physical effects, such as siltation. In such cases, the linkage between anthropogenic causes and their environmental impacts must be confirmed through detailed, site-specific scientific investigation.

In practically all the States of the region there are two aspects related to ground-water resources which require detailed investigation: the microbial contamination of ground water from on-site sewage disposal systems and saline intrusion. Although several national reports perceived that public ill-health was related to ground-water contamination, few studies have been conducted to confirm the epidemiological relationship or investigate the scale of the problem. The first priority is to investigate the extent to which ground waters are being contaminated. On the basis of these results, areas could be identified where immediate action is required, leading to the improvement of public health.

Although there are various reports of increasing salinity of ground waters due to increased abstraction, studies are required to assess the degradation of ground-water resources, particularly as climate change leading to sealevel rises will exacerbate the problem. One such study is currently being undertaken around Mombasa. Saline intrusion is likely to occur where demand for ground water is increasing around expanding urban centres with large tourist populations which utilize a far larger quantity of water per capita. Although fresh water can be pumped into aquifers to reverse the effects of saline intrusion, such remedial action would be expensive.

Scientific investigations are required to determine both the chemical and physical effects on coastal habitats of releasing large volumes of untreated domestic effluent into near-shore coastal waters as occurs around Mombasa, Dar es Salaam, the Comoros and Zanzibar Town. Although reduced growth of coralline algae was related to elevated inorganic nutrient concentrations around Zanzibar Town, the hydrodynamic conditions and pollution loads around the coasts of each country are different, and each warrants individual study. In Mombasa and Dar es Salaam, the uncontrolled dumping or release of domestic and industrial solid waste around mangroves and in coastal waters should also be prevented as a matter of priority.

There are several priority issues relating to land-based sources of pollution on Mauritius, including ground-water pollution by agrochemicals and domestic sewage, coastal-habitat and coral

degradation linked to industrial wastes, nutrients in domestic sewage, and siltation due to mining and quarrying. However, coral degradation resulting from direct human impacts such as anchoring and poling by fisherman may be far greater than the indirect effects which occur via water pollution. An assessment is required concerning their relative importance prior to action being taken to minimize their impacts.

The degradation of coastal habitats, particularly coral reefs, from siltation associated with soil erosion was identified as a priority for action in Comoros, Kenya and Mozambique. A detailed survey of past, current and potential impacts of damage due to siltation and a study of sedimentological impacts of land-use (agricultural) change is required in each of these States.

V. Strategies and measures

Governments should be responsible for initiating programmes to assess the extent of microbial contamination of ground-water supplies in each State where this has been identified as a priority. Once the extent of the problem has been assessed, funds should be made available for remediation, such as the improvement of on-site sewage disposal systems (WHO 1992b), or limiting the contamination of bore-holes and wells. In urban centres where sewage infrastructures are already in place, guidelines should be followed to ensure the operation and maintenance of urban water supply and sanitation systems (WHO 1994). Governments should also be responsible for assessing the threats posed to ground-water resources from saline intrusion. This should include an assessment of the effects of future ground-water resource requirements accounting for expansion in both local, urban and tourist populations.

Local authorities should be responsible for ensuring that solid domestic and industrial wastes are not dumped on or around sensitive coastal habitats such as mangroves. Such litter can also be transported offshore and cause physical damage to coral reef ecosystems. Approaches should include the provision of adequate waste collection and disposal services and enforcement of laws and regulations concerning the illegal dumping of wastes.

The use of remote-sensed imagery would be the most cost-effective approach in detecting and assessing the physical damage to coastal habitats and coral by siltation, solid domestic or industrial waste, or phytoplankton blooms (Clark 1993). High-resolution remote-sensed images can be used to pinpoint siltation plumes and algal blooms (red tides) associated with sewage outfalls or agricultural pollution. Subsequent site visits should be used to assess the extent of the degradation and the results used to amend agricultural practices to prevent soil erosion in coastal catchments.

A monitoring programme for heavy metals, hydrocarbon derivatives and BOD should be initiated in ports and harbours where industrial activities are likely to lead to high pollution loads, such as in Mombasa, Dar es Salaam, Maputo and the Export Processing Zone in Mauritius.

Studies of the environmental problems identified in Mauritius have been initiated by the Government. In certain areas of north and north-west Mauritius, only 20-60 per cent of coral cover remains. The degradation has been attributed to various natural and anthropogenic causes including the discharge of industrial effluents, run-off contaminated with silt and nutrients, sewer wastes, the dredging of coral sands, poling, anchoring and walking over coral. To combat the degradation, the Government of Mauritius initiated a Marine Conservation Programme in 1988 and a coral reef ecosystem study, and designated two areas as marine parks.

In Seychelles, there are plans to develop a sewage-treatment plant beginning in 1998. The plant will accommodate sewage from the east coast, including Victoria City.

VI. Conclusions and recommendations

The coastal areas of the East African region consist of a range of diverse habitats which are relied upon to provide food for the local population and to earn revenue by attracting tourists. The rapidly expanding coastal populations exert ever-increasing pressure on coastal habitats and resources. Land-based activities such as agriculture and industry, coastal urbanization and mineral exploitation, disturb natural conditions and processes, degrading coastal resources and habitats. The effects can have serious social and economic implications.

This regional overview of land-based sources and activities affecting coastal marine environments and the associated freshwater environment has identified several issues which are potentially detrimental to the social and economic prosperity of the East African region. On the basis of national inventories of pollution loads, the issues of greatest concern are:

(a) The microbial contamination of ground-water resources by coastal populations resulting from on-site disposal systems or poorly developed/maintained sewerage infrastructures;

(b) Saline intrusion leading to degradation of coastal ground-water resources and destruction of coastal habitats through siltation;

(c) Physical removal of mangrove vegetation to pave way for physical development of homes, industries, hotels, etc.;

(d) Degradation of coral reefs by algal blooms associated with elevated inorganic nutrient concentrations from domestic waste and agrochemicals may be a problem in the future; and

(e) Destruction of coastal habitats through inadequate disposal of solid domestic waste.

It should be stressed that the interpretations expressed in this assessment have been based on limited scientific data summarized in national reports. Therefore, the first priority to combat perceived problems is to conduct detailed scientific investigations, and on the basis of the results, take remedial action.

Strategies and measures have been suggested to address the priority issues. The improvement of on-site domestic sewage disposal systems, the maintenance and improvement of sewage infrastructure, and improved refuse collection would be effective in reducing the microbial contamination of ground water and associated threats to public health. Remote-sensing is one of the most effective methods which could be used to assess damage to coastal habitats from siltation, solid domestic waste and algal blooms.

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Annex I

Pesticide used in states of the region between 1982 and 1997
H Class IA - most toxic, Class IV - least toxic

Pesticide	H Class	Kenya	Zanzibar	Mozambique	Comoros
antilimace	-				√
atrazine	IV	√	√		√
barban			√		
benomy	IV				√
bentazone	III		√		
bicloram	IV	√			
bromacil	IV	√		√	
buminal	-				√
callidim	-				√
callidon	-				√
camphedor	-			√	
carbofuran	IB	√	√	√	
cypemethrin	II		√	√	
diaznon	II			√	√
dieldrin	IB		√		
dimethoate	II	√	√		
endosulphan	II		√	√	
fenitrothion	II		%	√	

Pesticide	[H] Class	Kenya	Zanzibar	Mozambique	Comoros
fentons	-				√
glyphosate	IV	√		√	√
labillite					√
lindane	II		√		
malathion	III		√		√
mancozeb	IV		√	√	√
metaxyl	III			√	√
omethoate	IB	√			
ossichloruko					√
oxine copper					
paraquat	II	√	√		√
peltar					√
phosphine			√	√	
propoxur	II			√	√
phoxim	II				√
pirimiphos-	III		√	√	
stelladone		√			√
synthetic	II	√			
triatrix		%			

Annex II

Number and type of Industries in selected coastal towns and Island states of the region in 1982 and 1992/1994/1997

City/State	Mombasa		Tanga		Dar es Salaam		Zanzibar		Seychelles		Maputo		Comoros		Mauritius	
Year	1982	1992	1982	1992	1982	1992	1982	1992	1982	1992	1982	1997	1982	1994	1982	1997
Food	6	22	2		13	10			8	3	4	38				
Metal	14	19	2		11	9					2	15				
Glass	2	1		1	1	1					1	2				
Plastic	6	8		1	8	7			3	1	1	6				
Electricity		1	2													
Refinery	1				1	1					1					
Cement	1		1	1	1	1										
Textile	3	22			9	12					1			1		
Chemical	1		4	1	7	6			1		1					
Paper	2				1	5								1		
Paint	1				3	6	1		1	1						
Soap	1	2	2	1	3	1		2	2	1		6		1		
Salt	1		1		1		1									
Cigarette							1									
Brewers		1				3				1				2		
Cooking		9				3						2				
Others						9						70		1		
Total	**33**	**85**	**14**	**5**	**49**	**74**	**3**		**15**	**7**	**11**	**137**		**6**		**425**

Annex III

Annual Biochemical Oxygen Demand (BOD) pollutant load to the water environment and waste disposal data in selected cities and states of the region in 1982 and 1992

	BOD5 (tons/year)		Solid waste/capita kg/year		% population connected to sewage system		% waste collected (tons/year)		Hazardous waste (tons/year)	
Year	1982	1992-1997	1982	1992-1997	1982	1992-1997	1982	1992-1997	1982	1992-1997
Mombasa	1760	25,800		193	20			61		0.04
Tanga	200	274		150	10	13		24		278
Dar es Salaam	2250		15	150		13		23		65
Seychelles	125	1368	25	255		45				1.5
Maputo	1540	909	10							
Madagascar	270	1351	6							
Mauritius	5300		64							
Comoros		4505		150		0		0		

Annex IV

Sites of current and potential mineral exploitation and quarrying in coastal areas

DEPOSIT	COUNTRY	LOCATION	USE/PRODUCT
Rock salt	Tanzania	Lindi	common salt
Limestone	Tanzania	Wazo Hill	cement
Kaolin	Tanzania	Pugu Hills	
Gravel	Tanzania	all coast	construction
Sand	Tanzania	all coast	construction
Limestone	Tanzania	all coast	construction
Rutile	Tanzania	all coast	menite
Pan salt	Kenya	Gongoni	common salt
Gypsum	Kenya	Roka and Tula valleys	cement
Iron Ore	Kenya	Jaribuni	cement manufacture
Lead	Kenya	Kinagoni	lead
Baryte	Kenya	Vitengeni	lead
Galena	Kenya	Vitengeni	
Limestone	Kenya	all coast	chalk, lime, cement and ballast
Coral stone	Kenya	all coast	construction
Pyrochlore	Kenya	Mrima Hill	niobium, iron manganese, gold
Clay and sand	Kenya	Gongoni, Mazeras and Mombasa	construction and pottery
Apatite	Kenya	Mrima Hills	bricks and tiles
Rock	Mauritius	sea and littoral zone	
Eolianite	Mauritius	sea and littoral zone	
Fossil Coral	Mauritius		lime
Sand	Mozambique	whole coast	construction
Titanium	Mozambique	Zambezia province	industry
Sand	Comoros		construction
Pebbles	Comoros		construction
Gravel	Comoros		construction

Annex V

Summary of priority issues relating to the impact of land-based sources and activities to the marine and the associated Freshwater environment in the region

Country	Issues	Cause(s)	Scale
Kenya	I. Water quality degradation	1. Domestic sewage 2. Domestic solid waste 3. Infrastructural inadequacy 4. Tourism development 5. Industrial aquacultural effluents	
	II. Habitat modification/ degradation	1. Population pressure 2. Agricultural activity 3. Urbanization 4. Industrialization of salt pans 5. Tourism development 6. Lack of proper Land-use planning 7. Resource over-exploitation: • sand and coral mining • Destructive parasites	
	III. Restricted access (usage) to Resources and Resource - use conflict	1. Poor land-use planning 2. Changes of use of resources 3. Lack of integrated approach to resources use	
	IV. Microbial contamination of groundwater	1. On-site domestic sewage disposal 1. Poor domestic refuse disposal 1. Soil erosion and siltation	
	V. Saline intrusion	1. Increased abstration of groundwater	
Tanzania	I. Pollution 1. Groundwater pollution • Freshwater • Marine waters	1. Domestic waste water 2. Domestic solid wastes 3. Industrial liquid wastes 4. Industrial solid wastes 5. Agrochemical run-off 6. Mineral exploitation	
	2. Atmospheric pollution	1. Domestic sources 2. Industrial sources 3. Transport 4. Fuels	
	II. Habitat/ecosystem degradation	1. Siltation due to poor land use: • Deforestation • Construction • Agriculture • Mining (sand, quarries, limestone, etc)	

Country	Issues	Cause(s)	Scale
Tanzania (cont.)		2. Destructive fishing methods 3. Pollution: • Industrial development and wastes • Littering • Atmospheric emissions 4. Aquaculture 5. Dredging	
	III. Restricted access to resources, e.g., beaches, fish-landing sites, ports and harbours	1. Poor/lack of land use plans: • coastal urbanisation • Tourism related development	
Zanzibar State of the United Republic of Tanzania	I. Pollution	1. Domestic waste water 2. Agrochemical waste 3. Sand extraction	
	1. Coastal waters 2. Ground waters 3. Atmospheric emissions	1. Domestic emissions 2. Transport emissions 3. Industrial emissions	
	II. Habitat/ecosystems degradation	1. Poor fishing methods 2. Resource over-exploitation 3. Ground pollution (solid and liquid wastes)	
	III. Restricted access to resources, e.g. beaches, landing sites, ports and harbours	1. Poor/lack of land use plans: • Tourism related development • Coastal urbanization	
Mauritius	Agrochemical groundwater pollution	Intensive fertilizer and pesticide application	
	Micribial contamination of groundwater	High BOD load from sugar processing	
	Coastal habitat (coral) degradation	Algal blooms due to the release of domestic sewage On-site sewage disposal Mining and quarrying	
Mozambique	I. Coastal habitat (coral) degradation	1. Siltation from poor land use: • agriculture • deforestation • construction	Localized (intensive)
		2. Saline intrusion due to excess ground water intrusion	Localized (intensive)
		3. Industrial development 4. Aquaculture development	
	II. Pollution	1. Domestic waste water	National
		2. Agrochemical run-off	National
	1. Groundwater	3. Domestic solid waste	Localized
	• freshwaters	4. Industrial waste	Localized
	• marine waters	5. Mineral exploitation	Localized

Country	Issues	Cause(s)	Scale
Mozambique	2. Atmospheric pollution	1. Transport 2. Industrial emissions	
	II. Restricted access to resources, e.g. beaches, fish landing sites, ports and harbours, etc.	1. Poor/lack of land use plans: • coastal urbanization • tourism related development	Localized Localized
Mada gascar	I. Habitat/ecosystems degradation	1. Siltation from poor land use: • deforestation • agriculture • construction 2. Pollution • ground, e.g. Wastes • atmospheric e.g. waste 3. Industrial development 4. Aquaculture development 5. Mining 6. Saline intrusion 7. Dredging - siltation 8. Ground water extraction	
	II. Restricted access to resources, e.g. beaches, fish landing sites, ports/harbours, etc	1. Poor/lack of land use plans: • coastal urbanization • tourism related development	
	III. Pollution 1. Ground water 2. Atmospheric pollution 3. Surface water	1. Domestic waste water 2. Agrochemical waste 3. Mineral exploitation 4. Aquaculture effluent 5. Heavy metal extraction/use 6. Sand 1. Industrial 2. Transport 3. Domestic 4. Fuel 5. Atmospheric emissions 1. Domestic solid wastes 2. Industrial solid wastes	
Comoros	1. Ground water • Organic and liquid wastes • Saline intrusion • Oil from vehicles • Dead bodies 2. Atmospheric pollution • Sulphur emissions (volcanic) • Carbon dioxide emissions		

Country	Issues	Cause(s)	Scale
Seychelles	Public health concerns Water quality and potential coastal habitat degradation	On-site domestic sewage disposal Industrial effluent disposal	
	Coastal deposition of red soil during rainy season due to an unplanned access road construction sites	Siltation	