

Transboundary Diagnostic Analysis of the Western Indian Ocean Coastal and Marine Environment



PART II: ANALYSIS OF TRANSBOUNDARY PROBLEMS IN THE WIO



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1. Assessment of major transboundary problems and issues

1.1 Introduction

This chapter presents an analysis of the major documented and perceived problems related to land-based sources and activities in the Western Indian Ocean (WIO) region. The identification of the major perceived problems and issues is a first step in the TDA process. It constitutes the basis for subsequent in-depth scientific and technical analysis of the perceived problems and issues in order to validate and prioritize the same. The classification of key transboundary problems related to LBSA, LME and fisheries is primarily based on the results of a regional specialist TDA/SAP workshops¹ (held under the auspices of the WIO-LaB, ASCLME and SWIOF projects), which identified and grouped problems into five clusters:

- Coastal and marine water and sediment quality degradation.
- Physical alteration, destruction of habitats and community modifications.
- Alteration in river freshwater flows and sediment loads.
- Decline in marine living resources.
- Climate change/variability and extreme events.

The experts drawn from various institutions in the WIO region were involved in the establishment of initial problem trees for the above listed problem areas and their sub-clusters. The specific problem areas were further defined in more detail by the WIO-LaB and ASCLME-SWIOFP TDA Task Teams in consultation with the various Task Forces and Working Groups established by these regional projects. The following section provides the methodology that was used to identify problems or issues of concern including the national and regional processes that were used in the prioritization of problems and issues of concern that were considered to be of regional priority.

1.2 Approach and methodology

A number of targeted studies commissioned by the UNDP/ASCLME, World Bank/SWIOFP, UNEF/GEF WIO-LaB, UNEP/WIO-SAP and UNDP/SAPPHIRE projects formed the main basis for data and information that was used in the analysis presented in this section of the joint TDA. Apart from these supporting documents, the analysis also comprised a comprehensive examination of data and information presented in other studies and reports² that were prepared under the auspices of Nairobi Convention and WIOMSA. The process of identification of data and information was undertaken through a series of technical workshops that were attended by experts drawn from various institutions in the region. The analysis of the transboundary problems or issues of concern followed a systematic approach (Figure 2-1). Each section first presents a general overview of the specific problem at hand, including (i) a general overview of the problem; (ii) a general overview of the root and direct causes as well as the environmental impacts and socio-economic consequences related to the problem; and (iii) an identification and description of the perceived hotspots of the problem in the WIO region. Subsequent to this general overview, each problem is then further analysed in more detail at the level of the problem sub-categories as defined above. Each of the above problem areas are analysed in detail in the following sub-sections:

Problem statement

Presents a brief definition of the problem including its general perspective and context in the WIO region.

Transboundary elements

¹ Held in April 2007 in Nairobi, Kenya

² Such as the African Process, the Global International Waters Assessment (GIWA) programme, the Eastern African Marine Systems (EAMS) programme, GESAMP, TRANSMAP and various reports prepared by the UNEP Nairobi Convention Secretariat and the UNEP Global programme of Action for the Protection of the Marine Environment from land-based Activities (UNEP/GPA).

Provides a brief review of the transboundary elements of the problem, demonstrating the extent to which the problem is relevant within the context of the TDA, and in particular responding to questions such as, ‘Is the problem truly transboundary, in that it has transboundary causes and/or impacts? Is it a common problem in the region, or is it relevant to certain regions only?’

(a) Root-cause analysis

This is the most substantial section providing first a diagrammatic presentation of the transboundary problem in the form of a problem tree, and describing and reflecting on the elements of the problem tree. The analysis is supported by a summary of relevant data and information based on detailed assessment reports prepared by the GEF projects³.

(b) Risks, uncertainties and trends

This sub-section presents an analysis of risks and uncertainties, such as important gaps in data/knowledge that may hamper adequate assessment of the problem and its effects, as well as uncertainties in future development. It also identifies any observed trends such as developments that might cause a problem to be greater or more significant in future and which need to be noted now.

(c) Stakeholder analysis

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

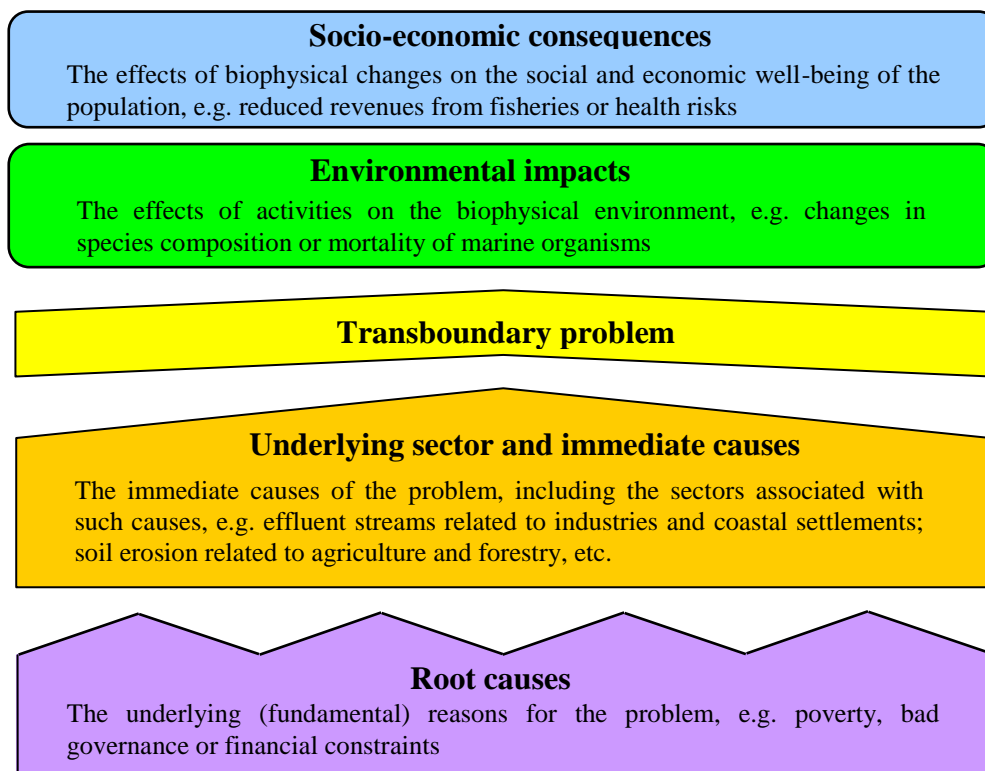


Figure 2-1 Schematic presentation of the various levels of analysis in the problem trees.

³ Joint TDA presents only a summary of supporting data and information and detailed supporting data and information can be found in detailed thematic reports.

1.3 Prioritisation of main transboundary problem areas

The process for the identification and prioritisation of areas of concern in the WIO region commenced at the national level. Areas of concern were captured from various thematic reports including national MEDA reports through an issue scoping, categorisation and classification process, which resulted in the preparation of a 'Draft Issues Framework'. The issues included in the 'Draft Issues Framework' were then validated and prioritised by the countries in national workshops that were held in participating countries in the period between 2009 and 2011. The prioritisation process was repeated at the regional level through regional workshops. The final results for the TDAs were subsequently consolidated in regional workshops attended by experts in the region. The final outcome of the national to regional process was the identification of a suite of priority transboundary issues for inclusion in the WIO-LaB and ASCLME-SWIOFP Strategic Action Programmes (SAPs).

1.3.1 Scoping and Prioritisation Process

WIO-LaB Process: The identification of the transboundary problems related to LBSA in the WIO region built upon the “major perceived issues and problems” that were initially identified by the African Process that delivered the Preliminary TDA in 2002. The TDA Task Team embarked on a process of gathering and analysing more updated data and information generated through implementation of the WIO-LaB Project and came up with the initial list of transboundary problems and or issues of concern within the WIO region. The findings of this exercise enabled the team to establish a clear work plan with division of responsibilities for each of the team members. This also led to the formulation of activities and mechanisms for consultation with national and regional stakeholder groups on the issues and problems identified.

1.3.1.1 National Issue Validation and Prioritisation Process of the LBSA TDA

The Task Team also facilitated a regional TDA workshop that was attended by representatives of each of the participating countries. The purpose of the TDA workshop was to:

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

The first TDA workshop was attended by more than 40 experts drawn from various technical fields, who were grouped into the following four regional Technical Task Forces established by the WIO-LaB Project:

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

Representatives of key academic and research institutions in the region, other regional organizations, including NGOs, active in marine ecosystem conservation in the WIO region also attended the TDA workshop. On the basis of the outcomes of the first TDA workshop, the Task Team embarked on a detailed analysis of documented and perceived priority transboundary problems, based on available scientific and technical information at national level. Much of these data were collected as part of WIO-LaB thematic assessment studies or through other initiatives⁴.

⁴ Such as the African Process, the Global International Waters Assessment (GIWA) programme, the Eastern African Marine Systems (EAMS) programme, GESAMP, TransMap and various reports prepared by the UNEP

1.3.1.2 Regional Issue Validation and Prioritisation Process of the LBSA TDA

Based on the detailed thematic studies and in consultation with other specific experts, the LBSA TDA Task Team undertook a comprehensive causal-chain analysis of the priority transboundary problems related to LBSA. Detailed consultations on the various priority transboundary issues were also undertaken through the regional Technical Task Forces, specifically at a series of meetings held throughout the region⁵. The final step involved a detailed governance analysis which was undertaken through a process that was coordinated by the Legal and Technical Review Task Force.

An important step in the LBSATDA involved validation of the results by experts and institutions in the region to provide credibility to the process of prioritisation of transboundary problems and/or issues. The principal mechanism for validation of the TDA was the Scientific and Technical Advisory Committee (STAC) established by the Project. The STAC comprised selected heads of academic and research institutions (or their delegates) as represented in the Forum for Academic and Research Institutions in the WIO-Region (FARI), as well as selected independent experts. As part of the review process, the draft LBSA TDA was discussed in a FARI workshop that was held on 27 November 2007 in Durban, South Africa. Subsequently, the draft TDA was circulated to the selected experts for review and the results of this review process were discussed in a meeting of the STAC held on 25-26 August 2008. This process led to the preparation of the updated TDA that integrated STAC inputs. Following endorsement by STAC, the updated TDA was submitted to the WIO-LaB Project Steering Committee in May 2009 for endorsement.

ASCLME/SWIOFP Process: The issue identification process commenced with a review of data and information presented in the national MEDA reports of each of the participating countries. The purpose of the review was to capture the full range of issues impacting the WIO in each of the participating countries. Issues of concerns described in the national MEDA reports were documented for each country. All issues from the participating countries were compiled and used to create a simplified generic list of issue categories. This process resulted in the identification of 50 issue categories, which were distributed between four broader Main Areas of Concern (MAC) as follows:

- MAC01: Water quality degradation (8 issue categories)
- MAC02: Habitat and community modification (15 issue categories)
- MAC03: Declines in living marine resources (20 issue categories)
- MAC04: Unpredictable environmental variability and extreme events (7 issue categories)

The 50 issue categories identified provided the basis for the construction of a 'Draft Issues Framework'. Issue captured from each of the national MEDA reports were back-classified and captured as relevant in the 'Draft Issues Framework'. The resulting matrix showed which countries had identified which issue categories as a relevant national concern in their MEDA.

1.3.1.3 National Issue Validation and Prioritisation Process of ASCLME TDA

National CCA meetings were held in each of the nine participating countries in the WIO region in the period between 14th July 2011 and 15th August 2011. The National CCA meetings followed the same agenda in each country. Each meeting commenced with a series of presentations to update participants on progress of the project, to introduce the 'Draft Issues Framework' and to explain the CCA process. Meeting participants were then divided into three working groups, one for each of the first three Main Areas of Concern (MAC01, MAC02, and MAC03), and each group was tasked with a series of exercises which aimed at helping the participants to:

Nairobi Convention Secretariat, the UNEP Global programme of Action for the Protection of the Marine Environment from land-based Activities (UNEP/GPA).

⁵ The 2nd meeting of the Regional MWW Task Force (Toliara, Madagascar, 3-5 June 2007);

The 2nd meeting of the Regional PADH Task Force (Toliara, Madagascar, 3-5 June 2007); and, the 3rd meeting of the Regional Working Group on Water, Sediment and Biota Quality (Maputo, Mozambique, 19-20 July 2007). The 3rd meeting of the Regional Legal and Technical Review Task Force (Stone Town, Zanzibar, 31 January – 2 February 2007);

- Validate the issues included in the 'Draft Issues Framework' and complete a Level 1 prioritisation process.
- Identify the availability of baseline data or a monitoring programme related to the issue.
- Complete a more detailed Level 2 prioritisation process and;
- Construct impact and causal chains for these top priority issues within each MAC. The outcomes of this process are presented in Chapter 9.

The Level 2 prioritisation process identified 20 potential top priority transboundary issues of concern within the WIO LMEs, which included 4 issues in MAC01, 7 issues in MAC02 and 8 issues in MAC03. A total of 72 impact and causal chains were prepared for these priority issues. After the National CCA meetings, the countries were provided the opportunity to review and correct the outputs.

1.3.1.4 Regional Issue Validation and Prioritisation Process of ASCLME TDA

At the subsequent Regional TDA-III workshop that was held in Johannesburg between 9th and 10th May 2012, participants replicated the Level 1 and Level 2 prioritisation exercise that had been completed at the national and regional levels. During this process, three new issues were added to the MAC01, these included '1.3.7 Noise pollution', '1.3.8 Thermal pollution', and '1.3.9 radioactive contamination (risk of dumping)'. Agreement was also sought from the countries about the removal of several of the issues, which from the National CCA Meeting results were clearly not transboundary in nature. One issue was removed entirely from the issues framework (3.3.5 Decline in populations of sea urchins). Two further issues were combined with other similar issues; 3.3.8 crayfish was combined with issue 3.3.7 on lobsters, and issue 3.2.2 on abalone was combined with issue 3.3.1 on molluscs.

The Level 2 prioritisation results from the National CCA Meetings and the Regional TDA-III Workshop were nearly identical, with the exception of 6 issues. These 6 issues were either identified by the countries as a priority at the national level but not at the regional level or vice versa. The six issues included: 1.3.4 Suspended solids, 1.3.6 Oils spills, 2.3.2 Seagrass habitats, 2.6 Introduction of exotic non-native species, 3.1.4, Sea turtles, and 3.2.3 Small pelagics.

At the Regional TDA-IV workshop, held in Mauritius between 21st and 24th July 2012, the experts from the participating countries reviewed the national and regional results and agreed upon a final list of 21 priority transboundary issues of concern as shown in Table 2.1. In addition to these high priority transboundary issues, the participating countries also identified some emerging issues.

Table 2.1: Priority Transboundary Issues

Main Area of Concern	Issue No.	Issue
MAC01	1.1.	Alteration of natural river flow and changes in freshwater input and sediment load
	1.2.	Degradation of ground and surface water quality (fresh and estuarine, not marine)
	1.3.1	Microbiological contamination from land-based (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) sources
	1.3.5	Solid wastes / marine debris (plastics etc.) from shipping and land-based-sources
	1.3.6	Oil spills (drilling, exploitation, transport, processing, storage, shipping).
MAC02	2.1.	Shoreline change, due to modification, land reclamation and coastal erosion
	2.2.1.	Disturbance, damage and loss of upland / watershed habitats (>10 m elevation)
	2.2.3.	Disturbance, damage and loss of coastal habitats (beaches, dunes, coastal vegetation and flood plain habitats to 10 m elevation)
	2.2.6.	Disturbance, damage and loss of mangrove habitats
	2.3.1.	Disturbance, damage and loss of coral reef habitats
	2.3.2.	Disturbance, damage and loss of seagrass habitats
	2.4.	Disturbance, damage and degradation of pelagic habitats (nearshore <30 m, neritic 30-200m and oceanic >200m depth)

	2.6.	Introduction of exotic non-native species, invasives and nuisance species
MAC03	3.2.1.	Decline in populations of sharks and rays
	3.2.2.	Decline in populations of large pelagic
	3.2.3.	Decline in populations of small pelagic
	3.2.5.	Decline in populations of reef and demersal fish
	3.3.3.	Decline in populations of sea cucumbers
	3.3.5.	Decline in populations of prawns and shrimp
	3.3.6.	Decline in populations of lobsters
	3.4.	Excessive bycatch and discards

1.4 Analysis of main problem areas of concern and issues

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

1.4.1.1 Overview of the situation in the WIO

Deteriorating quality of the coastal waters of the WIO region poses a significant threat to public health as well as to the health of its living marine resources and ecosystems – and thus also to the economy. The sources of pollution which contribute to this deterioration include both land-based and marine-related activities. According to a global study by the UN Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), 80% of the pollution of the coastal and marine waters originates from land-based sources and activities. The main land-based sources of pollution in the region include the discharges of municipal wastewater and sewage, industrial effluents, contaminated surface and sub-surface run-off and agricultural return flows. Discharge of wastewaters and effluents from land-based activities affects estuaries and nearshore waters including critical coastal habitats such as mangroves, seagrass beds and coral reefs. The magnitude of pollution differs from country to country and also within a given country, there are significant spatial-temporal differences.

The African Process that preceded the GEF funded projects in the WIO identified hotspots of pollution or sensitive areas and unique ecological areas along the sub-Saharan African coast (GEF/MSP, 2001). The identified hotspots of land-based sources of marine pollution were described as the localities where there was readily observable evidence of pollution impacts that affected the health of the coastal ecosystems or the ability of coast's natural systems to deliver services (Francis *et al.*, 2002; Kazungu *et al.*, 2002; Jones *et al.*, 2002; Dulymamode *et al.*, 2002; Hogueane *et al.*, 2002; Clark *et al.*, 2002)⁶. Further assessment of hot spots of pollution was undertaken through the UNEP-GEF WIO-LaB project that also implemented a regional monitoring programme to assess the quality of water and sediments at the pollution hot spots that were identified during the African Process (UNEP/Nairobi Convention Secretariat *et al.*, 2009b).

The development and implementation of a water, sediment and biota quality monitoring plan for the WIO, under the WIO-LaB project, followed an attempt to provide a first regionally comparable estimate of pollution in perceived hotspots of pollution in each of the eight participating countries. This included the preparation of National Pollution Status Reports (Anon. Mauritius, 2009, Mong *et al.* 2009, Anon Mozambique 2007, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Antoine *et al.* 2008, Weerts *et al.*, 2009), as well as the implementation of a regional monitoring programme coordinated through a Regional Activity Centre (RAC), in this case the Council for Scientific and Industrial Research (CSIR) of South Africa. Results from these national reports were incorporated into a Regional Synthesis Report on Marine Pollution in the WIO region (UNEP/Nairobi Convention Secretariat *et al.*, 2009b). Other studies commissioned under the WIO-LaB project that are of relevance include the regional reports on the assessment of the status of municipal wastewater

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

(MWW) management and marine litter problems in the WIO region (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a, UNEP and WIOMSA, 2008).

Land-based sources of marine pollution in the WIO region are primarily associated with densely populated areas and industrial zones within urban centres and in the vicinity of river discharges, particularly those from larger river basins. Although, at present urban centres in the WIO region are still several hundred kilometres apart thus creating distinct hotspots, rapid urbanization in the region in the near future could result in so-called 'strip development' of coastal areas where smaller coastal towns and suburban areas eventually join with the main cities creating larger continuous urban zones along the coastline (Ruwa, 2006).

While globally land-based activities are considered to contribute between 80–90% of the chronic pollution load to the marine environment, marine sources also make a significant contribution to localised and trans-boundary pollution, especially in terms of single-point impacts such as blow-outs or massive-scale oil spills from tanker strandings. From a technical perspective, there is lack of detailed information on marine sources of pollution in most countries in the WIO region due to the fact that the sources are not adequately managed either because there is limited or no legislation or there is a lack of technical capacity – or both. While there is a limited amount of dumping (as defined in the London Convention/Protocol) in the region, ports in all countries undertake dredging on a reasonably regular basis and that many of them are dumping dredged materials at sea. Moreover, although four of the countries are Party to the London Convention/Protocol, most of them do not appear to be implementing it. In addition, there have been reports of illegal dumping of toxic wastes off of the coast of Somalia. These represent a threat to the WIO region as a whole.

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

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

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

- Litter from vessels, offshore rigs and port activities.
- Petroleum hydrocarbons from shipping, port operations and offshore oil and gas activities (including accidental and operational discharges).
- Tributyltins (TBTs) and other toxic constituents from anti-fouling coatings on vessels and submerged infrastructure.
- Heavy metals and other toxic contaminants (e.g. pesticide residues) which accumulate in port sediments and which are discharged into other coastal areas after dredging operations.
- Noise pollution associated with seismic surveys used in oil and gas exploration.

Table 2-2 Overview of selected pollution hotspots in the WIO region and associated or perceived pollution problems.

COUNTRY	HOT SPOT	CATEGORY ^a	TRANSBOUNDARY PROBLEM				
			Microbial contamination	Eutrophication (nutrient enrichment)	Marine litter (solid waste)	Suspended solids	Chemical Pollution
Comoros	Mitsamihouli beach	2	■	■	■		■
	Chindini Beach	4	■		■		
	Chomoni Beach	4			■		
	Moroni Port	1	■	■	■		■
	Anjouan Port	1	■	■	■		■
	Fomboni Port	4	■	■	■		■
Kenya	Mombassa	1	■	■	■	■	■
	Lamu inshore waters	1	■	■	■	■	■
	Malindi Bay and Sabaki Estuary	1	■	■	■	■	■
	Diani	2	■	■	■	■	■
Madagascar	Port de Mahajanga	1	■	■			■
	Port de Nosy-Be	1	■	■			■
	Toliara	1	■	■		■	
	Port de Tamatave	2					■
	Bay de Diego	1		■			■
	Baie de Fort-Dauphin	2	■				■
Mauritius	Pointe Aux Sables to Bay du Tombeau (through Port Louis)	1	■	■	■	■	
	Belle Mare/Palmar	1	■	■			
	Flic and Flac	4	■	■		■	■
	Grand Baie	3	■	■		■	
	Rodrigues ^b	?				■	
Mozambique	Maputo Bay	1	■	■	■	■	■
	Beira	4	■	■	■		
	Nacala Bay	4	■	■	■		
	Pemba Bay	4	■				
	Incomati Estuary	4		■			
Seychelles	Port Victoria	2	■	■			■
	La Digue	3	■				
	Anse Volbert	4	■				
	Beau Vallon Bay	2	■	■			
	East coast Mahe	3	■	■			■
South Africa	Richards Bay	3				■	■
	Durban	1	■				
	East London	4	■	■			
	Port Elizabeth	4	■				■
	Eastern Cape and Kwazulu-Natal estuaries and adjacent coastal areas	4	■	■			
Tanzania	Dar es Salaam	1	■	■			■
	Tanga	1	■	■			

COUNTRY	HOT SPOT	CATEGORY ^a	TRANSBOUNDARY PROBLEM				
			Microbial contamination	Eutrophication (nutrient enrichment)	Marine litter (solid waste)	Suspended solids	Chemical Pollution
	Zanzibar	1	■	■			

^aHot spots ranked in order of decreasing severity from 1 to 3; Category 4 refers to emerging hot spots.

^bRodrigues did not form part of the WIO-LaB regional monitoring programme and is consequently not ranked.

1.4.2.2 Microbial contamination from land- and marine-based sources

(a) Problem statement

In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater (including sewage), contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing and industrial effluents (mainly from food processing industries). Most of the countries in the WIO region identified microbial contamination of their coastal waters as an issue of concern. Microbial contamination refers to the presence of pathogenic organisms (protozoa, bacteria and viruses) of either human or animal origin in the aquatic environment. Usually these occur as a result of inappropriate disposal of un- or under treated municipal wastewater, contaminated surface and sub-surface runoff from populated areas, contaminated runoff from agricultural areas used for livestock rearing, and industrial effluents (often food processing) (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009). Microbial contamination of coastal waters can have serious socio-economic impacts, and presents a risk to human health through direct contact or ingestion of contaminated seafood. These consequences can affect local communities, tourists, industry and aquaculture operations. The reduced quality (and economic value) of seafood, whether cultured or wild harvested can have serious economic consequences. The loss of the recreational value of coastal waters, due to high levels of faecal bacteria (typically used as indicators of microbial contamination), is evident throughout the coastal zone of the WIO region. Concentrations are often higher in areas in close proximity to larger urban centres (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). In many areas, the situation is accompanied by unpleasant aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

(b) Transboundary Scope

In the Comoros, there is no sewerage, drainage or wastewater treatment (ASCLME 2012a). Households typically use pit latrines that leaks and contaminate groundwater and coastal and marine ecosystems. In Ngazidja, there is a massive risk of groundwater pollution due to seepage from septic tanks (ASCLME 2012a). In Kenya, microbial pollution levels in urban centres such as Mombasa are several orders of magnitude higher than in coastal waters found in rural areas (Mwangi and Munga 1997, Mwanguni 2002, UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009, ASCLME 2012b). Over 50% of all reported infections in Kenya have been attributed to poor water quality due to inadequate wastewater treatment and management, although the sources of the microbial contamination, whether from drinking contaminated water or from coastal recreational is not always certain (Mwanguni 2002, ASCLME 2012b).

Studies conducted around Taolagnaro (Madagascar) measured *E. coli* counts as high as 13,300 counts/100 ml in coastal waters. These high levels of faecal contamination have been attributed to defecation on the beaches as well as inappropriate treatment of municipal wastewater (Mong *et al.* 2009). There have several reported cases of illness resulting from eating marine turtles (seven cases), sharks (eight cases), fish (one case) and molluscs (two cases), although the causal link to microbial contamination was not always clear. Recent (2007-2008) data collected for the purposes of the WIO-LaB water and sediment quality monitoring programme confirm that microbial pollution is a

persistent problem in some Madagascan coastal areas (Mong *et al.* 2009). High counts of enterococci and total coliforms have been reported at Mahajanga and Nosy Be.

In Mozambique, faecal coliform counts in the channel adjacent to the Infulene River in Maputo was found to be high (460,000 bacteria counts/100 ml) and exceeded 2,400 bacteria counts/100 ml in the river mouth (ASCLME 2012d). Faecal coliform, faecal streptococci and *Escherichia coli* were also detected in both marine waters and shellfish tissues in other places within Maputo Bay. In Maputo Bay, microbial contamination has been recorded in shellfish. The bacteria *Vibrio parahaemolyticus* and *V. mimicus* have been found in clams in the Incomati River mouth, in the bay adjacent to the Polana Hotel and near Matola in the Maputo Estuary. *Vibrio* spp. are the main causes of severe gastrointestinal illnesses (Fernandes, 1996). High faecal coliform counts were also detected at several locations near the Infulene river mouth where values exceeded 2,400 counts/100 ml. Such high contamination levels are due to inappropriate sewage treatment facilities - there is only one sewage treatment plant in Mozambique, located in Maputo City, which treats about 50% of the city's sewage. Areas near the entrance of the Maputo Estuary (Miramar) are no longer considered safe for swimming due to faecal contamination. Faecal contamination has also been recorded in Beira Bay and Nacala Bay, although levels were lower than those recorded in Maputo Bay (Fernandes, 1995).

In Madagascar, studies conducted around Taolagnaro reported high *E. coli* counts of the order 13,300 bacteria counts/100 ml in coastal waters. High counts of enterococci and total coliforms were also reported from Mahajanga and Nosy Bé. The high levels of faecal contamination were attributed to defecation on the beaches as well as inappropriate treatment of municipal wastewater (Mong *et al.* 2009). WIO-LaB water and sediment quality monitoring surveys confirmed that microbial pollution is a persistent problem in some Madagascan coastal areas (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). In Mauritius, the situation is not better as 73% of households use cesspits or septic tanks whilst 2% use pit latrines and therefore most of the effluents are discharged directly to the sea or are carried to the sea via surface runoff and rivers causing microbial pollution of coastal waters after heavy rains (ASCLME 2012h). Along the coast of Mauritius, total and faecal coliforms are monitored on a monthly basis at eleven selected public beaches, namely Flic en Flac, Albion, Pointe aux Sables, Trou aux Biches, Mon Choisy, Le Goulet, Grand Baie and Blue Bay. The Ministry of Fisheries reported in 2004 that most of these public beaches were within the recommended water quality guidelines for contact recreation (counts of total coliform < 1,000 per 100 ml and faecal coliform < 200 per 100 ml). The exception was some areas in Pointe aux Sables (near Port Louis) where levels exceeded the recommended guidelines (Dulymamode *et al.*, 2006).

Studies conducted in Mombasa (Kenya) showed that microbial pollution levels in urban aquatic environments were several orders of magnitude higher than in aquatic environments located in rural areas (Mwanguni, 2002). Over 50% of all reported diseases in Kenya have been attributed to inadequate wastewater management, although no distinction has been made between effects due to drinking of contaminated water and those due to recreational activities such as swimming (Mwanguni 2002). Surveys conducted during the implementation of the WIO-LaB monitoring programme, showed that the highest levels of microbial contamination occur in the Kilindini/Port Reitz creek area and to a lesser extent in the Sabaki estuary/Malindi Bay complex and Funzi Bay further to the south coast of Kenya. In the Seychelles, effluent from wastewater treatment plants discharged directly into the ocean contain total coliform counts of between 2,000 and 5,000 per 100 ml, which is far above the stipulated standard of 500 per 100 ml (Antoine *et al.*, 2008). High microbial counts have also been recorded at Beau Vallon Bay during the rainy season mostly associated with runoff from non-point sources such as rivers and small streams (Antoine *et al.* 2008). In Seychelles outbreaks of water and insect borne diseases usually occur during the rainy season and have been attributed to defective on-site wastewater disposal systems.

In South Africa, since 1985, the design of offshore sewage outfalls have largely complied with the receiving water quality objectives approach where effluent quantities and composition must be within limits that meet site-specific Environmental Quality Objectives, as recommended in the South African Water Quality Guidelines for Coastal Marine Waters. Generally, long-term environmental monitoring

programmes at these outfalls have indicated no detrimental impact on the marine environment or its beneficial uses in terms of chemical and microbiological contamination. However, of greater concern is the rapid increase in discharges in less dynamic and sensitive areas such as surf zones and estuaries, where effluents from malfunctioning or overloaded treatment facilities are adversely affecting the marine environment and its beneficial use, albeit in a localised manner (RSA DWAF 2004a,b,c). In Cape Town, an extensive monitoring programme for microbiological contamination (using *E. coli* as an indicator organism) is conducted by the local municipality. In 2005 approximately 80% of stations sampled complied with the recommended South African water quality guidelines for contact recreation. Stations that did not comply (i.e. *E. coli* exceeded 200 counts/100ml in 80% of samples and 2000 counts/100 ml in 95% of samples) were in highly developed and urbanised zones along the coast (City of Cape Town, 2005). In Tanzania, surveys conducted as part of implementation of the WIO-LaB monitoring programme in 2007 showed that serious contamination of coastal waters occurs around the city of Dar es Salaam as well as in Stone Town, Zanzibar (Mohammed *et al.*, 2008). In Zanzibar, high total and faecal coliform levels have prompted health concerns and issuance of health risks warning to swimmers in certain coastal areas such as the popular beaches located adjacent the Stone Town. Similarly, Ocean Road and Banda beaches in Dar es Salaam have also been closed for swimming and other recreational activities due to high levels of microbial contamination (Mohammed *et al.*, 2008).

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

All the nine countries in the region identified the issue as being 'Relevant', so it is a shared issue of concern amongst the countries. While only 2 of the countries identified the issue as being of 'High' importance in the Level 1 prioritisation, 5 countries ranked the issues as being of 'Medium' importance because the impacts were often spatially localised. In the Level 2 prioritisation, 5 of the 9 countries allocated the issue with an above average score for the 'Overall rating' within MAC01, suggesting that it is a priority issue of concern for the countries within the WIO. It is likely that the problem will intensify in the future, posing an even greater risk to society and economies, especially those dependent on coastal tourism, unless the sectors that contribute to the problem take measures to address it. The Regional 'Overall rating' score was also above average, indicating that countries consider this to be a high priority transboundary issue of concern within the WIO.

1.4.2.3 High suspended solids/sediments and turbidity due to human activities

(a) Problem statement

High concentrations of suspended solids/sediments and turbidity in WIO coastal waters are mainly through municipal and industrial wastewater discharges, river discharges and surface runoff, particularly during rainy seasons. Dredging activities usually associated with ports and harbours, can also significantly contribute to this problem albeit for the period that dredging activities takes place. High suspended sediments load enter the coastal waters due to river discharges. Major rivers from the central highlands, including the Maputo, Incomati, Limpopo, Thukela, Save, Tana, Athi-Sabaki, Rufiji, Zambezi and Ruvuma, discharge large volumes of siliclastic sediment to the sea (Kairu and Nyandwi 2000). River sediment load is estimated to range 5-34 million tonnes per annum (UNEP/Nairobi Convention Secretariat, and WIOMSA 2009). Land-based activities, such as deforestation, poor agricultural practices in the hinterlands, disposal of municipal and industrial wastewaters and effluents including artisanal and industrial mining, all significantly increase the amount of sediment load in coastal waters (UNEP/Nairobi Convention Secretariat, and WIOMSA 2009). Also, within the marine waters, activities that mechanically disturb benthic sediments such as dredging and trawling, re-suspend sediment particles and increase water turbidity (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009, van der Elst 2012). High concentrations of

suspended solids can have both chronic and acute effects on marine biota. For instance, suspended sediments can block light penetration through the water column thus reducing the photic zone with serious implications on the productivity of photosynthetic organisms (Yentsch *et al.* 2002). The settling sediment particles also smother benthic flora and fauna, and clog gills and feeding apparatuses of filter feeding marine organisms (Fabricus 2005, Woolridge and Done 2009). Sedimentation can result in the mortality of some species and lead to shifts in community structure and composition (Fabricus 2005, Ahamada *et al.* 2008). The loss of critical habitats such as mangroves, corals or seagrasses due to sediment loading can negatively impact fisheries and the livelihoods of people dependent on these resources (Ahamada *et al.* 2008).

(b) Transboundary Scope

The transboundary element is based on the problem being common to most of the WIO countries, rather than interlinked (see Table 4-1). However, taking into account ocean circulation patterns in the region (Figure 2-4), true transboundary impacts cannot be excluded, particularly where large discharges from rivers are concerned. Also, high levels of suspended solids tend to affect nearshore habitats such as mangroves, seagrass beds and coral reefs and estuaries, which are important nursery and reproduction sites for a variety of species, resulting in a secondary transboundary impact. Increased sediment loads in coastal waters and increased sedimentation therefore affects transboundary waters, habitats and associated living marine resources. All 9 countries in the WIO Region recognized the issue as being 'Relevant'. Only 4 of the 9 countries considered the issue to be 'High' priority, another 4 recognized the issue as being of 'Medium' importance, with only one country rating the issues as being of 'Low' importance. The 'Overall rating' scores were above average for only 2 countries, indicating that it was not considered to be a priority issue by the countries at the moment (Appendix VII). The Regional 'Overall rating' score was however marginally above average, indicating that the countries consider this to be a 'borderline' priority transboundary issue of concern.

(c) Risks/uncertainties and trends

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

1.4.2.4 Chemical Pollution from land-based and marine-based sources

(a) Problem statement

Chemical pollution of the coastal and marine waters in the WIO region is still low in view of low levels of industrial development in most countries in the region. The problem is usually confined in few scattered pollution hotspot areas located in the main urban centres in the region. In these hotspot areas, the main sources of chemical pollution are usually diverse and vary from one country to another but these usually include agrochemical discharges, release of sediment-bound heavy metals and hydrocarbons due to dredging operations in ports and harbours, discharge of industrial effluents and leachates from dumpsites (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). There is also a diverse range of industries in the region that contributes to chemical pollution and these include manufacturing, textiles, tanneries, paper and pulp mills, breweries, chemical, cement, sugar and fertilizer factories.

(b) Transboundary Scope

Although the magnitude of chemical pollution is generally low in the WIO region, the problem is common in specific hotspot areas located in most of the countries. The problem has transboundary implications due to the fact that chemical contaminants can be transported by ocean currents leading to impacts on coastal and marine ecosystems throughout the region. In cases where bio-accumulation occurs especially in larger migratory species such as marine mammals and sharks, the contaminants can impact resources and thus communities far removed from the originating source. Chemical

pollution can also affect one or more life stages of migrating marine organisms, which could impact on their distribution and abundance in a neighbouring country or region.

Chemical pollution has distinct transboundary implications in many cases. Chemical contaminants can be transported by ocean currents and in sediments and given their persistence in the environment, this is often considered to be a typical transboundary issue, although there is no direct evidence of this occurring within the WIO region. The chronic or sub lethal impacts associated with chemical contamination are often localised and contained within the vicinity of the source of origin. However, the issue can be considered transboundary where the issue is shared between one or more countries. All nine countries in the WIO Region identified chemical pollution issue as being 'Relevant', only 2 of the countries ranked the issues as being of 'High' importance in the Level 1 prioritisation, a further 5 ranked it as being of 'Medium importance, and 2 ranked it as being of 'Low' importance. Only one country allocated an 'Overall rating' score that was above average compared with the scores for the other issues within the MAC01. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider chemical pollution to be a high priority transboundary issue of concern in the WIO region at the present time.

To exacerbate the impacts of oil spills, dispersants which are commonly used to clear oil spills contain toxic solvents which penetrate the protective waxy cuticles of seagrass blades. This affects the biological functioning of cellular membranes and chloroplasts, thereby causing plant loss and as well as other harmful effects on other benthic biota (Ellison and Farnsworth, 1996, Abuodha and Kairo, 2001).

In Madagascar, chemical pollution is confined in hotspots located at Mahajanga and Nosy-Be. Heavy metals in sediments in these two hotspot areas are some of the highest in the entire WIO region, especially in areas in close proximity to sewage outfall points (Mong *et al.*, 2008).

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

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

Similarly, studies investigating heavy metal accumulation in Cape Town revealed that the coastal environment is generally in a clean condition, except in localised areas such as the Port of Cape Town (Brown, 2005; CSIR, 2006a, 2006b). The fairly good state of the environment is also reflected in the results of a Mussel Watch Programme conducted along South Africa's west coast. Results for cadmium, lead, zinc and mercury do reflect inter-annual variations but, as yet, no clear long-term trends seem to be apparent (Figure 2-2).

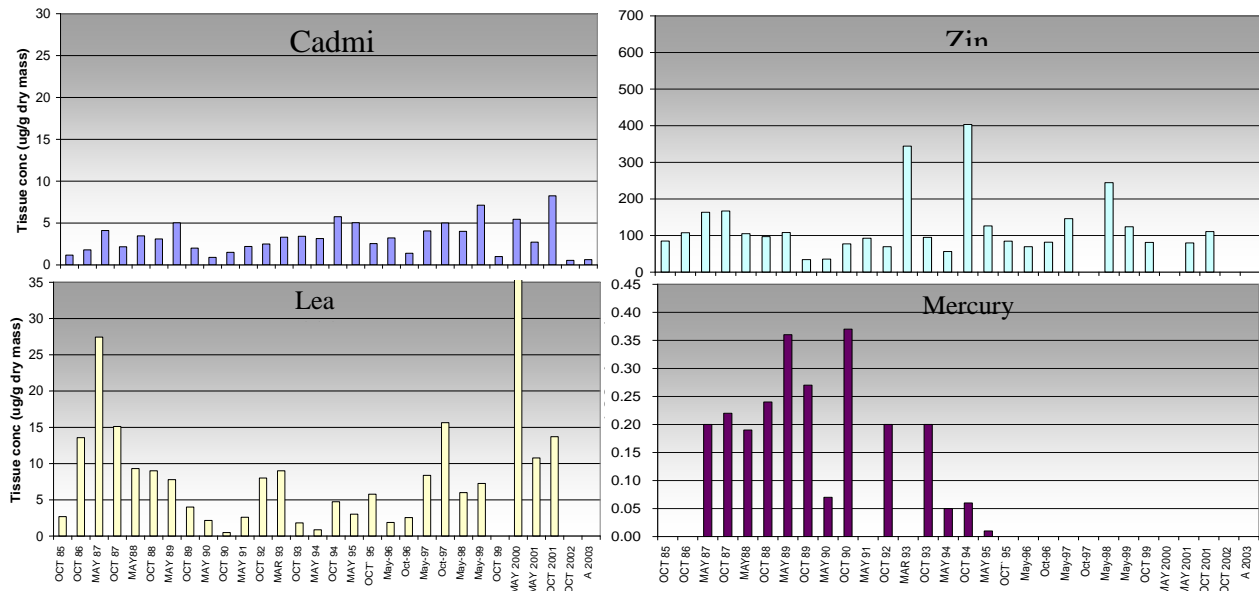


Figure 2-2 Heavy metal concentrations ($\mu\text{g/g}$ or mg/kg dry weight) measured in mussel tissue along the South African coast (Cape Town) (1985 – 2003)

In Tanzania, significant concentrations of heavy metals have been reported in mangrove forest sediments and associated biota near the city of Dar es Salaam (Mremi and Machiwa 2003). Sediment samples from Msimbazi and Mtoni mangrove areas, which are located within the city, had three-fold higher levels of heavy metals compared to samples obtained at a mangrove forest located some distance from the city at Mbweni. This clearly indicated that anthropogenic input is the main cause of the spatial variation of heavy metal concentrations with higher concentrations in mangrove areas located near the city and low concentration in areas that are far from the city (see Table 2-). Surveys conducted as part of implementation of the WIO-LaB monitoring programme in 2007 also established that some areas around Dar es Salaam had concentrations of copper in sediments that were well above the recommended guideline value for the WIO region (Mohammed *et al.*, 2008).

Table 2-3 Average concentration (mg/kg dry weight) of heavy metals in mangrove sediment and biota in the Dar es Salaam area and Environmental targets (EQTs) for sediments in the WIO (UNEP, 2009).

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

A ten-fold increase in heavy metal concentration in several algal species has been reported in different parts of Zanzibar and Dar es Salaam (Ferletta *et al.*, 1996). Another study has shown that macroalgae at Chapwani and Changuu Islands off Zanzibar have significant levels of aluminium and cadmium with the source being the various industries located in the nearby Stone Town (Engdahl *et al.*, 1998). Studies conducted on the accumulation of heavy metals in algae have also indicated that in the period

1989-1994, there was a significant increase in heavy metal concentrations in algae (Ferletta *et al.*, 1996) (Table 2-4). Along Dar es Salaam and Zanzibar beaches, high concentrations of zinc and other heavy metals have been reported in beaches located close to the city centre compared to those located in rural areas. Analysis of heavy metals in sediments in the inner area of Dar es Salaam harbour also revealed an accumulation of certain heavy metals, notably chromium and copper (Machiwa, 2000) (see Table 2-5). The harbour area is the recipient of large quantities of industrial waste from the city of Dar es Salaam.

Table 2-4 Comparison of heavy metal concentrations measured in algae in 1989 (Wekwe *et al.*, 1989) and 1994 (Ferletta *et al.*, 1996) in Dar es Salaam (Oyster Bay) and Zanzibar (Mdudya Island).

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

nd - Not detected

Table 2-5 Average concentration (mg/kg dry weight) of total heavy metals measured in sediments in Dar es Salaam harbour and Mauritian estuaries (Sources: Machiwa, 2000; Mauritius Pollution Status Report, 2006), as well as the recommended environmental targets (EQTs) for sediments in the WIO (UNEP/Nairobi Convention Secretariat and CSIR, 2009).

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

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

(c) Risks/uncertainties and trends

Although several scientific studies conducted in coastal areas in the WIO region revealed elevated levels of chemical pollutants, most likely attributable to land-based sources, uncertainties remain regarding the geographical spread of chemical contamination as most studies were not designed to reflect the spatial extent of the pollution in the entire region. Also, data on environmental impacts and socio-economic consequences directly linked to chemical pollution are not available in the region. Industrialization in the WIO region remains slow relative to other parts of the world but, it is increasing rapidly. Development trends in other parts of the world have shown that rapid development often takes place without proper environmental impact assessments or legislative controls, often leading to increased pressure on the coastal and marine environment. This is expected to be so in the WIO region. It is also important to note that commercial agricultural activities that are characterised by increased use of agrochemicals are also rapidly increasing in most countries in the WIO region with potentially greater adverse impacts on the coastal and marine ecosystems. Thus, chemical pollution from industrial and agricultural sectors is likely to intensify in the near future unless mitigating measures are implemented through better legislation, best practice guidance and awareness creation. Despite the lack of data on the impacts, the risk of chemical pollution of coastal water from land-based and seas-based activities should not be ignored. There is a need for a timely intervention by industry managers, farmers and the government authorities responsible for regulating the specific activities that are responsible for chemical pollution in hotspot areas located in the region.

1.4.2.5 Solid waste and marine debris including plastic litter from land- and marine-based sources

(a) Problem statement

Marine litter pollution refers to the introduction of solid waste material, which either floats or sinks, into water bodies and their coastal zone surroundings. Marine litter is considered to be any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment (UNEP 2005b). Few studies have been carried out on marine and microplastic litter in the WIO region (UNEP and WIOMSA 2008, 2022). Majority of the studies have been carried out in South Africa (57%), Kenya (8%) and Mozambique (5%), with very few in Madagascar, Seychelles, Comoros, Tanzania, Mauritius and La Réunion. The occurrence of plastic litter in other coastal-marine habitats has been poorly studied in the WIO (UNEP-Nairobi Convention/WIOMSA, 2022 Marine Plastic Litter Regional Synthesis report). Lack of comprehensive studies and especially data on plastic litter in most countries make it difficult to establish the long-term trends in micro- and meso plastic litter densities in the WIO Region. Few surveys carried out in South Africa have shown that the average density of mesoplastics increased in the period between 1984 and 1989 and there was little change in densities in 1990s and 2010s. However, in view of lack of effective mitigation measures coupled with rapid increase in human population and consequent anthropogenic activities in most of the WIO countries, it is expected that the magnitude and extent of marine plastic litter pollution in the WIO will continue to increase. There is scarcity of data and information on the spatial distribution of micro-, macro- and meso-plastic litter in the WIO region. Few studies undertaken in Kenya, South Africa, Tanzania and Comoros have shown that higher densities of meso-, macro- and micro- plastic litter are found on beaches located within or closer to urban areas. Densities in beaches located in semi-populated and remote rural areas are usually low. The microplastics also tend to be concentrated around large coastal cities in the WIO region. Most of the studies have shown that plastic packaging dominates marine litter loads in most of the sandy beaches located within or close to urban areas. Few studies undertaken to determine the origin and fate of marine plastic litter in the WIO Region have shown that most of the plastic litter in the WIO Region originates from local land-based sources. The litter reaches the ocean via rivers, direct runoff or through direct deposition by beachgoers (UNEP and WIOMSA 2008, UNEP 2005b; UNEP/WIOMSA 2022). The shorelines of the WIO region are considered important sinks for plastic litter as most of the litter deposited along the shoreline is not dispersed far from source. Mangroves and rocky shores have been found to be important sinks for larger and heavier litter items.

Since the WIO region is downstream of south-east Asia, some of the plastic litter reaches the WIO from South-East Asia via ocean currents. Few studies carried out in the WIO region to determine the interaction between marine organisms and marine plastic litter or microplastics have reported plastic ingestion in some species of seabirds, bony fishes and sharks. Also, some studies have shown that all four species of sea turtles in the WIO have plastic debris in their stomach contents. Four species of marine mammals that had been investigated in the WIO Region did not have evidence of ingestion of macrolitter. However, invertebrates such as mussels, oysters, crabs, sea anemones and some zooplankton in the WIO have been found with microplastics in their guts. Entanglement has been reported for seabirds, marine mammals, sea turtles, bony fishes and sharks. Fisheries litter (nets and lines) have also been found to entangle coral reefs, macro-algae and horny corals in the WIO. Some invertebrates such as echinoderms, sea anemones have been found with plastics attached to their body. Some studies in the WIO have also reported floating plastic litter been colonized by various species of bryozoans, spirorbid worms and goose barnacles. The potential impact of marine litter and microplastics on human health remains severely understudied and unknown in the WIO Region. However, one study from Tanzania confirmed presence of high concentrations of human pathogens and multi-drug resistant bacteria on waste plastics. Some studies conducted in South Africa and Mozambique have indicated that the ingestion of microplastics can potentially be harmful to humans because of the toxicity of plastic additives and sorption of persistent organic pollutants (POPs) on the surfaces of polyethylene pellets (UNEP and WIOMSA, 2022).

Marine litter typically originates from the inappropriate disposal of solid wastes, which is may be deliberately discarded on land and transported to the sea from rivers, storm drains or winds; dumped on the shore and carried out to sea by waves and currents or dumped intentionally or accidentally into the sea from vessels or other installations. The dumping of many types of waste from ships was legally banned in 1972 onward (London Convention 1972). A new convention was negotiated in 1996, but did not enter into force until 2006 (<http://www.imo.org>). The main sea or ocean-based sources of marine litter include: merchant shipping, ferries and cruise liners; fishing vessels; military fleets and research vessels; pleasure craft; offshore oil and gas platforms; fish farming installations (UNEP 2012). The main land-based sources of marine litter: municipal landfills (waste dumps) located on the coast or inland; riverine transport of waste from landfills or other sources along rivers and other inland waterways (canals); discharge of untreated municipal sewage, including storm water (including occasional overflows); industrial facilities: solid waste from landfills, and untreated waste water; tourism (recreational visitors to the coast; beach-goers) (UNEP 2012).

Marine-based sources of litter do not appear to be as significant as land-based sources in the WIO (UNEP and WIOMSA 2008). While the loss of fishing gear and dumping of garbage from commercial shipping traffic and fishing vessels is likely a major source due to the numbers of vessels operating or passing through the region, knowledge is limited. The most significant source of marine litter appears to be solid waste associated with surface runoff from urban areas (UNEP and WIOMSA 2008). In some countries in the WIO waste, may simply be dumped directly onto the coast for dispersal via the sea or used as a barrier against coastal erosion (UNEP and WIOMSA 2008). Although the levels of marine litter produced by the WIO countries may be lower than from more industrialised nations, the capacity to manage solid waste appears to be closely linked with a country's GNI and HDI ranking, and the situation in the WIO has the potential to become serious (UNEP and WIOMSA 2008).

Inappropriate disposal of solid waste represents a serious problem in most of the urban centres in WIO coastal regions. General littering by the populous lowers the surrounding environmental ambience and hence compromises the quality of life. It degrades the aesthetic quality of coastal areas, especially if such littering occurs along tourist routes or near resorts, cultural sites and other popular sites. Often, such litter is also routed through rivers and transported from adjacent catchments into coastal waters.

(b) Transboundary Scope

It has been estimated that over 13,000 pieces of plastic litter are floating on every square kilometre of ocean surface (UNEP 2005b), and in this regard marine litter and solid waste is already a global transboundary issue. Given the nature of ocean currents, marine litter dumped or abandoned anywhere in the Indian Ocean can be transported for thousands of kilometres, thus affecting marine ecosystems across borders but also further afield. Floating marine litter can be carried over long distances, especially considering the prevailing nearshore circulation and current systems of the WIO (see Figure 2-4). Litter at sea is known to disperse over vast distances, crossing ocean basins, and arriving at remote locations such as oceanic islands. While the full implications of the actual transboundary effects of litter in the WIO region may not have been investigated, studies from Antarctica and other parts of the world provide ample evidence of the transboundary polluting nature of floating marine litter, most certainly also common to most WIO countries. In 1989 the aircraft the SAA Helderberg crashed off Mauritius, but its flotsam was widely dispersed over the SW Indian Ocean carried by currents and gyres (Grundlingh, 1989; UNEP and WIOMSA, 2008; van der Elst *pers com*).

Marine litter has the potential of becoming a significant transboundary problem in the WIO region if it is not addressed as a matter of urgency. All 9 countries in the region identified the issue as being a relevant concern. Then 6 of the 9 countries ranked the issue as being of 'High' importance at the national level in the Level 1 prioritisation and; 7 of the 9 countries allocated above average scores for the 'Overall rating'. The Regional 'Overall rating' score was also above average. This suggests that solid waste is considered to be a high priority transboundary issue by the countries in the WIO region.

(c) Risks/uncertainties and trends

The impact of marine litter and especially plastic litter on the aesthetic quality of coastal areas in the WIO region is visibly real. As was the case with microbial contamination; population growth, poverty and inequality are all factors contributing towards the root causes of marine litter problem in the region. These causes are likely to intensify, posing even greater socio-economic risks to society, unless there are significant shifts in behaviour and unless those responsible for the different waste management systems intervene. Serious impacts on tourism development are likely, thereby further degrading the socio-economic standards and environmental quality of coastal regions. As economies develop and infrastructures improve, there will be a growing demand for products with a higher waste component. Paradoxically, this will also offer opportunities. For example in Dar es Salaam, there has been a growing demand for empty plastic mineral water bottles for re-cycling in China, resulting in their removal from local waste dumps, roadsides and beaches (Richmond, M. *pers comm*). The trend in Seychelles has been to ban take-away boxes, plastic bags. Grills have been placed on most river outlets and marine litter in the port area and on all of the major beaches is collected. For several years it has been illegal for stores in South Africa to give customers free plastic bags, a law that has seen an enormous drop in plastic pollution countrywide. One really successful activity has been the "Collect-a-Can" programme (www.collectacan.co.za) where all cans are recycled with the help of community, schools and environmental organizations, generating for these groups very substantial sources of income. This programme, initiated in 1993, now recycles 72% of all cans sold in South Africa.

1.4.2.6 Eutrophication or nutrient over enrichment in coastal waters

(a) Problem statement

Eutrophication occurs when there is elevated organic matter loading in coastal waters due to the increased availability or supply of nutrients, usually as a result of inappropriate disposal of municipal wastewater or nutrient-enriched agricultural run-off. Eutrophication is often more apparent in closed systems and in estuaries where higher levels of organic nutrients are concentrated. Nutrients such as nitrate, nitrite, phosphates and silicates are necessary for the growth of phytoplankton. These inorganic substances are constantly lost from marine surface waters as they are taken up by phytoplankton during primary production, and also because of gravitational sinking. Nutrients are naturally brought up to the surface by upwelling, when cold nutrient-rich deep waters are advected upwards, and there are several important areas of upwelling within the region. Nutrients may also be enhanced by circulation patterns around seamounts (Harris 2011, Keating *et al.* 1987). Coastal waters are however also enriched by nutrients as a result of land-based sources, and this was raised as an

issue of concern by the majority of countries. Elevated nutrient levels in coastal waters can generate artificially enhanced primary production (e.g. algal and phytoplankton growth) and an increase in the amount of organic material in the water column. Nutrient enrichment can also promote rapid growth of certain benthic species (e.g. macroalgae), and cause shifts in community composition (e.g. phase-shifts). Changes in the composition of benthic communities that can occur as a result of nutrient enrichment include shifts from coral to algal dominated habitats (e.g. Hughes *et al.* 2007), and shifts from seagrass to algal dominated habitats (e.g. Waycott *et al.* 2009). Nutrient enrichment usually occurs as a result of inappropriate disposal of un- or undertreated municipal wastewater near to urban areas, from nutrient-enriched surface run-off or return flows from agricultural areas where there is a high usage of fertilizers, or livestock, or from atmospheric sources. Wastewater containing high levels of inorganic nutrients (e.g. nitrogen and phosphate) or a high organic content (with high biological or chemical oxygen demand, BOD or COD) can also contribute towards eutrophication and the creation of 'dead zones'. Although such areas have not yet been reported in the WIO it is feasible that such areas could occur in the future with increased nutrient enriched run-off. Harmful or nuisance algal blooms which can, but not always, occur as a result of nutrient enrichment, can be problematic in some areas, but these are dealt with under a separate issue category in MAC02.

(b) Transboundary Scope

Eutrophication is a common problem in most WIO countries, albeit at a local level. Nutrient enrichment of the waters of the WIO occurs as a result of seasonal wind driven upwelling processes, but also as a result of anthropogenic point and non-point inputs from agricultural, municipal, industrial and other land-based and marine sources. While the oceanographic processes associated with natural upwelling systems have a major influence on the productivity within the region, enriched surface run-off and point sources, can also have a localised impact on the productivity of coastal waters, the status of marine habitats and associated living marine resources. This issue can therefore also be classed as a transboundary issue if the impacts are common between the countries.

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

All 9 of the countries identified the issue as being 'Relevant' although Mozambique considered the issue to be more of a future relevant issue due to concerns about the expansion of the sugar and bio-fuel sectors. Only 4 out of the 9 countries identified nutrient enrichment as being of 'High' importance, a further 2 countries ranked it as 'Medium' importance, and 3 ranked it as being of 'Low' importance. Only two countries assigned an above average score for the 'Overall rating' in the Level 2 prioritisation; one of which had identified the issue as being of 'Low' importance in the Level 1 prioritisation. It is likely that this issue will intensify in future, particularly with expansion of certain agricultural activities and population growth, unless the sectors that contribute to the problem take measures to address it. The Regional 'Overall rating' score was below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern at the present time.

(c) Risks/uncertainties and trends

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

(d) Stakeholder analysis

When a stakeholder matrix analysis of the five types of transboundary marine pollution problems is undertaken (Table 2-6), it becomes clear that the main sectors contributing to the problem are urbanisation, agriculture and industry. These all have broad, cross-cutting effects while aquaculture, tourism, mining, transportation and energy add further, specific types of pollution. The stakeholders most impacted are the local communities, as well as the fisheries and tourism sector; i.e. those commercial sectors linked directly to the use of coastal and marine resources. To a lesser degree, certain mining, industrial and transportation activities may be impacted.

Table 2-6 Analysis of sectors and stakeholder groups causing (C) transboundary marine pollution problems as well as those impacted (I) by pollution.

Sector	Stakeholder	Transboundary problem									
		Micro-biological contaminants		Eutrophication (nutrient enrichment)		Marine Litter (solid waste)		Suspended solids		Chemical pollution	
Fisheries and Aquaculture	Artisanal fishers				I				I		I
	Industrial fishers				I				I		I
	Seaweed farmers				I				I		I
	Industrial prawn farmers			C	I			C	I		I
	Fish and shellfish farmers		I	C	I			C	I		I
Agriculture and Forestry	Charcoal makers			C				C			
	Small-scale loggers			C				C			
	Industrial loggers			C				C			
	Small-scale farmers			C				C		C	
	Large-scale farmers			C				C		C	
	Pastoralists	C		C							
	Ranchers			C							
	Poultry farmers	C		C							
	Dairy farmers	C		C							
	Beekeepers										
Tourism	Tourists		I		I	C	I		I		I
	Hotel owners/operators		I	C	I	C	I		I		I
	Small-scale traders					C					
	Tourist boat/SCUBA operators		I		I	C	I		I		I
Mining	Coral/lime miners							C			
	Sand miners							C			
	Small-scale salt producers		I		I				I		I
	Industrial salt works		I		I				I		I
	Small-scale miners							C		C	

Sector	Stakeholder	Transboundary problem									
		Micro-biological contaminants		Eutrophication (nutrient enrichment)		Marine Litter (solid waste)		Suspended solids		Chemical pollution	
	Industrial mining companies							C		C	
	Fuel suppliers and stations									C	
	Oil and gas production									C	
Industry	Heavy manufacturing					C		C		C	
	Light manufacturing					C		C		C	
	Agro-processing industries	C		C			I		I		I
	Oil refining									C	
Transportation	Ports	C			I	C	I		I	C	
	Dredging companies							C		C	
	Clearing and forwarding										
	Railway										
	Roads (incl. traffic)									C	
	Airports										
	Airlines										
Shipping						I				C	
Energy production	Hydroelectric power generation										
	Power station operators										
	Renewable energy producers										
	Fossil fuel users			C				C		C	
Urbanisation	Solid waste operators	C		C		C		C		C	
	Sewage plants	C		C				C		C	
	Property developers	C	I	C	I		I		I		I
	Town planners										
	Coastal communities	C	I		I	C	I		I		I

1.4.2.7 Degradation of groundwater and surface water quality

(a) Problem Statement

The status of both surface and ground waters within the WIO region has declined over the years as a result of contamination arising from agriculture, municipal and industrial effluents and run-off, siltation and from saltwater intrusion (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). Saltwater intrusion into groundwater supplies is also a common concern among countries, and this affects the availability of potable freshwater as well as soils, with consequences for human health, agriculture and national economies. Contaminated ground and surface waters can also impact upon

coastal waters through surface run-off, especially during heavy rains, and groundwater seepage. The relative contribution of ground and surface waters is however seldom accounted for as it is more difficult to measure diffuse inputs than point sources (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). In the future, it is highly likely that domestic water use will need to increase substantially to meet growing demands and to help move people out of poverty (Hunter *et al.* 2010). Only 5 % of the arable land in Africa is irrigated (Siebert *et al.* 2010), and more water will also be needed to meet rising demands for food production (UNEP 2010, Pfister *et al.* 2011). As rainfall reliability and predictability declines with climate change (UNEP 2010, Pfister *et al.* 2011) demands on groundwater resources will likely increase (MacDonald *et al.* 2012).

(b) Transboundary Scope

Degradation of groundwater and surface water quality is a transboundary issue where there are shared catchments, aquifers or international rivers. Within the ASCLMEs, this is also a shared transboundary issue that is common to all of the countries. All countries considered the issue to be 'Relevant', and it was ranked as a 'High' priority by 6 of the 9 countries in the Level 1 prioritisation, and allocated an above average score by 5 of the 9 countries for the 'Overall rating'. It is likely that this issue will intensify in future, posing an even greater risk to society and the economy unless the sectors that contribute to the problem take measures to address it. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

Both Kenya and Tanzania reported that leachate and overflow from septic tanks, soak pits and pit latrines have contributed towards contamination of ground and surface water resources (ASCLME 2012b, c). Similarly in South Africa, overflows and leaks from the septic tanks used for sewage disposal in coastal holiday homes, may be causing groundwater contamination as well as nutrient enrichment of estuarine and inshore environments (ASCLME 2012e). Pollution of ground and surface water is a concern in Mauritius (ASCLME 2012h) and in Somalia, where most freshwater is obtained from boreholes or shallow wells (ASCLME 2012i). In Comoros, the entire rural population, more than two thirds of the population, relies on rain, surface and ground water supplies. In Grande Comore, the total absence of surface water means that potable water comes from groundwater and cisterns. Groundwater is however being affected by salt water intrusion and is at risk of pollution (ASCLME 2012a). In Seychelles, it is predicted that sea-level rise will result in saltwater intrusion in rivers, marshes and wetlands adversely affecting the habitats of certain species of fish (ASCLME 2012g). In Madagascar, salinisation of soils is already one of the main problems encountered (ASCLME 2012f). For Somalia, salinisation is a serious problem in the irrigated areas along the Jubba and Shabelle river valleys. Both rivers have high salt content even during periods of high flows (ASCLME 2012i), which limits the extent to which the waters can be used for irrigation.

1.4.2.8 Pollution of coastal waters due to oil spills associated with the drilling, transportation, processing and shipping activities.

(a) Problem Statement

Oil spills may occur as a result of drilling, exploration, transport, processing, storage and shipping. All countries in the region have downstream oil storage facilities, and some but not all have processing facilities. Oil experts are increasingly speculating that Africa's eastern coast could represent one of the few remaining major petroleum frontier regions in the world. Over the last few decades, seismic surveys have revealed natural gas deposits and signs of oil from Somalia to Mozambique, along a geological structure known as the Davie Fracture Zone (Herbert Burns 2012). Numerous international and national oil companies are increasing their upstream operations (seismic surveying and exploratory and wildcat drilling) off Kenya, Tanzania, Mozambique, and Madagascar (Herbert Burns 2012). Only a few have commenced extraction, therefore the most common current cause of spills at present is from transportation and shipping. Pollution from shipping can occur as a result of the release of oily bilge water and oil sludge from engine rooms, accidental oil spills from damaged tankers, and blasting and cleaning operations. All marine traffic calling at ports or in transit

within the region poses a risk of oil pollution resulting from collisions, groundings, oil cargo and bunker transfers, structural failure or any other number of maritime emergencies or accidents. The Mozambique Channel is a major route for large oil tankers, with an estimated 450 million tonnes of hydrocarbon products transported by large crude oil carriers every year. The risk of oil spills is therefore high, and there have already been a number of medium sized oil spills with serious impacts on biodiversity and critical habitats within the region. Offshore installations pose an additional newer risk, but no major spills have yet occurred from an offshore installation. New port developments, increased shipping traffic and an increase in oil operations in the region will increase the risk of oil spills in the future.

(b) Transboundary Scope

Oil spills in the marine environment can be carried long distances and have devastating impacts. While there has not yet been a major spill from exploration or extraction activities that has spread across international boundaries within the WIO region, there have been several serious oil spills associated with the transportation of oil along the major shipping routes in the region, so this is already a transboundary issue of concern. Given the expansion of industry in the region, more exploration and the new finds, as well as the development of new ports, this is also an emerging issue of growing concern. All countries recognised the issue as 'Relevant' so this is at present a shared transboundary issue. Furthermore 6 of the 9 countries ranked the issue as being of 'High' importance at the national level. Only 4 of the 9 countries allocated the issue an above average score for the 'Overall rating'. The Regional 'Overall rating' score was however marginally above average, indicating that the countries consider this to be a borderline priority transboundary issue of concern at this time.

1.4.3 Problem area 2: Physical alteration, destruction of habitats and community modification

1.4.3.1 Overview of the problem in the WIO

The WIO hosts a huge diversity and complex array of different coastal and marine habitats including some of the world's most important marine habitats (seagrass, coral reefs and mangroves), that are important not only for the biodiversity that they support, but also for carbon retention, food production and natural shoreline protection. In the WIO region, national and regional processes and assessments such as the African Process (GEF/MSP, 2001), Nairobi Convention (UNEP, 1998b), GIWA (UNEP, 2006) as well as the WWF's-Eastern African Marine Ecoregion (WWF, 2004) have identified the need to address the loss and transformation of habitats as a priority issue for all countries in the region. Such 'physical alteration and destruction of habitats' (PADH) manifests itself among others in the form of coastal erosion, removal of vegetation cover (coastal grasslands, forests, mangroves and seagrasses), coral reef degradation and the establishment of invasive species.

The main cause of PADH is directly related to human interventions and activities in the coastal zone. Land transformations for agriculture, urban development, as well as extensive deforestation in the WIO region river basins such as Athi-Sabaki, Tana, Rufiji, Pangani, Limpopo, Betsiboka, all contribute to PADH by altering river flows, water quality and sediment loads from river basins (Arthurton *et al.*, 2002, Kitheka, 2003)⁷. Coastal and marine habitats are under increasing pressure from the intensification of human activities in the coastal and marine environment. As coastal populations continue to grow, in part fuelled by rural poverty, and as people move to the coast to seek employment, these pressures will increase. Inadequately or completely unplanned coastal developments, destructive fishing techniques, and the expansion of the extractive industries will continue to contribute towards the degradation, disturbance, fragmentation, or complete removal of habitats. The loss of these natural habitats will affect the flora and fauna that depend on these for different ontogenetic life stages.

⁷ Impacts from river-coast interaction are discussed in detail in section 4.4 of this TDA.

Global climate change, itself attributable to human activities, is precipitating extreme hydrological droughts and flood events, sea level variability and coral bleaching further accentuating PADH. The cumulative impacts of these phenomena have seen significant physical alterations and modifications of ecological systems in the WIO region, leading to an overall decline in the productivity of many coastal and marine ecosystems, concurrently reducing their capability of providing expected ecosystem services.

The following five categories of PADH are discussed in this chapter: (1) Degradation of mangrove forests, (2) Degradation of seagrass beds, (3) Degradation of coastal forests, (4) Degradation of coral reefs and (5) Shoreline change.

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

The first phase of the GEF/MSP Sub Saharan Project, commonly referred to as the African Process (GEF/MSP, 2001), provided a consolidated analysis of the PADH hotspots in the region. In the context of this TDA, hotspots are broadly defined as coastal and marine areas threatened by human activities (WGIPA-I, 2000). PADH hotspots are located at sites with important human activities, such as estuaries, islands, harbours, bays and lagoons. These sites are threatened predominantly by pollution, over-exploitation of coastal-marine resources (e.g. mangroves and fisheries) and habitat modification. An overview of the specifics of hotspots of PADH in the WIO region is presented in Table 2-7.

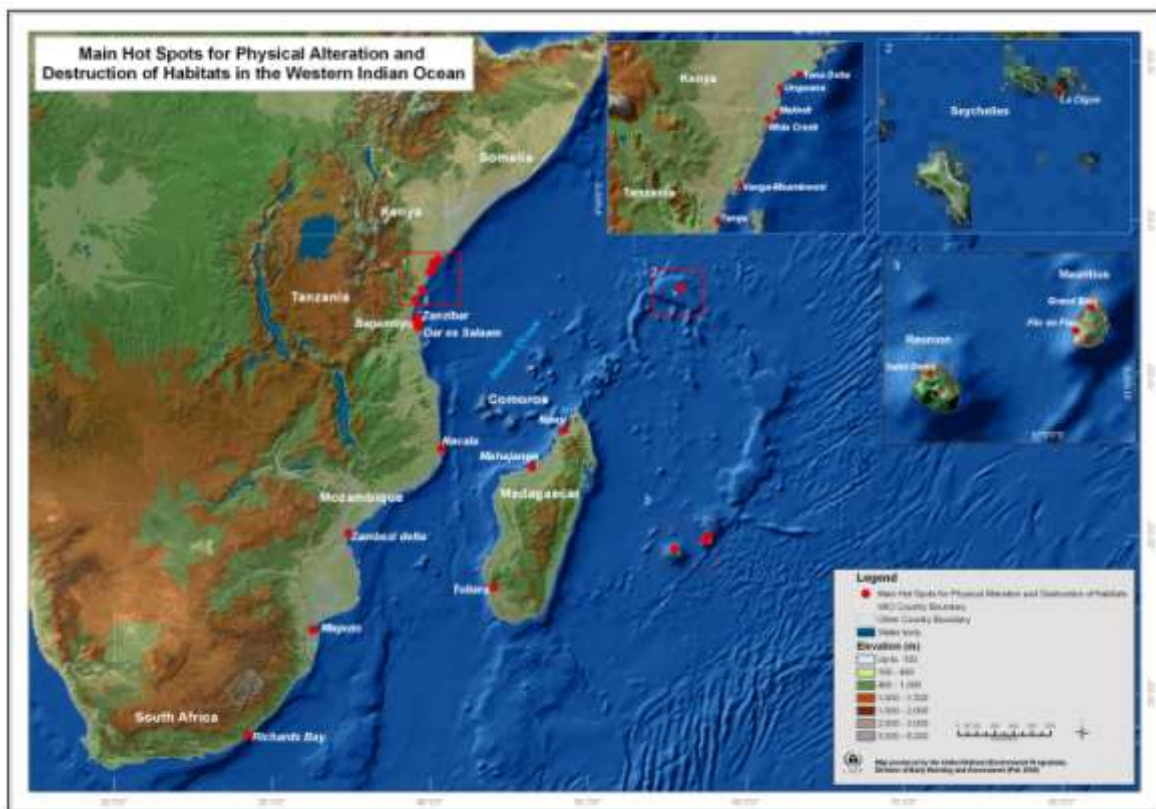


Figure 2-3 'Hotspots' of PADH in the WIO region

Table 2-7 Summary of typical PADH hotspots in WIO countries (modified from the African Process Reports: GEF/MSP, 2001).

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

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

1.4.3.2 Disturbance, damage and loss of upland watershed habitats (>10 m elevation)

(a) Problem Statement

The WIO region hosts a diversity of different coastal and watershed habitats, which support a range of different biodiversity. For these purposes, upland watershed habitats are those inland habitats, above 10 m elevation, whereas coastal habitats are those from high water mark to < 10 m. Disturbance to upland and watershed habitats occurs throughout the countries of the WIO region. The majority of people in the WIO region in the upper-reaches of the river basins are dependent on agriculture and forestry (UNEP/Nairobi Convention Secretariat and WIOMSA 2009). Intense or inappropriate

farming techniques, and poor land-use management practices, such as the removal of natural vegetation from watersheds, planting on steep slopes or deep drainage furrows, can destabilise soil structures, and result in the loss of top soil, which is then transported via watercourses or in surface run-off into the coastal and marine environment (UNEP/Nairobi Convention Secretariat and WIOMSA 2009). The degradation of upland and watershed habitats can impact shorelines through causing shifts in coastal sediment budgets, and result in siltation, changes in erosion and accretion patterns and coastal flooding. Marine water quality may decrease due to increased turbidity, and critical habitats may be impacted by increased sedimentation and nutrient enrichment, particularly during heavy rains or floods.

(b) Transboundary Scope

Eight of the 9 countries identified degradation of upland/ watershed habitats as 'Relevant', with the exception being Seychelles due to the majority of upland areas on these islands being protected as National Parks. Furthermore, 7 of the 9 countries ranked the issue as being of 'High' importance, with the exception of Mauritius. In the Level 2 prioritisation, 6 of the 9 countries assigned the issue an 'Overall rating' score that was above average at the national level. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern.

1.4.3.3 Degradation and loss of coastal forests and floodplain habitats

(a) Problem Statement

The coastal forests of mainland East African extend from southern Somalia to southern Mozambique and are recognised by WWF as a Global Ecoregion (WWF 2012) and by CI as a Biodiversity Hotspot (CI 2012), which also includes the islands off the coast of Tanzania. These forests occupy a relatively narrow coastal strip of about 40 km in width, except along the Tana River where it extends about 120 km inland; and from the coast to 500 m above sea level, although in Tanzania they occur up to 1,030 m, though this is unusual. The original area occupied by these forests was estimated to be 29,125,000 ha, but only 2,912,500 ha now remains. The climate is largely tropical, with high temperatures and high humidity, though some of the southern areas are almost subtropical. The forests are now composed of a large number of remnant forest and thicket patches, which are typically small and fragmented. Despite this, they still tend to support high levels of biodiversity and exceptionally high levels of endemism, often varying dramatically from one forest patch to the next. There are different types of closed canopy forests within the region including: dry forest, scrub forest, *Brachystegia* forest, riverine forest, groundwater forest, swamp forest, and coastal/afromontane transition forest. Endemism is particularly high within the remaining closed canopy forest patches. The forest patches are surrounded by coastal woodlands, wetlands, grasslands and farmlands that are much less biologically distinctive, but still support additional endemic species. Coastal forests provide a wide range of wood and non-wood products for local use, and support the livelihoods of an estimated 20 million people who live along the eastern African coast in Somalia, Kenya, Tanzania and Mozambique. The forests are increasingly threatened by expanding agriculture, fuelwood and charcoal production, uncontrolled fires, unsustainable logging and the expansion of settlements. Disturbance to coastal forests impacts on the marine environment through clearing of buffer vegetation in environmentally sensitive areas close to shorelines, resulting in increased erosion and sedimentation.

(b) Transboundary Scope

The coastal forests spanning the mainland east African coastline, even though fragmented, are transboundary in nature. Furthermore, 7 of the 9 countries, including some of the islands, identified this issue as 'Relevant' at the national level. This suggests that the issue is a shared transboundary issue. From the Level 1 Prioritisation, 5 of the 9 countries ranked the issues as being of 'High' importance at the national level. From the Level 2 Prioritisation, the 'Overall rating' scores for 6 of the 9 countries were above average. However the Regional 'Overall rating' score was not above average,

indicating that the countries do not presently consider this to be a high priority transboundary issue of concern.

1.4.3.4 Disturbance, damage and loss of coastal habitats (beaches, dunes, coastal vegetation and flood plain habitats to 10 m elevation)

(a) Problem Statement

Situated at the interface of land and sea, coastal habitats, such as beaches, dunes, and floodplains, provide a unique habitat that supports endangered species and communities of specially adapted flora and fauna, and a resource offering specific amenities and recreational opportunities. Coastal habitats act as a focal point for a wide range of activities, which can intensify the level of disturbance and impacts and lead to conflicts between resource users. Coastal habitats throughout the WIO region have been disturbed as a result of uncontrolled urban expansion, construction of roads and infrastructure, and tourism developments. These types of developments can degrade and fragment natural coastal landscapes and create noise and light pollution, threatening turtle populations, as has been observed in Kenya, Madagascar, Mozambique, Somalia, Tanzania and Mauritius. Disturbance of coastal areas may also have adverse impacts on seabirds and shorebirds utilizing the coastal environment. Coastal tourism, both within the region and globally, is strongly dependent upon the combination of natural (climate, landscape, ecosystems) and cultural (historic and cultural heritage, arts and crafts, traditions, etc.) resources. Certain areas are particularly well suited to specific types of tourism activities. The potential wealth that can be generated by the expansion of the tourism sector, through the development of big hotels with private beaches, can restrict access for local communities, with serious socio-economic consequences. Beaches which were traditionally used as landing sites for local fisher communities may no longer be accessible. Other activities such as sand mining are also problematic within the WIO region. Climate processes are another major factor controlling the status of coastal habitats, and wind and wave action may be exacerbated by global climate variability and change.

(b) Transboundary Scope

The mainland countries of East Africa have a contiguous coast lines and there is the potential for the loss and degradation of coastal habitats in one country to have impacts on those of another adjacent country, as a result of disturbance and fragmentation. The majority of countries however also identified concerns associated with the status of their coastal habitats suggesting that this is also a shared issue between mainland and island countries within the WIO. All 9 countries identified this issue as 'Relevant' and of 'High' priority in the Level 1 prioritisation. The 'Overall rating' from the Level 2 prioritisation, revealed that 7 of the 9 countries allocated above average scores. The Regional 'Overall rating' score was also above average, indicating that the countries do consider this to be a high priority transboundary issue of concern.

1.4.3.5 Disturbance, damage and loss of wetland habitats

(a) Problem Statement

Wetlands can be temporarily or permanently wet ecosystems dominated by emergent vegetation. The wetlands in the region can be broadly divided into two categories, seasonal and permanent, both of which form as a result of impeded drainage and are communities at the edge of dry lands and open water (Harper and Mavuti 1996). Coastal wetlands are impacted by human factors including alteration of river flows and land clearing and drainage for urban development as well as natural factors linked to climate change and natural variability. Disturbance of wetlands may have adverse impacts for shorebirds and migratory birds utilizing this habitat as an over-wintering ground.

(b) Transboundary Scope

There are several important wetlands in the WIO region which are important at the national level and internationally recognised (Directory of Wetlands of International Importance 2004). These habitats are under increasing pressure from coastal development activities, alteration in the quality, quantity

and timing of river flows and sediment inputs and climate change. Eight of the 9 ASCLME countries recognised wetlands as a 'Relevant' issue, and 5 of the 9 countries considered the issue to be of 'High' importance. Only 3 of the 9 countries gave the issue an above average score for the 'Overall rating'. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern.

1.4.3.6 Disturbance, damage and loss of estuarine habitats

(a) Problem Statement

An estuary is defined as 'a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land' (Pritchard 1967). There are several very large estuaries along the mainland coast of the region, notably in Tanzania (Rufiji) and Mozambique (Zambezi). Rainfall and river discharge in the northern parts of the WIO region (e.g. Somalia and Kenya) is typically lower than in the southern parts (e.g. Tanzania, Mozambique and South Africa) (UNEP/Nairobi Convention Secretariat and WIOMSA 2009). Consequently, the southern parts of the WIO region are characterized by the presence of large estuarine zones supporting extensive mangrove forests (UNEP/Nairobi Convention Secretariat and WIOMSA 2009). Disturbance of estuaries as a result of poor agricultural practices, deforestation, urban and industrial development, trawling, pollution and sand mining threatens coastal wildlife, especially shorebirds, and nursery habitats for commercially important species such as prawn, shrimp and fish and may also lead to coastal flooding.

(b) Transboundary Scope

The Ruvuma Estuary is situated on the border between Tanzania and Mozambique and this estuary is a transboundary concern, shared between these countries. The Ruvuma and other estuaries within the WIO region are also a shared transboundary concern due to the fact that they support critical habitats such as mangroves (e.g. Zambezi), endangered species (e.g. turtles), and provide an important habitats for commercially important species (e.g. prawn and fish). Degradation of estuarine habitats was however only recognised as 'Relevant' by 6 of the 9 countries. Only 4 of those considered the issue to be of 'High' importance. Furthermore, only one country (South Africa) allocated the issue an above average score for the 'Overall rating'. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern at this time.

In Mozambique, the estuaries of big rivers such as the Zambezi, Púnguè, Buzi and Save, provide important habitat for mangroves. The Zambezi delta mangroves, for example, extend 50 km inland. These areas are also important fishing grounds, where small pelagic and demersal fish and crustaceans of estuarine waters are dominant. The semi-industrial prawn fishing areas are located along the navigation channels of Maputo Bay and in the estuaries of the Maputo and Nkomati rivers (at depths between 10 and 20 m) (ASCLME 2012d). The Ruvuma Estuary is situated on the Tanzania-Mozambique border, between the coastal provinces of Mtwara Region and Cabo Delgado, and covers approximately 15 % of the 200 km coastline (UNEP/Nairobi Convention Secretariat and WIOMSA 2009, van der Elst *et al.* 2012). While the beaches are otherwise mainly sand, the estuary is muddy tropical area, which is suitable for mangrove growth. In the Mozambican side of the Ruvuma estuary there is a protected area in form of marine parks, the Quirimba National Park. Environmental problems in the Ruvuma basin are related to natural (flooding) and agricultural factors (UNEP/Nairobi Convention Secretariat and WIOMSA 2009).

There are important estuarine ecosystems further north as well. In Somalia, for example, where the Shabelle and Jumba rivers meet there is a floodplain, after which they cross marshy land and drain into a mangrove fringed estuary (Hughes and Hughes 1992). The Shebelle river mouth is one of the priority seascapes mentioned in the Eastern Africa Marine Ecoregion (WWF EAME 2004). The area has been proposed for protection as it is the most northern estuary in eastern Africa, the largest estuarine-offshore 'mud ecosystem' and the only permanent estuarine system in Somalia.

Estuaries and mouths of major rivers often exhibit some of the most dramatic examples of shoreline change due to sedimentation. The Sabaki estuary is one of Kenya's main drainage areas and is characterized by heavy sediment deposition and transport (Kitheka *et al.* 2004). The estuary, including the congruent coast of Malindi Bay, has experienced heavy sedimentation in the recent past, and the deposition of dark brown clay forms mudflats (UNEP/Nairobi Convention Secretariat and WIOMSA 2009). In the Bay of Betsiboka in Madagascar, the estuary has serious sedimentation problems (ASCLME 2012f). The river carries huge quantities of silt which is deposited in large quantities at the bay. In the Southwest, the same heavy sedimentation occurs at the mouth of the river Fiherenana, resulting in smothering of reef flats and mangrove forests (Bemiasa 2009). Gill nets and fish barriers are used across rivers and estuaries (ASCLME 2012f).

Estuaries are often centres for development. In Tanzania, increased economic activities and expanding populations in the growing coastal towns have resulted in production of large amounts of waste water and industrial effluent, which are directly released in the nearby estuaries (ASCLME 2012c). In Mozambique, due to the low lying coastal plain, most of the ports (with exceptions of Pemba and Nacala) have been developed in shallow bays and estuaries and this poses a problem for handling large modern ocean-going vessels. The high costs of maintenance dredging are constraints in port development. There is a gap in the understanding of the coupled river basin and coastal systems, including the main drivers of ecological, hydrodynamics and morphodynamic changes in the estuaries (and coastal waters) and a gap in knowledge on the influence of nutrients inputs through rivers and rainfall in the biogeochemical processes in estuaries (and coastal waters). Sea level rise could cause flooding of estuaries, placing coastal cities at risk (e.g. ASCLME 2012i).

1.4.3.7 Degradation and loss of mangrove forest habitats

(a) Problem statement

Mangrove forests are found in the inter-tidal zone, from mean sea level to highest spring tide, in the tropical and subtropical coastal regions of the WIO region, where they survive harsh environmental conditions (high salinity, high temperature, extreme tides, high sedimentation and muddy anaerobic soils). Their global distribution is believed to be delimited by major ocean currents and the 20° C isotherm of seawater in winter (Alongi 2009). The WIO region supports an estimated 790,000 ha of mangroves, which is equivalent to 5 % of the world's total estimated area coverage (13,776,000 ha in 118 countries) (Giri *et al.* 2011). This is however already less than half of what it once was (Spalding *et al.* 1997, Spiers 1999). Globally, only 15 countries host approximately 75 % of world's remaining mangroves, two of which are within the region (Madagascar and Mozambique).

Mangrove forests in this region typically form narrow fringing communities along the shores or small patches in estuaries, along seasonal creeks or in lagoons. The trees do not usually grow to more than 10 m in height, with a minimum height of 1–2 m in South Africa. Madagascar (especially the northwest region), Mozambique and Tanzania represent the few exceptions. The extensive deltas and estuaries found in these countries allow for the development of well extended communities, with tree heights reaching 25–30 m. The Messalo and Zambezi river deltas (Mozambique) are home to some of the most extensive mangrove forests in the region.

There are 14 true mangrove species known to occur in the region, which is higher than the 7 species found in West Africa. The highest species richness is found in Mozambique (10 species), Kenya (9 species) and Seychelles (9 species), and the lowest species richness is in Mauritius (2 species). A few species, such as *Avicennia marina* and *Rhizophora mucronata*, are wide-spread, whereas other species grow only in one or a few countries, for example *Bruguiera cylindrica* (found in Mozambique) and *Ceriops somalensis* (endemic to Somalia). The mangroves present are a subset of the species found in the West Pacific region, isolated by the expanse of the Indian Ocean and the arid coastlines of the Middle East. They may thus represent a distinct sub-region of the Indo-West Pacific mangrove fauna and flora. Only 6.9 % of mangroves are protected under the existing protected areas network (IUCN I-IV) (Giri *et al.* 2011).

Mangrove forests are among the most productive and biologically important ecosystems in the world and they provide important and unique ecosystem goods and services. The forests help stabilize shorelines and reduce the impact of natural disasters (e.g. tsunamis and cyclones). They provide breeding, spawning and nursery grounds for marine species, and food, medicine, fuel and building materials for local communities. Mangroves, and associated soils, are thought to sequester approximately 22.8 million metric tons of carbon each year. Covering only 0.1 % of the earth's continental surface, these forests account for 11 % of the total input of terrestrial carbon into the ocean (Jennerjahn and Ittekkot 2002) and 10 % of the terrestrial dissolved organic carbon (DOC) exported to the ocean (Dittmar *et al.* 2006).

Mangrove wetlands are multiple-use systems that provide protective, productive and economic benefits to coastal communities. The forest provides timber and non timber products such as fuelwood, poles, fodder and fisheries resources to millions of people in the tropics, including the WIO region (Saenger, 2002). They buffer land from storms and provide safe havens for humans (Spalding *et al.*, 1997). Mangroves have the capacity to absorb heavy metals and other pollutants, thus controlling the quality of water reaching coral reef and seagrass ecosystems (Larcenda *et al.*, 1997). In addition, mangrove forests provide nursery grounds for a number of commercially important fish species, prawn, crabs and other animals, and enhance fishery productivity of the nearby waters (Kathiresan and Bingham, 2001). As a dynamic zone between land and the sea, mangrove wetlands are controlled by several interacting factors such as tides, periodicity of freshwater and sediment influx, topography, soil and water salinity, temperature and sedimentation patterns. These factors are closely related to land and water use practices in the areas adjacent to and upstream of the mangrove forests. In some instances, human-induced stresses on mangrove forests range from diversion of freshwater, poor land-use in and around the forests to over-exploitation of the mangrove resources. These stresses disrupt the natural equilibrium, ultimately leading to the degradation of the mangrove wetlands which in turn not only depletes the resources within their boundaries, but also affect the productivity of the adjacent coastal and marine ecosystems.

Mangrove forests of the WIO have been heavily impacted by human activities including over-harvesting for firewood, timber and charcoal; clearing for agriculture, aquaculture, urban development, tourism, and salt and lime production; pollution; changes in river flow rates and sedimentation. Relative sea-level rise could be the greatest threat to mangroves (Gilman *et al.* 2008). Predictions suggest that 30–40 % of coastal wetlands (IPCC 2007) and 100 % of mangrove forests (Duke *et al.* 2007) could be lost in the next 100 years if the present rate of loss continues. As a consequence, important ecosystem goods and services (e.g. natural barrier, carbon sequestration, biodiversity) provided by mangrove forests will be diminished or lost (Duke *et al.* 2007).

(b) Transboundary Scope

Mangroves in the WIO countries constitute about 5% of the current global area of mangroves (see section 2.2.3). A number of these mangrove stands or their catchments are shared by several countries in the region, as are mangrove goods and services by communities adjacent to the forests (Semesi, 1998). Besides the common uses for firewood, charcoal and building materials, herbal medicine and traditional lime making are common practices in coastal communities throughout the region. Key transboundary elements as far as mangrove forests are concerned are related to the fact that mangroves provide important nursery or feeding grounds that are vital for several marine fishery resources of the entire WIO region. Pressures on mangroves throughout the WIO countries are similar and are mostly human-induced. The area of mangrove in the WIO region that has been lost over the last century is estimated to exceed 50% of the current area (FAO, 2005c). Direct causes of mangrove degradation include tree felling for firewood and building materials, clearance of mangrove areas for aquaculture and solar salt works, urban development, and human settlement. Other causes include reduction in freshwater flow (both surface and groundwater) and heavy or increased sedimentation and pollution. The impacts of mangrove degradation are difficult to quantify for the region and more thorough analyses should consider the rate of loss brought about by each cause.

Mangroves occur along almost the entire coast of Mozambique mostly in sheltered shorelines and estuaries, covering an estimated 396,080 ha (Barbosa *et al.* 2001) to 390,200 ha (FAO 2007), which is the largest area coverage for all the countries in the region. Mozambique also hosts the highest species richness, with a total 10 species of mangrove, including *Bruguiera cylindrica*, which is only found in Mozambique. Mangroves are being depleted at a rate of 4 % (ASCLME 2012d), although the rate of depletion is lower in the north around the Quirimbas archipelago. The central sector, has the most extensive and well established mangroves, this zone is one of the largest extents of mangrove forests in Africa representing close to 50 % of Mozambique mangroves (Barbosa *et al.* 2001).

Mangrove coverage in Madagascar is the second highest after Mozambique: estimates range from 278,078 ha (Giri *et al.* 2011) to 300,000 to 400,000 ha (FAO 2007, Mozambique MEDA 2007). There are reportedly 8 (9) species found including: *Acrostichum aureum*, *Avicennia marina*, *Ceriops tagal*, *Heritiera littoralis*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Sonneratia alba* and *Xylocarpus granatum* (and possibly *Bruguiera gymnorrhiza*) (FAO 2007). Mangrove resources were traditionally used for house and boat construction, in traditional medicine against stomach ulcers, for the collection of crabs and fish and for firewood. Shrimp aquaculture in mangrove areas is being encouraged in certain areas. Increased sediment loads, due to deforestation upland and changes in rainfall patterns is resulting in hyper sedimentation and smothering of mangroves. Sedimentation at the mouth of the river Fiherenana, for example, is silting the nearby mangroves. Overharvesting of the mangrove crab *Scylla serrata*, is common in the mangrove areas near coastal cities, while more remote areas still support fishable stocks.

Mangrove forests in Kenya are estimated to cover 50,000 ha (FAO 2007) with nine mangrove species that include *Rhizophora mucronata* and *Ceriops tagal* which are the dominant species represented in almost all mangrove formations (ASCLME 2012b). The rare species include *Heritiera littoralis* and *Xylocarpus moluccensis*. Mangroves have been impacted by human activities particularly through removal of wood products, conversion to other uses and pollution. Recent estimates suggest a 20 % decline in mangrove cover over the last two decades (ASCLME 2012b), although this is higher than the 10 % estimated loss from FAO (2007). Reduction in river flow has increased erosion of the delta mouth, and through increased salt-water intrusion, lead to a reduction of downstream habitats for mangroves and other species. Conversion of mangrove areas has also contributed to mangrove degradation in Kenya, for example more than 5000 ha of mangroves at Ungwana Bay have been cleared to pave way for solar salt works and aquaculture (Abuodha and Kairo 2001).

In Tanzania, mangroves are found in various locations, covering an estimated 127,200 ha, the third largest coverage within the WIO. The Rufiji delta is home to the largest estuarine mangrove forest in East Africa, with an estimated surface area of 53,200 ha it constitutes approximately 46 % of total mangrove forest cover in Tanzania (ASCLME 2012c). The estuary serves as a nursery ground for shrimps, supporting a commercially important fishing industry around 80 % of Tanzania's prawn catch comes from the Rufiji delta and the area to its north (Mwalyosi 2004). In the Comoros, mangroves cover an estimated 115 to 117 ha (FAO 2007), with more significant coverage on Mohéli (91 ha), and less on Grande Comoro (18 ha) and Anjouan (8 ha) (ASCLME 2012a). There are 5 mangrove species known to occur, the most common of which are: *Sonneratia alba*, *Avicennia marina* and *Rhizophora mucronata*. The forests are mostly situated on the south side of the islands, due to exposure patterns and rainfall distribution. At the water's edge other species such as: *Pandanus sp.*, *Hibiscus tillaceus*, *Ipomea pescaprae*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, *Avicennia sp.* and *Lumnitzera sp.*

The major transboundary issues associated with mangrove degradation that affects the entire WIO region is the loss of cover, resulting in a decrease and/or loss of biodiversity, decreased fisheries productivity, shortage of firewood and building materials, and increased coastal erosion (Semesi, 1998; FAO, 2005c). These ultimately lead to loss of livelihood and increased poverty among the coastal population. In this TDA, the quality of information to support the transboundary nature of the problems are assessed in the light of data provided by the national PADH reports of the participating countries, as well as data accessed during the preparation of this analysis. None of these issues have

been well documented across the countries in the region, thereby identifying a major research or knowledge deficiency.

Illegal trade of mangrove wood products across the borders, such as between Somali and Kenya, and Kenya and Tanzania is a major transboundary concern. Apart from depleting wood resources at the Kenya-Tanzania border, over-exploitation of the Tanga-Vanga transboundary mangroves has triggered coastal erosion and sediment transport with a negative effect on fisheries in the area (Semesi *et al.*, 1999). Cross-border mangrove sites have been ranked as being of regional importance due to the unique flora and fauna they support. For example the Tanga-Vanga seascape contains some of the tallest mangroves in the region at Challe Island (Kenya) measuring up to 34 m (WWF, 2004). Mangrove forests are present throughout the region, and some of the forests are in fact transboundary in that they are continuous between the countries. The types of impacts on these critical habitats are similar between the countries. All 9 of the countries considered the issue as 'Relevant' and 6 of the 9 countries considered it an issue of 'High' importance. The 'Overall rating' was above average for 8 of the 9 countries. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern.

Table 2-8 Loss of coverage of mangrove areas in the WIO region (1980 – 2005).

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

Source: FAO, (2007)

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

The growth of coastal towns and cities has greatly contributed to loss of mangrove forests in the region, through clearing for development and pollution. At least four major cities on mainland Africa, namely Mombasa, Dar es Salaam, Beira and Maputo, are located in the vicinity of mangrove forests. Between 1972 and 1990, the cover of peri-urban mangroves of Maputo decreased by 15.2 % (Saket

and Matusse, 1994) and between 1991 and 2003, the loss of mangrove cover in Maputo exceeded 17%. Similar problems have been reported for Mombasa (Abuodha and Kairo, 2001); Beira (Hoguane, *et al.*, 2002) and Dar es Salaam (Semesi, 1991; Wang *et al.*, 2003).

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

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

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

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

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

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

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

(c) Risks, uncertainties and trends

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

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

1.4.3.8 Degradation and loss of Seagrass habitats

(a) Problem statement

Seagrasses are marine angiosperms, widely distributed in both tropical and temperate coastal waters, creating one of the most productive aquatic ecosystems on earth. Thirteen species of seagrass have been reported from the WIO region (Philips and Mendez 1988). Seagrass beds may be found intertidally as well as subtidally, to depths of 40 m, and often in close connection to coral reefs and mangroves (Philips and Mendez 1988). Seagrass habitats are an important functional component of coastal ecosystems. Due to the complex architecture of the leaf canopy and the dense network of rhizomes, seagrass beds stabilize sediment and serve as hydrodynamic barriers reducing wave energy, thereby reducing turbidity and coastal erosion (Gullstöm *et al.*, 2002). More recent research has shown that seagrasses also help to alter the carbonate chemistry and acidity of seawater, which may be important under future climate change scenarios (Unsworth *et al.*, 2012). Due to the high primary production and complex habitat structure, seagrass beds support a variety of benthic, demersal and pelagic organisms. Many fish and shellfish species, including those of commercial interest, are attracted to seagrass habitats for foraging and shelter, especially during their juvenile life stages. Consequently, seagrass ecosystems in the WIO are valuable resources for fisheries at both local and regional scales (Gullstöm *et al.*, 2002). Seagrass degradation occurs throughout the WIO as a result of: physical dragging of fishing nets, trampling and anchoring of boats, pollution, and increased sedimentation from river systems. Seagrass beds are also threatened by changing shoreline dynamics involving sand deposition and removal. The degradation and loss of seagrass habitats results in a loss of habitat for focal species such as dugongs and a reduction in coastal fisheries production.

Seagrass degradation in the WIO is generally evidenced by destruction and/or reduction of seagrass as a result of physical-mechanical action (Ochieng and Erfermeyer, 2003). Typically this includes clearance of seagrass beds by hotel operators (Daby, 2003), people trampling and uprooting seagrass for clam collection (Balidy, 2003; Bandeira and Gell, 2003) and destructive fisheries practices, for example the use of drag nets (de la Torre-Castro and Rönnback, 2004; Mangi and Roberts, 2007).

Unregulated coastal development, as well as dredging and land reclamation also impact on seagrass beds. All are common practice in the region. Another direct cause of seagrass degradation is increasing pollution that reduces water quality, which negatively affects seagrass ecophysiology. Pollution from industrial activities has been documented in Mauritian coastal waters where reduction in seagrass habitat in port and jetty areas is also a common consequence of water quality degradation (Ramessur *et al.*, 1998). For example, at Inhaca Island (Mozambique), a seagrass community dominated by *Zostera capensis* was effectively destroyed in an area known to have heavy boat use (Bandeira, 2002). Climate change, through increased discharge of sediment-laden low salinity water derived from flooded river systems also could potentially affect seagrass beds (Short and Neckles, 1999; Bandeira and Gell, 2003). The degradation of seagrass beds has a negative impact on the ecosystem's productivity and potentially has negative environmental and socio-economic impacts across the WIO region. Common socio-economic consequences include reduction in fishing areas and fisheries productivity with a concomitant reduction in revenue from fisheries, thus impacting on food security (Short and Neckles, 1999). Ultimately the degradation leads to a potential change loss of livelihoods and increased poverty among the coastal populations.

(b) Transboundary Scope

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

In Kenya, seagrass beds cover a surface area of about 3360 ha, with the most important sites in the region between Lamu and Kiunga, Malindi, Mombasa, Gazi Bay (800 ha), and Mida Creek and Diane- Chale lagoon (450 ha) (Dahdouh-Guebas *et al.* 1999, Ochieng and Erftemeijer 2003). Twelve species of seagrass are found, with the most common being *Thalassodendron ciliatum*, *Halodule wrightii* and *Halophila minor* (Obura 2001, Gullstöm *et al.* 2002). There has been significant loss of seagrass along the coast, due to increased smothering as a result of increased sediment loading of rivers. Another cause of seagrass loss is the increase in sea urchin populations. In Diane-Chale lagoon for instance, preliminary studies indicate that *T. ciliatum* beds experienced a loss of more than 50 % of cover. These degraded sites were also found to have a density of the sea urchin *Tripneustes gratilla* of more 37 individuals/m², while healthy sites had a density of 4 individuals/m² (Uku 2006). Increased discharge of sediment loads in Malindi Bay affected the coral reefs in the Malindi National Park and Reserve (McClanahan and Obura 1997) resulted in a decrease in the number of seagrass species, from four to two species (Wakibia 1995).

Seagrass beds cover an estimated surface area of 55 ha and 649 ha respectively on Mauritius and Rodrigues (Turner and Klaus 2005). The most abundant species in Mauritian lagoons is *Syringodium isoetifolium*, with other species present being *Thalassodendron ciliatum*, *Halophila ovalis*, *H. stipulacea*, *Halodule uninervis* and *Cymodocea serrulata* (Montaggioni and Faure 1980, Database of Marine Organisms of Mauritius 2007). Seagrass beds are found both as extensive beds of mixed species and monospecific stands constituting natural habitats for a diverse group of organisms in these lagoons. The Saya de Malha bank also supports extensive stands of seagrass. Species which depend on seagrass, such as dugongs which were once common in the lagoons, are now extinct.

Sedimentation and degradation of seagrass beds due to farming practices and deforestation is also common in Mozambique. Likewise, in Tanzania, excessive sedimentation increasing turbidity and reducing light penetration threatens seagrass habitats (Wells *et al.* 2004). Dugong populations in Mozambique are found in areas with mixed seagrass species in intertidal regions and subtidal seagrass

species dominated by broad-leafed species such as *Thalassodendron ciliatum* (see Bandeira and Gell 2003).

In Tanzania, major seagrass beds are found around Pemba, Unguja and Mafia Islands (Ochieng and Erfemeijer 2001). One of the best described is in Chwaka Bay, Unguja Island, Zanzibar (Gullström *et al.* 2006). Seagrasses can be found throughout the bay, but there are two types of shallow seagrass bed those situated in the embayment, away from the coral reefs, near mangroves and mud flats, and those situated on the shallow continental shelf adjacent to coral reefs and far from mangroves and mud flats (Dorenbosch *et al.* 2005). There are 11 species and the dominants include *T. hemprichii*, *E. accoroides* and *T. ciliatum* (de la Torre e Castro and Ronnback 2004, Eklof *et al.* 2005). Since 1990s, the island has become an important site for seaweed farming, which is reportedly negatively affecting seagrass beds (de la Torre e Castro and Ronnback 2004, Eklof *et al.* 2005).

(c) Risks, uncertainties and trends

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

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

Habitat destruction – The degree to which over-harvesting affects habitats through impacts on dominant invertebrate species is unknown and baseline data are lacking.

Level of seagrass degradation - Precise data on regional distribution and degradation of seagrass beds and their species composition within the WIO are scarce.

Future trends - Seagrasses are fast-growing plants that can rapidly replenish denuded seabed areas, provided the physical damage to the habitat is minor or reversible. Future scenarios could include (i) natural recovery of seagrasses occurring in areas where water quality is maintained despite physical alteration of the habitat; (ii) the continuous depletion of seagrass beds in areas of intense impact (e.g. collection of invertebrates or intense tourism that leads to clearing of beaches) and (iii) seagrass rehabilitation in areas where intense habitat destruction has been alleviated and re-colonisation is assisted by propagation.

1.4.3.9 Degradation and loss of Coral Reef habitats

(a) Problem Statement

Coral reefs are among the most biologically rich and productive ecosystems on earth. They also provide valuable ecosystem benefits to millions of coastal people. In the wider Indian Ocean, more than 65 million people reside in the direct vicinity of coral reefs (within 30 km of reefs), which provide them with jobs, livelihoods, food, shelter and protection (Burke *et al.* 2011). The WIO region contains approximately 4.5 % of the world's coral reef area (Spalding *et al.* 2001). The majority of the East coast of Africa is edged by well-developed fringing reefs that occur along the fairly narrow continental shelf of Somalia, Kenya, Tanzania, and Mozambique and around the offshore islands between latitudes 5°N and 15°S. Breaks in the reef occur where there are major rivers or estuaries. The volcanic islands of Comoros, Mauritius, Rodrigues and Réunion show classic reef development with limited fringing reefs on the most recent islands, but wide fringing and barrier reef development on the older ones (Turner and Klaus 2005). Madagascar has some discontinuous fringing reef development as well as more complex systems of offshore reefs and a well developed barrier reef system off its west coast. The granitic islands of Seychelles are surrounded by discontinuous fringing reefs whilst the reefs in the outer islands include true atolls, raised atolls, submerged or partially submerged atolls and platform or bank structures (Spalding *et al.* 2001). The reefs of the region have high levels of species diversity with coral species richness ranging from 297 (Nacala, Mozambique) to 174 (Farquhar, Seychelles) (Obura 2012). The northern Mozambique Channel had the highest diversity and similarity, forming a core region defined by its unique oceanography of characterised by

mesoscale eddies that confer high connectivity within this region (Obura 2012). The mainland and island fauna are not distinct but there is a gradual decline in species richness which radiates outwards from the northern Mozambique Channel.

Coral reefs are facing multiple threats from many directions. It has been suggested that more than 60 % of the world's reefs are under immediate and direct threat from one or more local sources and approximately 75 % of the world's coral reefs have been rated as threatened when local threats are combined with thermal stress (Burke *et al.* 2011). Within the WIO, coral reefs and coral dominated habitats are threatened by a combination of coastal development, unsustainable and destructive fishing practices, sedimentation, coral harvesting, pollution, corallivores (e.g. crown-of-thorns, *Acanthaster planci* and the gastropod mollusc, *Drupella* sp.), coral bleaching and other climate related impacts leading to loss of biodiversity and a decline in reef fish populations.

Coral bleaching devastated many of the coral habitats in the WIO during the 1997–1998 coral bleaching event. The increase in emissions of carbon dioxide into the atmosphere is expected to result in increased dissolved CO₂ concentration in ocean water causing a decrease in pH value of the sea water, known as ocean acidification. Under the current forecast of CO₂ levels in the atmosphere, in 2100, the growth rate of scleractinian corals will be significantly compromised (Kleypas *et al.* 2006). The importance of these potential effects is unknown, but the hypothesis is that the acidification will contribute to the decline of coral reefs and other species with carbonate skeletons or shells.

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

(b) Transboundary scope

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

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

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

Coral reefs and coral communities create a highly productive habitat, and the majority of coastal communities in the region depend in part or wholly upon the ecosystem services that these habitats provide. While the fringing reef edging the mainland coast is a near continuous structure, and therefore transboundary, the issue is also a shared concern between the countries in the region. All 9 countries identified coral reefs as 'Relevant' and 8 of the 9 countries ranked the issues as being of 'High' importance, with the exception being South Africa. In the Level 2 prioritisation, 8 of the countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

1.4.3.10 *Degradation and loss of Coastal Forests*

(a) Problem Statement

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

(b) Transboundary Scope

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

(c) Risks, uncertainties and trends

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

Habitat destruction, biodiversity change and impacts on marine habitats - The lack of good baseline data makes it difficult to assess real changes in biodiversity and impacts on marine life due to coastal forest degradation.

Governance issues – Uncertainty surrounds the responsibility for maintenance of the current levels of pristine coastal forests in the WIO region.

Extent of coastal forests - The precise area of coastal forest in each country remains to be determined. A standardized assessment across the WIO region is needed to develop an agreed baseline assessment. The potential for rehabilitating coastal forests and grasslands needs to be evaluated.

Relationship to coastal ecosystems - The importance of coastal forests to other ecosystems, especially coastal and marine systems remains to be better understood.

Economic value - The economic value of coastal forest goods and services have not been clearly established.

Uncertainties in trends - Coastal forest encroachment as a result of the development of settlements and tourism is already an ongoing process. Further reduction of coastal forests is foreseen over the next 20-50 years.

1.4.3.11 Disturbance, damage and loss of macroalgal habitats

(a) Problem Statement

There are over 3,355 species of algae recorded from the Indian Ocean (Silva *et al.* 1996), and more recent species additions have been described by Coppejans *et al.* (2000, 2001). Macroalgal communities are an important and often overlooked functional component of nearshore shallow water tropical marine communities. Together with seagrass beds, macroalgae are one of the most important primary producers, and they form the basis of many foodwebs, providing a food source for a variety of other organisms. Macroalgae can occur in a wide variety of different habitats, in estuaries, on rocky shorelines, coral reefs, mangrove forests, soft sediments or in seagrass beds. Most algae are known to exhibit a distinct preference for a given suite of environmental parameters, and there are species that can be used as indicators of environmental conditions. Some species are known to respond rapidly to nutrient inputs, and can be used as an indicator of pollution. Calcareous species, such as *Halimeda*, are composed of calcified segments which contribute towards sediment processes and the presence or absence or condition of these species may provide an early indication of ocean acidification. Other species such as the corallinaceae species, often found on reef flats, provide more structural function, as they bind together loose rubble and sediments helping to stabilise reef flats and reef slopes. Other species such as *Euchema* and *Gracillaria* have become an increasingly important economically due to the chemical compounds that they contain, and such species are now being farmed in several countries in the region. Impacts on macroalgal habitats in the region are generally overlooked, but may include smothering of algal communities as a result of siltation, exploitation of *Euchema*, introduction of exotic algal species and the proliferation of macroalgae as a result of nutrient enrichment.

(b) Transboundary Scope

Macroalgae can form highly productive and diverse communities, many species are integral to coral reef ecosystems, and some species can be used as indication of pollution and of ecological phase shifts. Only 6 of the 9 countries identified issues related to macroalgal habitats as 'Relevant', none of the countries identified this issue as being of 'High' importance and only 5 of the 9 countries ranked the issues as being of 'Medium' importance. In the Level 2 prioritisation, only 2 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern.

1.4.3.12 Disturbance, damage and loss of soft sediment habitats

(a) Problem Statement

Information on the distribution, composition and morphology of soft sediment habitats, and the fauna that they support, is generally limited within the WIO region. These types of habitats often harbour rich and highly productive infaunal macrobenthic communities, which may include a wide range of worms, small crustaceans and mollusc species, which in turn support commercially important fish and invertebrate species (Mackay 2012). Soft sediment habitats and their associated macrobenthos communities are vulnerable to physical disturbances as a result of fishing activities such as beach seining, and trawling, sand mining, dredging, land reclamation and chemical pollution (Mackay 2012). These types of disturbance events can eliminate certain species, whilst other more tolerant

species may remain, resulting in a change in the community composition (Mackay 2012). Activities such as trawling and dredging also re-mobilise sediments creating sediment plumes. Studies elsewhere have shown that trawl sediment clouds can contribute to the total suspended sediment load and may be the primary source of suspended sediments (Churchill 1989, Jones 1992), with consequences for photosynthetic and filter feeding organisms.

(b) Transboundary Scope

Knowledge about soft sediment habitats and the diversity and composition of the resident fauna within the WIO region is limited (van der Elst 2012). The physical impacts of trawling and dredging on these types of habitats are well known from other regions (Mackay 2012). Eight of the 9 countries identified disturbances to soft sediment habitats as a 'Relevant' issue but only 3 of the 9 countries ranked the issues as being of 'High' importance, while a further 4 countries ranked the issue as being of 'Medium' importance. In the Level 2 prioritisation, only 3 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern.

1.4.3.13 Disturbance, damage and loss of deep water habitats (including sea mounts)

(a) Problem Statement

Deepwater habitats such as reefs, banks, abyssal plains, canyons and seamounts can support rich benthic communities, including deepwater corals and sponges, populations of commercially important fish and invertebrate species, endemics and threatened species (Clark *et al.* 2006, 2009, Rogers *et al.* 2009). Seamounts in particular are known to attract an abundance of marine life and provide important habitats for commercially valuable species that may aggregate to feed or spawn (Clark *et al.* 2006). Some examples in the Indian Ocean include Walters Shoal, which is located near the southern end of the Madagascar Ridge, and consists of a large number of knolls, seamounts and ridges and faults (Shotton 2006), Atlantis Bank (a Benthic Protected Area or BPA), Sapmer Seamount, Middle of What Seamount, Melville Bank and Coral Seamount (BPA) (Rogers *et al.* 2009). At Walter Shoal, the shallow areas of the seamount reach 10-12 m below the surface and support high biodiversity. The seamounts of the Agulhas Plateau are also reported to support coral stands, and extensive deep-water coral beds occur on some of the seamounts to 160 m below the surface.

Deep water habitats are vulnerable to impacts by deepwater trawling, mining, oil and gas exploration and extraction, bio-prospecting, disposal of solid and liquid wastes, disposal of animal carcasses and offal (from international shipments of livestock), dumping ballast water from ships, pharmaceuticals, disposal of greenhouse gases (sub-seabed disposal and surface seabed disposal), and mining and dredged spoils (Ramirez-Llodra *et al.* 2011).

Although deep sea mining has yet to become commercially viable, there is interest in meeting the ever increasing global demand for certain metals (e.g. manganese nodules on abyssal plains, cobalt-rich crusts on seamounts and massive polymetallic sulphide deposits at sites of hydrothermal venting) (Ramirez-Llodra *et al.* 2011). The regulations developed by the International Seabed Authority address the impact of mining on marine environment.

From the late 1960s onwards, large factory trawlers started targeting deeper offshore waters, in response to declines in major inshore stocks, regulations to reduce takes, and the declaration of EEZ, restricted fishing opportunities on the continental shelf. Heavy deepwater trawling gear can damage the ecosystems of both continental shelves and slopes by leveling the sea bed, creating sediment clouds, destroying coral, and generating huge amounts of bycatch. Fishing gear jettisoned due to entanglement or lost can result in ghost fishing.

Mining activity can disturb the sediment, leading to a mortality rate of 95 to 100 percent for macrofauna dwelling in marine tracks. Ships mining polymetallic nodules or massive sulphides eject discharge seawater after extracting its mineral content. The waste water can cause temperature changes, and contains trace metals, which can reduce the penetration of light through the water column and impact photosynthetic organisms.

Many of the deep water habitats in the WIO and the species and communities that they support have yet to be properly described. Exploitation of deepwater fish resources and offshore oil and gas reserves has already commenced in the WIO and the latter is likely to expand.

(b) Transboundary Scope

Knowledge about the global distribution of deep water habitats, knolls and seamounts (Yesson *et al.* 2011), and the species diversity that they support (Rogers *et al.* 2009) has improved in recent years, but it is still extremely limited. Despite this the resources are already being exploited and impacted (Ramirez-Llodra *et al.* 2011). Deepwater fish are particularly vulnerable to over-exploitation as they are often long lived, with slow growth and late maturity (Clark 2009). Then there is also the by-catch associated with the trawl fisheries in particular which is also a serious concern. In addition, the effects of trawling (and to a lesser extent line fishing) on benthic habitat and communities can be severe especially on the upper continental slope and seamounts. Heavy trawling can impact the structure and result in the loss of diversity and biomass of benthic invertebrates, especially framework-forming foundation species like cold-water corals (Clark and Rowden 2009). While some of these activities are likely to be restricted to within the EEZ, other activities will also likely impact on Areas Beyond National Jurisdiction (ABNJ). Only 4 of the 9 countries identified deep water habitats as 'Relevant' but 3 of these 4 countries ranked the issues as being of 'High' importance, while one country ranked the issue as being of 'Low' importance. In the Level 2 prioritisation, only 1 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern.

1.4.3.14 Disturbance, damage and degradation of pelagic habitats (nearshore <30 m, neritic 30-200m and oceanic >200m depth)

(a) Problem Statement

The pelagic realm represents the largest global ecosystem and 99 % of the Earth biosphere volume (Angel 1993) and is the least protected marine habitat (Game *et al.* 2009). Pelagic habitats, as referred to here, include the nearshore (<30 m), neritic (30-200 m) and oceanic (>200 m) water column. It has become increasingly apparent that the structure and function of this ecosystem has significantly changed largely due to fishing and pollution. The majority of the impacts to the pelagic habitats are captured under the issues of concern in MAC01 and MAC03. Under MAC01 these may include land- and marine-based sources of contamination including the discharge of un- or undertreated municipal and industrial waste, riverine inputs, surface run-off, and the accidental release of chemicals, and other liquid and solid wastes from marine sources. Additional impacts in the pelagic environment that have not yet been captured under MAC01, include noise pollution as a result of boat traffic, shipping and transportation, dredging and seismic surveys associated with oil and gas exploration, which are known to impact particularly on marine mammals and sea turtles.

(b) Transboundary Scope

The majority of impacts on the pelagic habitats are captured under the issues included in MAC01. While some of the issues are transboundary in nature, the majority of these issues are shared transboundary concerns. Nearshore pelagic habitats will be impacted by noise pollution associated with recreational vessels, which will increase with the ongoing expansion of coastal tourism, and other fishing and commercial vessels, particularly around ports. Neritic and oceanic pelagic habitats will also be impacted by noise impacts as a result of shipping but also from seismic surveys associated with the expansion of oil and gas exploration activities within the WIO. Eight of the 9 countries

identified concerns associated with pelagic habitats as 'Relevant' and 6 of these countries ranked the issues as being of 'High' importance. In the Level 2 prioritisation, 7 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

1.4.3.15 Increase in the occurrence of harmful or toxic algal blooms (HABs)

(a) Problem Statement

An 'algal bloom' occurs when there is a large accumulation of phytoplankton, macroalgae or protists in the water column. There are many species that can form blooms, some cause visible changes to water colour, resulting in so called 'red tides', 'brown tides', or 'green tides', while others may create a visible scum or foam on the sea surface, which can also cover beaches. Some species produce toxins that are poisonous to fish or to humans (if the toxin is bio-accumulated), and these are called 'harmful algal blooms (HABs)' or toxic algal blooms. Blooms can occur naturally in response to climatic and seasonal factors that influence the availability of nutrients in the water, and create conditions that promote rapid cell division and growth. Blooms can also be triggered by anthropogenic inputs of nutrient enriched waters (from land-based or marine sources), with high concentrations of nitrates and phosphates. Once the bloom has finished, decomposition of the algae removes oxygen from the water and can cause 'eutrophication' and the death of other organisms on the sea bed or in the water column. Algal blooms including HABs have been reported throughout the WIO region, while most have not resulted in eutrophication they have impacted upon benthic habitats and communities (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009). Not all toxic blooms occur on the sea surface. The photosynthetic dinoflagellate (*Gambierdiscus toxicus*) most commonly associated with ciguatera poisoning, is normally found growing as an epiphyte in other large algae or on the surface of dead coral. Herbivorous fish feed on the algae (and the dinoflagellate) assimilate the toxin into their muscle tissue, and the ciguatera toxin is thus bio-accumulated through the food chain. Outbreaks of ciguatera fish poisoning present a risk to human health within both the local and tourist population. Certain species of fish known to present a particularly high risk of ciguatera poisoning (e.g. barracuda, red snapper) are not consumed in the Mascarene region (Hamilton *et al.* 2002).

(b) Transboundary Scope

The algal bloom which occurred on the northern border of Kenya with Somalia demonstrated that these events can be transboundary. Reports of algal blooms and in particular HABs at the national level appear to be increasing within the WIO, which indicates that this may also be a shared transboundary issue. While some of the blooms that have occurred to date may have been caused by anthropogenic influences (i.e. run-off), other blooms appear to have been driven by unusual climatic factors. It is not really known if the blooms were due to new non-native or invasive species. Eight of the 9 countries identified concerns related to harmful algal blooms as 'Relevant' but only 4 of these countries ranked the issues as being of 'High' importance. In the Level 2 prioritisation, none of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the WIO region.

1.4.3.16 Introduction of exotic non-native, invasive and nuisance species

(a) Problem Statement

Nuisance species, such as the corallivorous crown-of-thorns (COTs) starfish (*Acanthaster planci*) and the gastropod mollusc (*Drupella* sp.) occur throughout the WIO, and can cause huge amounts of damage to live coral cover (e.g. Fagoonee and West 1983, Ahamada *et al.* 2008, Volger *et al.* 2008, Celliers and Schleyer 2006). The introduction of exotic non-native species (i.e. from outside the region) into the marine or coastal environment can have various impacts on local biodiversity. Once a non-native species starts to reproduce and become established it becomes an invasive species, the impacts can be devastating due to potential competition with indigenous species, hybridisation

causing genetic dilution, alteration of ecosystem dynamics, and the threat to the complexity and resilience of the local ecosystem. In the marine environment, international shipping is the principal agent for the introduction of exotic species, from ballast water or hull fouling organisms. Over 3,000 marine species travel around the world in ships' ballast water on a daily basis (Bax *et al.* 2003). Other sources may include the introduction of a species for mariculture purposes. Invasive species are more likely to settle in disturbed or degraded habitats and can further compound human-induced impacts such as over-harvesting or physical damage. Invasive species such as marine algae may impact on marine habitats, reducing coral growth and excluding native algal species.

(b) Transboundary Scope

The most widespread reason why non-native species and invasive species are introduced into the marine environment is through shipping, ports and coastal transport. Invasive species can be spread as a result of the practice of dumping ballast water from ships or from being carried on the hull of ships. The western Indian Ocean already has major shipping channels and several important ports. Many of these ports have inadequate facilities for receiving or processing ballast water, or for ship cleaning. The number of ports and the number of vessels in the WIO is already increasing, and will likely further increase to support the expansion of mining and energy sector. These developments will present the concomitant risk of further introductions. Eight of the 9 countries identified exotic, invasive and nuisance species as 'Relevant' but only 3 countries ranked the issues as being of 'High' importance at the national level. In the Level 2 prioritisation, only 3 of the 9 countries assigned the issue an 'Overall rating' score that was above average. There was however a discrepancy between the national results and the Regional 'Overall rating' score, which was above average, indicating that the countries do consider this to be a high priority transboundary issue of concern within the region.

1.4.3.17 Shoreline changes due to modification, land reclamation and coastal erosion

(a) Problem Statement

Shoreline change (erosion and accretion) is a major environmental concern that is already affecting countries throughout the WIO region (Kairu and Nyandwi 2000, UNEP/Nairobi Convention Secretariat 2009b). Changes in land use patterns, such as deforestation or poor agricultural practices, may increase sediment loads entering from rivers, resulting in accretion and potential infilling of shallow lagoons and embayments, and even ports (UNEP/Nairobi Convention Secretariat 2009b). Dams obstruct river flows and trap sediments resulting in a sediment deficit which can lead to severe coastal erosion (Kairu and Nyandwi 2000). Direct anthropogenic interventions, such as flat-land reclamation schemes, the construction of coastal defences, and other coastal development works, result in the loss of natural habitats and can cause coastal erosion in areas downstream. Other activities which mechanically disturb soft sediment habitats, such as trawling, dredging, and sand mining, can also all contribute towards the modification of shorelines (Kairu and Nyandwi 2000). Shifts in wind and wave patterns, arising from changes in climatic processes can also influence shorelines, and likely compound sea level rise. Sea level rise is one of the overarching major global concerns, exacerbating coastal erosion and shoreline change, and as is already evident in the WIO and particularly in the southern Indian Ocean. Existing trends in coastal erosion may escalate as a combined consequence of global and local natural and anthropogenic changes.

Shoreline changes, particularly those resulting from coastal erosion, pose serious threats to the coastal ecosystems and infrastructure development in the WIO (UNEP/GPA and WIOMSA, 2004e, IOC-UNEP-WMO-SAREC, 1994; Kairu and Nyandwi, 2000). Sedimentation and/or accretion of the coastline results in shoreline changes, generally from two sources: first, terrestrial sediments are carried to the sea by rivers, often derived from poor agricultural practices in the hinterland as well as deforestation, and secondly, re-suspension of benthic sediments by rough seas, vigorous longshore currents and at times through trawling over soft substrates. Coastal landscapes may shift or be lost entirely as a result of coastal erosion with implications for the organisms that live in or depend upon these critical habitats. Unstable shorelines can increase the risk of coastal flooding, during storms for example, and have implications for human safety, settlements and property, and coastal infrastructure,

such as roads and buildings (Kairu and Nyandwi 2000), with serious social and economic implications. Shoreline changes can occur for a variety of reasons often associated with changes in the riverine sediment input into sea, changes in the environmental processes that control marine sediment transport patterns and re-suspension, or as a result of direct anthropogenic impacts, interventions and construction activities on the land or in the sea.

In many parts of the WIO, coastal areas are dominated by loose sand and sediments which can erode rapidly. In some cases this has led to loss of land for agriculture, human settlement, infrastructure development as well as damage to coastal infrastructure, such as roads and buildings (Kairu and Nyandwi, 2000). Increased water turbidity, due to re-suspended sediments, interferes with the amount of light reaching corals and seagrass beds and, as the suspended sediments settle, they smother corals and seagrasses leading to loss of productivity, ultimately impacting on the system. In addition, coastal erosion has contributed to loss of critical ecosystems such as mangroves in Kenya, Tanzania and Mozambique through burial of their breathing roots leading to suffocation and eventually death of the trees. The socio-economic impacts of coastal erosion have serious repercussions on the livelihood and incomes of coastal communities.

Sea level rise is an additional problem of concern for low lying coastal areas, as is the case of the swampy coasts in central Mozambique, the west coast of Madagascar, and the Tana and Rufiji deltas. The Intergovernmental Panel on Climate Change (IPCC, 2001) has predicted that sea level will rise between 20 and 80 cm over the next century as a result of global climate change. Under this scenario, the low-lying coastal settlements are considered to be at risk, as the expected coastal inundation will displace a large segment of the coastal population and lead to major impacts on the socio-economic well-being of the coastal populations.

(b) Transboundary Scope

The most common transboundary issues associated with shoreline changes include modification and/or loss of habitat, increased coastal erosion/sedimentation, loss of property and increased poverty. The impacts of shoreline changes, either through sedimentation or erosion, are significant in all the countries in the WIO. The problem is most prevalent in Malindi –Mambrui area in Kenya (Abuodha and Kairo, 2001; Abuodha, 2003); NW coast of Madagascar (Joottun *et al.*, 1994); Beira and Macaneta Peninsula in Mozambique (Lundin and Linden, 1996; Kairu and Nyandwi, 2000) and Unguja Islands (Zanzibar) in Tanzania (Shaghude *et al.*, 1994). Some of the affected marine and coastal ecosystems, for example Tanga-Vanga and Lindi-Ruvuma systems, are cross-border areas. The silting of Mahajanga Port in Madagascar, as further discussed in section 4.4, can be viewed as a transboundary problem as the port was rendered useless thus affecting regional trade in terms of loss of revenue and livelihood. In this example, the transboundary issue is firstly economic in nature rather than environmental.

All 9 countries identified shoreline change and coastal erosion as 'Relevant' and 6 of the 9 countries ranked the issue as being of 'High' importance, with the exceptions being Comoros and South Africa, although this may be due to a lack of data in the Comoros. In the Level 2 prioritisation, 7 of the 9 countries assigned the issue an 'Overall rating' score that was above average at the national level. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

Table 2-9 Examples of eroding/accreting shorelines in the WIO region

Site	Geology	Comments
Comoros Grande Comoros	Low volcanic rock cliffs and narrow coastal lowlands	Removal of beach sands for construction has reduced beach areas (Kairu and Nyandwi, 2000).
Kenya Malindi	Sandy beaches	Major beach accretion of micaceous sand has occurred since the 1960s.
Madagascar		In 1953, the Morondova city lost 100 m of shoreline

Morondova	Wide low-lying area	due to the swell and storm events (Kairu and Nyandwi, 2000).
Mauritius Flic en Flac	Sandy beaches are the most common and exposed basaltic cliffs in the northern end	Between 1980–1994, the position of high water mark at Flic en Flac moved inland by a distance of 8 m (Jootum <i>et al.</i> , 1994). The ridge complex zone which runs parallel to the shoreline, stretching over 600 m and attaining 5 m high in some regions, has been mined for its good quality sand.
Mauritius Belle Mare	Sand beaches	Beaches receded by about 5 m in 1988 due to tropical cyclones (Jootum <i>et al.</i> , 1994).
Mozambique Beira	Sandy beaches, and coastal swamps	According to Lundin and Linden (1996), apart from natural causes, coastal erosion could be attributed to: inadequate maintenance of the buttress and sand retention wall, destruction of the dunes, mangrove and casuarina tree removal; removal of sand for construction, and building on beaches. Dam construction has also starved the coast of sediments.
Mozambique Maputo city	Sandy beaches	Floods, cyclones and swells accelerated erosion of the coastline north of Maputo, and the 2000 floods divided the small Chefina and Grande Island into two.
Seychelles Bird Island	Low-lying coralline island	Its south-western shoreline shift and recede naturally while, north-eastern shoreline is accreting (Shah, 1994).
Tanzania Mwambani, Tanga	Cliff erosion	Mwambani shoreline is characterized by a fringing reef platform bordered by a line of cliffs. The stretch is a high wave energy environment and fine sediment is lacking.
Tanzania Maziwi Island	Sandy island	The island disappeared in 1977/1978, attributed to sea level rise (Fay, 1992) and clearance of all vegetation (Shaghude <i>et al.</i> , 1994).
Tanzania Nungwi, Zanzibar	Sandy beaches	An erosion regime that threatened the village of in the early 1990s has been replaced by accretion.

(c) Risk, uncertainties and trends

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

Uncertainties with regard to the extent of shoreline changes – The problem of shoreline change in the WIO region has been studied and reported widely for some countries more than others.

Governance issues - There is at present no comprehensive set of strategies (policies, legislation and regulations) in the WIO which is specifically geared towards addressing problems of shoreline change. Also, most countries in the WIO lack key governance mechanisms such as Integrated Coastal Zone Management Programmes, guidelines or codes of conduct to address shoreline change. Consequently, there is large uncertainty as to what extent mitigation of shoreline changes will be implemented at least in the near future.

(d) Stakeholder analysis

Various stakeholders were identified for all natural ecosystems discussed in this TDA. For most habitats, the main stakeholders were those involved with coastal resource use such as local communities and management authorities. Those identified for PADH are fisheries and aquaculture, agriculture and forestry, tourism, mining industry, management authorities, NGO's, local communities and scientists. The principal stakeholders involved at the root of each problem, were the resource users and management authorities, whereas at the impact level, the most affected include again the resource users especially the tourism and local community sectors. Several stakeholders

SECTOR	STAKEHOLDER	TRANSBOUNDARY PROBLEM									
		Mangroves		Coral Reefs		Seagrasses		Coastal forests		Shoreline change	
	Light manufacturing										
	Agro-processing industries										
	Oil refining							C		C	
Transportation	Ports	C		C		C		C		C	
	Dredging companies			C		C				C	
	Clearing and forwarding										
	Railway							C		C	
	Roads (incl. traffic)							C		C	
	Airports							C			
	Airlines										
	Shipping										I
Energy production	Hydro-dam operators										
	Power station operators										
	Renewable energy producers										
	Fossil fuel users		I		I		I		I		I
Urbanisation	Solid waste operators					C					I
	Sewage managers	C		C		C				C	
	Property developers	C	I	C	I	C	I	C	I	C	I
	Town planners	C	I	C	I	C	I	C	I	C	I
	Coastal communities	C	I	C	I	C	I	C	I	C	I

1.4.4 Problem Area 3: Alteration of river freshwater flows and sediment loads

1.4.4.1 Overview of the problem in the WIO

One of the key areas of concern is the zone of interaction between river basins and the coastal and marine environment where the alteration and/or modifications of freshwater flows, of sediment loads, water quality and pollution are primary considerations. The seriousness of this concern is underscored by among others the Land Ocean Interaction in the Coastal Zone (LOICZ) Global Change Assessments and Synthesis of River Catchment – Coastal Sea Interaction and Human Dimension of African Basins (see LOICZ Reports and Studies No. 25, 2002) as well as the preliminary Transboundary Diagnostic Analysis for the WIO region (UNEP, 2002).

Around much of the region many of the coastal issues are linked to human activities and climatic variability that are distant, often far removed from the coast. Such up-country pressures have altered the nature of the drainage through the river systems – large and small – impeding the flow of freshwater, terrigenous sediment and organic matter. They have also affected the quality of the water, mainly through the addition of nutrients and pollutants from domestic sewage and industrial and agricultural chemicals (Crossland *et al.*, 2005).

Table 2-11 Overview of the main issues related to freshwater flow in the basins

River	Flow Issues	Quality Issues	Sediment Issues	Main Issues
Tana	Variable (Kitheka <i>et al.</i> , 2002b, 2003b-d & 2005)	Stable (Kitheka <i>et al.</i> , 2005)	Decrease – but not critical (Snoussi, 2004; Kitheka <i>et al.</i> , 2003b&d)	Reduction in sediment load due to construction of the HEP dams in the Upper Tana Basin (Ongwenyi, 1979 and 1983; Dunne and Ongwenyi, 1974 and 1976; Kairu, 1997; Kitheka <i>et al.</i> , 2003c). Salt water intrusion and erosion of the mangrove colonised delta (Kitheka <i>et al.</i> , 2003b&d)
Athi-Sabaki	Variable, possible (Fleitmann <i>et al.</i> , 2007, Kitheka <i>et al.</i> , 2002b & 2003c)	Stable – slight decrease (Kitheka <i>et al.</i> , 2004)	Increase (Fleitmann <i>et al.</i> , 2007, Kitheka <i>et al.</i> , 2002b, 2003a&c & 2004)	Increased siltation of the estuary and Malindi Bay resulting in degradation of the coral reef ecosystem at Malindi (van Katwijk <i>et al.</i> , 1993; Kitheka <i>et al.</i> , 2004)
Pangani	Decrease (PBWO/IUCN, 2006a).	Decrease (PBWO/IUCN, 2006a).	Small Increase (PBWO/IUCN, 2006a and (PBWO/IUCN, 2007).	Reduced freshwater flows resulting in increased sea water intrusion in the estuary (PBWO/IUCN, 2007). Reduced water quality, particularly increased oxygen demand (PBWO/IUCN, 2007).
Rufiji	Stable – small increase (Shaghude, 2004)	Stable	Variable	Limited water quality degradation due to agricultural runoff including nutrients and pesticides (Shaghude, 2004; Kulindwa <i>et al.</i> , 2001)
Ruvuma	Stable	Stable	Small Increase	Destructive fishing practices have led to a drop in biodiversity, negatively affecting seagrass beds (Francis <i>et al.</i> , 2002)
Zambezi	Decrease and less fluctuation (Turpie, 2006; Brown and King, 2002)	Stable – slight decrease	Decrease (Turpie, 2006; Brown and King, 2002)	Drop in sediment loads has led to landward erosion of the delta and sea water intrusion into the lower catchment. Size of delta has reduced from 18,000 km ² in 1977 to around 15,000 in 1998 (Chenje, 2000). Decreased variability of seasonal flow negatively impacting fisheries (Turpie, 2006; Brown and King, 2002).
Pungwe	Small Decrease (Hoguane, <i>et al.</i> , 2002 and Anon Mozambique, 2006)	Stable	Stable	Decrease in riverflow, due to increased abstraction upstream, is accelerating coastal erosion and salt-water intrusion through the estuary (Anon Mozambique, 2006; Van Der Zaag, 2000)
Limpopo	Decrease (Arthurton, <i>et al.</i> , 2002)	Decrease – not critical (Louw and Gichuki, 2003)	Decrease – not critical (Louw and Gichuki, 2003)	Streamflow reduction, nutrient depletion, biodiversity loss and salinisation receive impact codes of between 6 and 9 out of 10 in the LOICZ study (Arthurton <i>et al.</i> , 2002)
Incomati	Decrease (Hoguane <i>et al.</i> , 2009; TPTC, 2001; Van der Zaag and Carmo Vaz, 2003)	Decrease (Hoguane <i>et al.</i> , 2009; TPTC, 2001)	Decrease (Hoguane <i>et al.</i> , 2009; Van der Zaag and Carmo Vaz, 2003; TPTC, 2001)	Streamflow reduction due to heavy abstraction upstream resulting in salt water intrusion through the estuary. Reduction in sediment loads impacting mangrove vegetation (TPTC, 2001; Hoguane <i>et al.</i> , 2009; Van der Zaag and Carmo Vaz, 2003)

Maputo	Small Decrease	Decrease (Fernandes, 1995)	Stable	River is increasingly polluted due to industrial and urban wastes (Hoguane <i>et al.</i> , 2002)
Thukela	Decrease (DWAF,2004; DWAF, 2004a)	Decrease	Decrease (DWAF, 2004)	High risk of increased pollution and further flow and sediment reduction, particularly for prawn and fish nursing grounds (DWAF, 2004); Risk of decrease if further impoundments/ transfers reduce dilution capacity (DWAF, 2004a)
Betsiboka	Stable (Chaperon <i>et al.</i> , 1993)	Stable	Increase (Autrand, 1997)	High sediment loading of river outflow (IWMI, 2006) Accretion in the Bay hindering the of Mahajanga harbour shipping activities (Autrand, 1997) Increase in area of basin affected by bush fire practice leading to increasing runoff and heavy sediment loads
Tsiribihina	Stable (Chaperon <i>et al.</i> , 1993)	Stable	Increase (Salomon, 1987)	Continual accretion in the delta that could impact on mangrove ecosystem e.g. species dominance related to growth condition (salinity, type of soil etc)
Mangoky	Stable (Chaperon <i>et al.</i> , 1993)	Stable	Increase (Salomon, 1987)	Continual accretion in the delta but seems to be mitigated by strong oceanic currents bringing marine sediments to certain areas Marine sediments not conducive to optimal conditions for mangrove growth.
Fiherenana	Variable (Chaperon <i>et al.</i> , 1993)	Stable	Increase (Salomon, 1987)	Displacement of delta due to violent flood inundating the city of Toliara. Heavy sediment loads into the Bay of Toliara damaging the barrier reef (Vasseur, 1997/1967)

Key: Issues deemed “critical” or “important” are highlighted

The focus of this section of the TDA is on the main rivers flowing into the south-west Indian Ocean. The overview will cover information on hydrology, environmental issues such as water quality, flow alteration, sediment loads, etc. It will highlight main current environmental impacts related to freshwater flows, and analyse their drivers and impacts. For the purposes of this section of the TDA, the area of interest is the outflow of the river – where it transforms from being a freshwater system via an estuary into the saltwater marine environment. Thus, the issues may vary in different parts of the basin, but cumulatively there is an impact in the outflow area – be it a delta, estuary or a linear river mouth.

The six key underlying sectors, namely: Urbanisation, Agriculture and Forestry, Industry, Mining, Transportation and Energy production contribute to the problem of river flow and sediment load alterations in the WIO region. Each of the above sectors has potential impacts on one or a combination of river flow, water quality and sediment loads. Southern and eastern Africa is becoming increasingly urbanized, with some of the largest cities in the region located in basins included in this study – such as Nairobi in the Athi-Sabaki and Johannesburg and Pretoria in the Limpopo basins. Increased urbanization leads to an increase in paved areas, reducing infiltration of rainfall to the soil. A reduction in the holding capacity of the terrain leads to flash-floods during periods of intense rainfall, with possible increases in soil erosion in the lower reaches of catchments. Urbanisation results in an increase in water consumption. To accommodate this, large-scale water storage and transfer infrastructure has been constructed, with dams, impoundments and weirs altering the flow regime of rivers as well as trapping sediments.

Much of the population in the WIO region, especially in the hinterland of the upper-reaches of the basins in the study, is heavily dependent on agriculture and forestry. These activities are associated

with heavy water consumption – both through interception of rainfall (thus leading to a drop in groundwater levels) as well as through the evapo-transpiration of irrigated water. Intense or inappropriate farming techniques, such as planting on steep slopes or deep drainage furrows, can also lead to an increase in erosion with sediments reaching the main flow of the river. Furthermore, the return flows from fields frequently have elevated levels of nitrates, phosphates, salts and other pollutants such as herbicides and pesticides, which could impact river water quality.

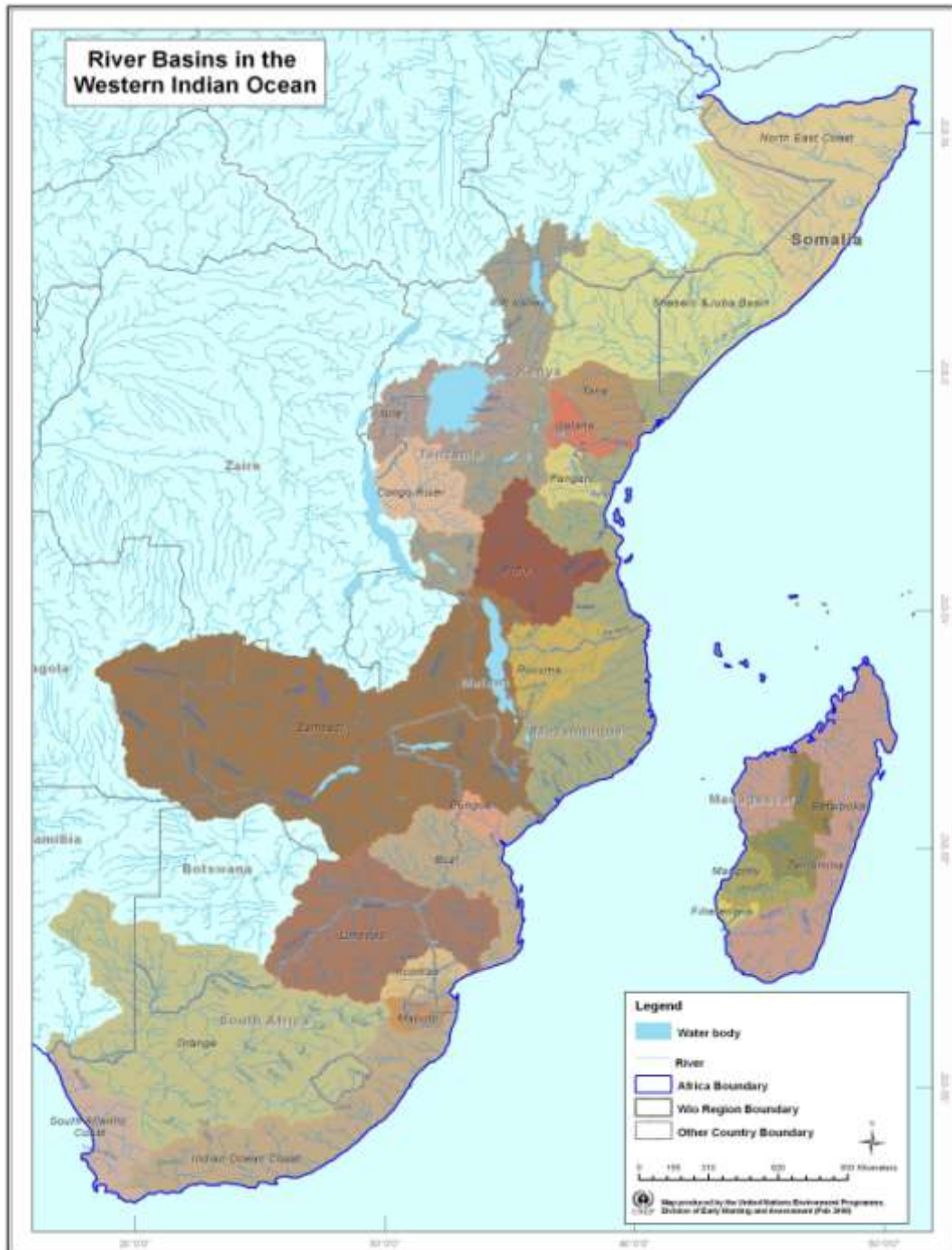


Figure 2-4 The key hotspot river basins in the WIO region

Accompanying, and in some cases driving, the increased urbanization is industrial development in various parts of the river basins of the region. From these industries there is the potential for organic and inorganic pollutants to reach the lower reaches of the rivers, while the increase in water use also raises the possibility of reducing the dilution capacity of the rivers.

Mining is a mainstay of economic development in much of the region. Although precautions are generally taken to ensure that environmental impacts from mining activities are minimized, there exists the potential for the contamination of water resources from mine water runoff. This has already become an issue in the headwaters of the Limpopo River where acid mine drainage from decommissioned gold mines on the Witwatersrand has found its way into the groundwater (Coetzee *et al.*, 2005). In addition to large-scale mining activities, there are in several parts of the basins of the region small-scale, unregulated or illegal, mining activities. These lead to erosion of river banks during the digging and panning process, increasing the sediment load and turbidity of the rivers. Numbers of these on a single system result in significant effects particularly in lower catchments and can irreversibly alter ecological goods and services afforded by estuaries.

The transportation sector has impacts on river basins in areas where road networks have been covered with impermeable surfaces. This reduces water infiltration to top soils leading to increased runoff and less tolerance to heavy downpours and flash floods, causing soil erosion and an increase in sediment loads. Dirt roads, through their construction as well as long-term use, may also increase soil erosion, conversely by exposing bare soil (cleared of vegetation) to the rain.

Several countries in the region rely extensively on energy produced by hydro-electric power schemes – important for Kenya, Tanzania and Mozambique. Much like dams constructed for water-supply these hydro-power dams alter the flow regime of rivers and trap sediments. The Cahora Bassa Dam on the Zambezi River has had an impact on its delta area by encouraging coastal erosion and reducing the nutrient supply carried downstream by floods (Turpie, 2006; Brown and King, 2002). In South Africa, large amounts of water are taken from rivers for wet cooling of thermal power stations, impacting particularly the Limpopo and Incomati rivers once the warmed effluent is returned to the rivers.

Some of the main specific issues related to each of the twelve river basins are introduced below:

Tana River

Since the development of the hydropower dams on the Tana River there has been a 56 % decline in sediment load to the Tana Delta (Kitheka *et al.*, 2004d). This drop has led to the erosion of beaches along the Tana Delta/Ungwana Bay (Otieno and Maingi, 1983; Kitheka *et al.*, 2002b, 2003d & 2005) and a loss of wetlands and mangroves in the delta (IUCN, 2003). The flow regime is highly variable, both year on year as well as seasonally. Some studies suggest that there is a long-term increase in runoff from the basin – however the reliability of the data cannot be confirmed (Kitheka *et al.*, 2004 & 2005). Although there has been an increase in the use of agro-chemicals in the Tana Basin, expected to lead to increased nutrient levels (Davis, 2000), the chemical water quality at the Delta has not reflected major deterioration although nutrients levels are generally high at the Tana Delta (Kitheka *et al.*, 2004).

Athi-Sabaki River

The Athi-Sabaki River has over the past five to six decades experienced a major increase in sediment load at the estuary (van Katwijk *et al.*, 1993; Kitheka *et al.*, 2002b, 2003a, 2003c & 2004). One of the prime causes of this is poor land-use patterns in the catchment, with intensive agriculture (both small-scale as well as large-scale farming, including livestock and wildlife over-grazing) leading to soil erosion (van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007). This has been coupled with an increase in rainfall in the catchment as well as a reduction of rainfall infiltration – all contributing to an increase in soil weathering and erosion (Snoussi *et al.*, 2004; Kitheka *et al.*, 2004). There is evidence that this increase in sediment transport started at the time of British colonial settlement in the central highlands of Kenya, when there was a shift from traditional subsistence agricultural practices to more intensive land use (Champion, 1933; Dunne, 1974 & 1975; Dunne and Ongwenyi, 1976; Fleitmann *et al.*,

2007). The consequences of this large increase in the sediment load from the river include the siltation of Malindi Bay, deposition of sedimentary matter and debris on beaches rendering them unappealing to tourists, and the degradation of nearby coral reefs and seagrass beds through suspended solid settlement and decreased water clarity (van Katwijk *et al.*, 1993; Snoussi *et al.*, 2004; Kitheka *et al.*, 2004; Fleitmann *et al.*, 2007).

Pangani River

According to the Pangani State of the Basin Report the “main causes of (Pangani) river degradation are: changes to the flow regime; changes to the channel and riverbed, including the extent of inundated areas such as floodplains; changes to water quality due to pollution; and the presence of alien plants and animals” (PBWO/IUCN, 2007). In the Pangani catchment, power production at the Nyumba ya Mungu Dam relies on storage of water during rainy seasons and a constant release of water through the turbines (PBWO/IUCN, 2007). Regulation at the dam also results in a relatively even flow through the year to the downstream power stations at Hale and New Pangani. The Nyumba ya Mungu Dam on the Pangani River and Kalimawe Dam on the Mkomazi River thus have the effect of smoothing-out the flow regime experienced at the estuary, significantly changing the natural hydrographic pattern (Lugeiyamu, 2002). In the dry season, the low flows are still present due to constant dam releases, but any higher flows are withheld by the dams. In the wet season, large floods still move down the system but smaller floods and a proportion of the low flows are trapped by the dams between floods. Thus, the flow is lower than natural (PBWO/IUCN, 2007). The quality of the water in the river generally deteriorates from upstream to downstream (Lugeiyamu, 2002), and most of the lower reaches of the river are classified by the State of the Basin Report as being “largely modified⁸” for parameters such as water quality, stream morphology and aquatic life. Poor quality is mostly related to increased levels of dissolved salts, nutrients, faecal coliforms, decaying organic material and turbidity in various parts of the system (PBWO/IUCN, 2007). Dissolved oxygen levels in the estuary are very low, especially in the upper reaches before the diluting effect of seawater plays a role.

Rufiji River

The Rufiji River, like the Athi-Sabaki River in Kenya, is one of the last undammed rivers (on the main stem) in the region (Shaghude, 2004). This makes it an interesting system to study, providing a valuable baseline against which to compare the situation after any future dam construction – such as the proposed hydro-power dam at Stiegler’s Gorge. At present there is some degree of water quality degradation in the Delta region, mainly as a result of DDT applied by rice farmers to combat freshwater crab damage to seedlings (Kulindwa *et al.*, 2001) though contamination is at a low level and seems to be locally confined. Nutrient flows from agricultural activities upstream in areas around Mbeya and Iringa are high, but again, most of this is broken down or absorbed by the ecosystem prior to it reaching the delta (Mwalyosi, 2004). The flow of water and sediment also appears to be stable, with no significant changes noted. Building of dams, such as the one proposed at Stiegler’s Gorge, would have the main impact of trapping sediments being transported downstream – preventing them from reaching the delta. Reduction of the fine sediments means reduction in the average supply of nutrients to the floodplain and delta. This is expected to have significant consequences to agriculture and the deltaic and offshore ecology (Shaghude, 2004).

Ruvuma River

The hydrology of the Ruvuma River has not been systematically studied, thus little is known of changes in flow rates or quantities or about sediment load (Francis *et al.*, 2002; DNA, 2004; Lerase, 2006). Floods and a high sediment load seem to be a natural part of the flow regime, with no evidence of anthropogenic drivers (DNA, 2004). The remoteness of the river and relatively low population densities in the catchment has meant that some of the best preserved mangrove forests along the coastline are found in the estuary (Kyewalyanga, 2004).

⁸ Ecological state: Severe modification with major disruptions in ecosystem functioning; mostly tolerant species remaining, often to pest proportions; alien species common; plants and animals may be diseased (PBWO/IUCN, 2007).

Zambezi River

The construction of the Kariba and the Cahora-Bassa dams has had the dual impact on the Zambezi Delta of reducing sediment load and reducing the seasonal variability of flow (ZRA, 1998; Beilfuss, 1999; Chenje, 2000; Brown and King, 2002; Turpie, 2006). According to a study by Gammelsrød (1996), as cited by the ZRA (1998) report, “in the case of the Zambezi River the construction of Cahora Bassa Dam in Mozambique has had a significant impact on fisheries, particularly along the Sofala Bank at the River mouth”. This has bearing to the shrimp *Fenneropenaeus indicus* (previously *Penaeus indicus*), for example, there is a close relationship between river runoff and abundance. Regulation of river flow has two main impacts on this shrimp: (a) increased runoff during the dry season is likely to set up currents heading offshore strong enough to prevent the larvae from entering nursery areas and (b) after having developed to a juvenile state in the nursery areas, a strong rainy season runoff facilitates high levels of recruitment to the fisheries - because higher runoff flushes a larger area and creates a stronger offshore current” (ZRA, 1998).

The economic losses from reduced fisheries landings, due to the reduction in nutrients entering the Indian Ocean at the Sofala Bank fishery (Arthurton, 2002), following alterations to the Zambezi River freshwater flows has been estimated at between 10 and 20 million USD (Turpie, 2006). In addition, there has also been a large reduction in the extent of the mangrove forests, due to desiccation following reduced freshwater flows (Beilfuss, 1999), while the reduced sediment load has led to increased coastal erosion.

Pungwe River

The Pungwe River has experienced a large increase in abstraction of water for use in agriculture, urban areas and industry (Van der Zaag, 2000; Hogueane *et al.*, 2002). This abstraction is taking place at various points throughout the basin, including the headwaters in Zimbabwe and the mid and lower reaches in Mozambique. No comprehensive studies have so far been carried out to assess whether there is a substantial change in the flow regime received at the Pungwe Delta (Van der Zaag, 2000; Hogueane *et al.*, 2002) thus no pressing issues have been identified related to the freshwater flow of this river into the ocean, other than the fact that coastal erosion in the area does seem to be increasing (Hogueane *et al.*, 2002).

Limpopo River

The water of the Limpopo River is heavily used by the four basin states (Botswana, South Africa, Mozambique and Zimbabwe). Agriculture (large and small scale), mining, industry, energy production and urban water use are all significant water consumers. The large number of dams in the basin (over 40), coupled with direct abstractions, has reduced the annual flow of the river significantly (Arthurton *et al.*, 2002; Louw and Gichuki, 2003; Anon Mozambique, 2006). The reduced flows in the lower reaches of the river have lowered the potential for the river to absorb pollutants. Thus water quality degradation, emanating from the sources above, is a problem, with high concentrations of chromium, copper, iron and manganese found in the gills, liver, muscle and skin of freshwater fish in the river (Louw and Gichuki, 2003). There has also been an increase in seawater intrusion into the floodplains in Mozambique, negatively affecting agriculture (Arthurton *et al.*, 2002). The Limpopo reaches the Indian Ocean cutting through a coastal dunes belt by a narrow river mouth lacking any deltaic features. This partly indicates the prevalence of natural ocean forces over the river mouth in creating the physical environment of the narrow coastal zone whereby typical river-ocean interrelations are confined to a relatively small coastal and marine area (Louw and Gichuki, 2002). The most significant direct impacts to reduced freshwater flows are the intrusion of the ocean saline water into the river course during high tides and the spread of sediment in the nearshore sea, particularly suspended particles which on extreme floods may be transported long distances by longshore currents.

Incomati River

Due to the heavy utilisation of its water resources, the flow regime of the Incomati River is significantly altered. Water quality has decreased in some areas (Hogueane *et al.*, 2009) but at present, flow alteration due to impoundment and abstraction from those impoundments has the biggest impact

on the system and the estuary. The estuary has suffered from reduced freshwater inflows and sediment deposition (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hogueane *et al.*, 2009), leading to salt intrusion and sediment deficit, and consequently erosion. Hogueane (2000) observed salt intrusion up to about 40 km upstream. There are currently numerous dams in the system and further dams are planned, which would potentially aggravate the described impacts on the estuary (TPTC, 2001).

Maputo River

The main issue on the Maputo River is the discharge of agricultural, industrial and urban wastes into the river shortly before it flows into Maputo Bay. The Bay has seen a general degradation in its water quality – partly caused by the discharge it receives from the Maputo River, but also from direct discharges from Maputo City (Hogueane *et al.*, 2002).

Thukela River

An increasing number of dams and inter-basin transfer infrastructure, such as pipelines and canals, has manifested itself in the flow and sediment load conditions of the Thukela and its estuary, which had until recently, remained relatively stable (DWAF, 2004a; DWAF, 2004b). The effect of the dams on floods and sediment dynamics at the estuary has over the past decade become an issue of increasing concern, with the estuary now closing for days at a time, whereas historically the system was permanently open to the sea. (DWAF, 2004a). While in the past the overall water quality was considered stable (DWAF, 2004a), there are now increasing pockets and stretches of river where water quality problems are more significant, for example in the upper reaches where acid mine liquid waste enters the river as well as lower reaches where municipal and industrial waste enters the system. Water quality at the estuary deteriorates whenever flow rates are reduced, such as during the winter dry season, which has seen an increase in water quality standard transgressions in terms of human health and ecosystem integrity. The Thukela Water Project, comprising the construction of the Jana and Groot Mielietuin Dam, has been deemed feasible (DWAF, 2001) but the approval to construct has not yet been given. If the Thukela Water Project does proceed, it might not become operational before 2020, possibly even later if Lesotho and South Africa go ahead with Phase 2 of the Lesotho Highlands Water Project (DWAF, 2004a). Though the estuary sediment dynamics have in the past been shown to be in a dynamic equilibrium state, some simulations of a post-dam scenario suggest that a dynamic equilibrium similar to the current conditions could prevail (DWAF, 2004b). However, the proposed Thukela Water Project is set to draw large volumes of water from the Thukela for industrial use in inland regions, effectively redistributing a large water flow from the Thukela to other catchments, the implications of which are not fully understood. Moreover, the reduced water flow is likely to accentuate the pollution problems increasingly being experienced.

Betsiboka River

Although there are two dams in the upstream part of the Ikopa River (a main tributary), flow regime issues seem not to be associated with dams, but rather from changing climate affecting the whole basin. Despite the absence of current data on climatic conditions in Madagascar, studies have reported increasing periods of drought, mainly in the south-western region, coupled with mostly irregular rainfall which often causes violent erosive flows downstream. Betsiboka River basin is much more affected by poor land use along its course. Bush fires and slash-and-burn practice are the main causes of the basin's degradation every year, leading to heavy sediment load transport into the Bay of Mahajanga. There is evidence that this problem began before independence in 1960. It was reported by Autrand (1997), during a study of the western coast potential for shrimp nursery, that the accretion in the Bay has reduced the water depth from 70 to 40 m. This process is thought to have transformed the former bay into a lagoon system (Autrand, 1997). Nowadays, shipping activities are the first affected by the changes but the water quality may also worsen from the reduced circulation combined with the continual and direct discharge of untreated municipal wastewater. Finally, some kilometres north, at Antrema, local coral reefs have also been impacted by the higher turbidity associated with the sediment load Maharavo (2003).

Tsiribihiny, Mangoky and Fiherenana rivers

The three south-western rivers, Tsiribihiny, Mangoky, and Fiherenana, located in a semi-arid zone have experienced the same problem of increasing sediment load due to: the irregular occurrence of

violent storms concentrated at the start of the rainy season; the relatively steep and long slopes in the crystalline zone of the river courses; and a catchment area in which the destruction of the vegetation cover has resulted in the erosion of topsoil. All of these impact, to varying degrees, on the mangrove ecosystem at the delta and the surrounding coral reef ecosystem, such as the Grand Recife in the Bay of Toliara, heavily impacted by siltation from the Fiherenana River. The current agricultural policies of government, encouraging and facilitating the use of chemicals and fertilizers, are likely to have an impact on the quality of freshwater downstream and subsequently on the fragile nearshore ecosystems such as coral reefs. The expansion of mining and petroleum investment and activities in the country, particularly in the western part, could have a severe impact on water use and quality and should not be overlooked.

Based on the above descriptions it may be concluded that all of the twelve rivers covered in this review have been modified by human activities to some degree. In certain cases, the modification is significant, such as Tana, Pangani, Zambezi and Incomati, as highlighted above. In others, the degree of impact is relatively low-such as the Athi-Sabaki, Ruvuma and the Rufiji. Again, when discussing the degree of modification for this transboundary impact study, it is the situation at the outflow of the river which is of interest and direct relevance to transboundary issues.

The degree of impacts of land and water use activities in the basins concerned is difficult to quantify and compare. This is due to the fact that no empirical studies using standardised methodologies have been carried out on all the rivers. A subjective categorisation of the degree of impact on the rivers has been performed by the authors of this TDA, largely based on citations from the literature consulted, whereby the rivers have been divided into three classes – severe, moderate and little affected (by human activities). Essentially, if studies have flagged an issue in a basin as “severe”, “pressing”, “important”, or “critical”, it has been classified under the “severe” heading in the present analysis. Likewise, “little affected” rivers or similar are those which the literature indicates there is low human impact at the mouth of the river. The remainder of the basins are placed in the “moderate” category – indicating either that the various studies consulted have concluded, on the basis of empirical evidence, that the impacts are moderate (or a similar description) or that studies and data are inconclusive. The final categorisation of the degree of impact severity on the rivers is thus, as follows:

Severe: Pangani, Athi-Sabaki, Incomati, Zambezi, Betsiboka

Moderate: Rufiji, Limpopo, Maputo, Fiherenana, Tana, Thukela

Little affected: Ruvuma, Pungwe, Mangoky, Tsiribihina

The majority of the main rivers of the WIO region are thus either moderately or little affected, while only four of the rivers appear severely modified – with measurable impacts on the immediate marine ecology associated with them (Table 2-11). The latter may therefore be considered as the main ‘hotspots’ in the region, as it comes to issues related to river-coast interaction. It should be noted, however, that even for rivers classified as “moderately affected” there are some issues which either currently are posing an environmental threat or have the potential to develop into one in future.

This situation, whereby most WIO rivers are little or moderately affected could change if economic and social development pressures in the basins increase. Table 2-12 provides an overview of the existing and proposed dams and inter-basin transfers (IBTs) for the main river basins. The planned dams are ones for which there is some likelihood that they will be constructed (or at least that construction will begin) in the next 15 years or so. As the economies of the region develop and populations grow, so will the pressures on the freshwater ecosystems increase, with a commensurate decrease in the quantity, quality and timing of flows into the coastal marine ecosystem.

Table 2-12 Overview of dams and inter-basin transfers in the WIO region – existing and planned

River	Current significant Dams ⁹	Potential/Planned significant Dams	Inter-basin transfers
Tana	Masinga, Kamburu, Gitaru, Kindaruma, Kiambere (Kitheka <i>et al.</i> , 2003c & 2005; IUCN, 2003)	Mutonga Grand Falls, Usueni, Adamson's Falls, Kora Hills (Kitheka <i>et al.</i> , 2003c & 2005; IUCN, 2003)	Transfer to the Athi river Basin through water supply to the City of Nairobi (Snoussi <i>et al.</i> , 2004)
Athi-Sabaki	None (Snoussi <i>et al.</i> , 2004 ; Kitheka <i>et al.</i> , 2004)	Yatta, Munyu and Ndarugu (Kitheka <i>et al.</i> , 2004 citing GOK-TARDA, 1981a-c)	Transfer from the Tana River to supply Nairobi (Gupta, 2001; Snoussi <i>et al.</i> , 2004)
Pangani	Nyumba ya Mungu, Kalimawe, Mabayani, Kihansi, Hale	Possible new hydro-power dams	None
Rufiji	Mtera	Stiegler's Gorge (Shaghude, 2004, Richmond <i>et al.</i> , 2002; Mwalyosi, 2004)	None
Rovuma	None	None	None
Zambezi	Kariba, Cahora Bassa, Kamuzu barrage, Itezihitezi, Kafue Gorge, Sebakwe, Mazvikadei, Manyame, Chivero	Mepanda-Uncua, Batoka, Mupata, Baroma, Lupata, Mutarare (ZRA, 1998; Turpie, 2006; Beilfuss, 1999; Pallet, 1997)	Matabeleland Zambezi Water project – to Bulawayo (Chenje, 2000)
Pungwe			Transfer to the Save basin to supply Mutare in Zimbabwe (Van der Zaag).
Limpopo	Macarretane, Massingir, Hartebeespoort, Eerstespoort, Loskop	Rehabilitation and raising of Massingir dam	Currently IBTs from the Orange-Senqu and the Incomati basins
Incomati	Maguga, Driekoppies, Nooitgedacht, Vygeboom, Mbambiso, Kwena, Ngodwana, Witklip, Klipkopje, Da Gama, and Corumana Dams (TPTC, 2001)	Corumana (raising), Moamba, Mountain View, Boekenhoutrand and New Forest Dams (Van Wyk, pers comm., 2007; TPTC, 2001)	Currently several IBTs to the Limpopo Basin in RSA (TPTC, 2001)
Maputo	Small earth dams only (less than 6m in height) DNA, 1994		
Thukela	Woodstock, Spioenkop, Ntshingwayo (previously Chelmsford), Zaaiohoek, Wagendrift (DWAF, 2001; DWAF, 2004a)	Jana, Mielietuin (DWAF, 2001; DWAF, 2004a & 2004b) Feasible but not yet decided on	Currently four IBTs into neighbouring catchments (DWAF, 2004a)
Betsiboka	Mantaoa and Tsiazompaniry (IWMI, 2006)		

Based on the earlier assessment of problems and issues related to the main river basins in the WIO region, the sections that follow provide a further systematic analysis of the two main problem areas related to river-coast interaction in the WIO region: (1) Alteration of river flow and degradation of river water quality and (2) alteration in river sediment loads.

⁹ These are dams on the main stem or important tributaries of the river which have an impact either due to their storage capacity or due to being located close to the mouth of the river, thus affecting sediment transport

1.4.4.2 Alteration of river flows and river water quality

(a) Problem statement

It should be noted that issues related to river flow alteration and the degradation of water quality, while seemingly different in nature, are strongly interconnected. This is because the eventual effect of pollution inputs on water quality depends on the assimilation capacity of rivers. This capacity is directly related to the flow of rivers. For the purpose of this TDA, therefore, these two issues are analysed in an integrated manner. The alteration (changes in quality, quantity or timing of flow) of the natural river flow occurs to different degrees in many of the major river basins in the WIO region. The four most frequent reasons for flow alterations are due to: (i) consumptive uses, (ii) increase of river surface area along sections because of impoundment, (iii) changed seasonal flow patterns (e.g. releases for hydropower-generation during the dry season), and (iv) increased floods due to wetland losses (loss of water retention capacity) (Hirji *et al.*, 2002). These are coupled with the large-scale realities and uncertainties brought about as a consequence of climate change, with some basins predicted to receive more rainfall than the historic mean, and others less (Bailey and Scholes, 1999; Hulme *et al.*, 2001; IPCC, 2001; Hirji *et al.*, 2002; Cave *et al.*, 2003; Kitheka *et al.*, 2004; UNEP, 2005; Earle and Malzbender, 2007).

(b) Transboundary Scope

The problem of flow alteration is specific to the rivers mentioned above, notably the Pangani, Zambezi, Limpopo, Incomati and Maputo. Although the impacts are relatively localized, the cumulative impacts of flow alteration are such that the effects on coastal communities and marine ecosystems are of considerable significance within the regional context. This is particularly the case when several rivers terminate in close proximity, as is the case in Maputo Bay where the Incomati and the Maputo rivers end. Individually, the water quality of these rivers is not considered critical (Anon Mozambique, 2006) but combined with increased pollution directly from the city of Maputo, the water quality of the Bay has deteriorated significantly (Fernandes, 1995; Arthurton *et al.*, 2002; Anon Mozambique, 2006).

For most of the rivers in the region, pollution of the marine environment from freshwater flows is not significant, although (as described earlier) various studies undertaken in the Pangani, Limpopo, Incomati and the Maputo rivers show that there has been some reduction in water quality and that the spatial-temporal distribution of such reduction is usually significant. In a few hotspot areas however, where there are changes to the estuarine environment due to increased pollution levels, reduced flows and changed sediment deposition patterns have severely affected fish and shrimp catches (for example, at the Zambezi Delta), confirming that the estuaries' function as fish and prawn spawning areas, nurseries and feeding habitats is compromised. The reduction in flow, and especially the flood events, has led to the physical alteration and destruction of habitats (PADH) of the lower delta, mainly through salt-water intrusion, impacting on important spawning grounds for fish and shrimp (ZRA, 1998). The other PADH impact on the Zambezi Delta area is the reduction in mangrove forests coverage. Similar trends, leading to reduced fish catches linked with alteration of flow and drop in water quality, have been observed for the coast off the Incomati River mouth (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and off the Pangani River mouth (PBWO/IUCN, 2007). The Maputo River has experienced high levels of chemical and biological pollution emanating from industries and from effluent from neighbouring towns, threatening seagrass beds (Fernandes, 1995). The combination of increased pollutants from the city of Maputo and a reduction in freshwater flows from the Incomati River which leads to salt-water intrusion, threatens mangrove forests and seagrass beds in the vicinity of Maputo Bay (Hoguane *et al.*, 2002). Increased demands for water in the region, coupled with possible drops in rainfall due to climate change, could lead to further problems. In Mozambique, alteration of river flow from impoundments and water abstraction e.g. the Incomati River has led to the delta suffering from an increase in the salt-water intrusion, extending upstream for about 40 km. This is accompanied by an increased erosion of the delta due to reduced sediment load and consequent reduction in mangrove forest areas (Hoguane *et al.*, 2004).

The growing demand for water and unsustainable land use practices are often coupled with limited awareness at grassroots levels of the cause-impact relationships as well as weak legal and institutional frameworks and capacity to address the problems. Poor enforcement of water use licenses, such as in the Pangani basin (PBWO/IUCN, 2007), limited knowledge of environmental water requirements, such as in the Incomati basin (Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and lack of financial and human resources to effectively mitigate and adequately manage causes and impacts are common problems throughout the WIO region.

Governance is specifically related to flow alterations from the damming of rivers through dam operating rules. Hydro-power and water supply dams aim to provide maximum hydraulic pressure at times when power is needed most and store wet season runoff for use in the dry season respectively. The net impact is a reduction in the natural flow variability of the river, leading to loss of biodiversity and habitat destruction. For instance, the construction of the Cahora-Bassa Dam and its operation and its impact on the downstream fisheries has been mentioned above. The same is true for the Pangani River where hydro-power reservoirs upstream have impacted the flow regime at the estuary (PBWO/IUCN, 2007).

Addressing the underlying root causes requires cooperation between countries as solutions often cannot be developed on a national basis. The transboundary nature of the resource renders national or local responses, often in isolation, ineffective at addressing the described environmental problems. These can only be solved if they are addressed throughout entire basins, some requiring harmonisation of legal instruments on a regional level beyond the basin scale. Increased cooperation between sectors is also needed to overcome management interventions that are mainly sectoral in nature with little coordination between sectors.

(c) Risks, uncertainties and trends

Increasing demands for water (for irrigation, industry, mining and domestic use) due to population growth and economic development, coupled with changing rainfall patterns and greater climatic variability increases the pressure on the water resource. Although the problem of flow regime alteration (and its impact on the marine environment) does not occur in all rivers of the region, there exists the possibility for it to increase as economic development continues.

One of the biggest challenges faced is to obtain reliable hydrological data for most of the rivers. Records which do exist tend to be incomplete due to failure of gauging stations and reporting procedures for a variety of reasons. Additionally, the quality of the data is questionable, being measured by different types of instruments, often mixed and corrupted. Several countries in the region have plans for new large-scale water infrastructure and use thus it will become increasingly necessary to be able to understand the impact of such developments on downstream users and ecosystems. Without sound data on which to base decisions, it is likely that damage to other users and the ecosystem will continue to increase.

1.4.4.3 Alteration of river sediment loads

(a) Problem statement

A number of factors, such as changing climatic conditions, land use practices and dam construction, have led to changes in the sediment load transported by some of the rivers in the WIO region. Broadly, the alteration of river sediment loads manifests itself in three ways:

Increased river sediment loads – The Athi-Sabaki and the Pangani rivers, among others, suffer from increased sediment loads (e.g. van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007; PBWO/IUCN, 2007). The increase in the sediment load of the Athi-Sabaki River has a negative impact on the marine environment, through the degradation of the coral reef ecosystem in Malindi Bay (van Katwijk *et al.*, 1993; Kitheka *et al.*, 2004).

Decreased river sediment loads – The Tana, Zambezi, Limpopo and Incomati rivers are all experiencing decreases in their sediment loads, important for downstream ecosystems (e.g. Kitheka *et al.*, 2003; Turpie, 2006; Hogueane *et al.*, 2009) According to the literature consulted, the issue of decreased sediment load is having a negative impact on the marine environment in the Zambezi and the Incomati rivers. The size of the Zambezi Delta has decreased from 18,000 km² in 1977 to around 15,000 km² in 1998, due to the construction of the Cahora-Bassa Dam (Chenje, 2000). In the Incomati Delta, there is an increase in salt-water intrusion (up to 40 km upstream) and increased erosion of the delta due to a decrease in the sediment load. The result is a reduction in mangrove area (Hogueane *et al.*, 2004).

Variable river sediment loads in different parts of the basin - In some rivers, both increased sediment loads, from erosion in upstream areas, and reduced sediment transport downstream of dams, following the trapping of the sediments behind the dam wall, are observed. The latter situation could affect more rivers in the WIO region, as more dam development projects are planned. Even where rivers are dammed, the sediment load reduction immediately downstream of the dam can at times be off-set by sediment load increases caused by bad land use practices on the river stretch between the dam and the river mouth. It is difficult to judge what the impacts of such an altered situation will be on the marine ecology, with no studies found covering the issue.

The combination of direct anthropogenic causes such as erosion with changing climatic conditions (e.g. changing rainfall patterns) makes it difficult at times to determine the exact contribution of a specific factor to the problem of sediment load alterations.

(b) Transboundary Scope

A common problem in the WIO region is poor land use practices (e.g. over-grazing, deforestation) which are often aggravated by increased population pressure. Poor land use practices can lead to problems of large-scale soil erosion (and resulting increase in sediment load), which may severely impact river floodplains. Combined with reduced or significantly altered flows, detrimental effects can be felt at the estuaries (e.g. Dunne and Ongwenyi, 1976; Kitheka *et al.*, 2004; Turpie, 2006) Natural phenomena such as climatic extremes (violent rainfall) coupled with slash-and-burn practices to clear land for grazing is a common cause of wide-scale soil erosion. An example is the western sedimentary zone of Madagascar, with resulting dramatic increases in sediment load in affected rivers. Salomon (1987) measured the average rate of specific degradation of south-western Malagasy river basins reporting 3,000 tonnes/km²/yr, a value significantly higher than those of other major rivers.

Sediment load alterations can be found to some degree in most rivers of the WIO region, be they transboundary or rivers flowing through only one country. However, as described above, the impact of sediment load alterations on the marine environment emerges as a major problem only for the following five river basins: Athi-Sabaki (increase); Zambezi (decrease); Incomati (decrease); Tana (decrease) and Betsiboka (increase).

Changes in sediment loads have been observed for some of the other basins in this study, with no apparent negative impact on the marine environment, but no conclusive studies exist to confirm these observations. Where rivers are shared between countries, the factors causing sediment load alterations usually occur in all countries with poor land use practices that lead to erosion being a typical example. Effectively addressing transboundary environmental problems such as sediment load alterations would significantly benefit from harmonised legislation and institutional frameworks.

In the case of sediment load reductions as a result of river impoundment – dams being a major contributor to sediment flow reduction – the effects occur downstream of the dam, hence making downstream countries more vulnerable to the impacts. However, under the SADC Protocol on Shared Watercourses (relevant to all continental WIO countries except Kenya) major infrastructure development requires notification of the other riparian states as well as data and information exchange. The implementation of major water infrastructure development thus needs to be on the basis of transboundary cooperation.

(c) Risks, uncertainties and trends

One of the prime challenges faced is the general lack of reliable, long-term hydrological data. For most of the basins in the study there was less data available on sediments (rates, fluxes, variation, etc.) than on water flow. The future dams planned for the region will certainly have a noticeable impact on the amount of sediment reaching the ocean from these rivers. Without a good long-term understanding of sediment transport dynamics it will not be possible to develop and implement mitigating strategies for such dams.

(d) Stakeholder analysis

There are important differences between stakeholders involved in the various problem categories, for example, between stakeholders causing water quality degeneration and those causing flow alteration or sediment flux. Also, the nature of the problems related to the different river basins differs considerably. An obvious example of this is the difference between rivers with large dams, such as Tana, Pangani, Zambezi, Incomati and Thukela, and those without. For this reason, the stakeholder analysis presented in this section warrants a case-by-case scrutiny. As the region is still heavily reliant on farming as a principal economic activity, the bulk of stakeholders causing as well as being impacted by flow alteration and water quality issues derived from this sector include small-scale farmers, large-scale farmers, pastoralists and loggers. However, in several of the basins, the actions of light manufacturing industries as well as hydro-electric dam operators are having an increasing impact. Most impacted by upstream activities are the artisanal and industrial fishers. Table 4-26 provides a tabular overview of the main sectors and stakeholder groups causing flow alterations and degeneration of water quality, as well as of sectors negatively affected by such issues.

The sectors mostly responsible for causing impacts from sediment flux alterations, as well as the most affected by the impacts are agriculture and forestry. On the whole the impacts which they cause are due to many and diffuse activities—small dams, run-off and erosion from fields. While these collectively represent substantial impacts, the largest impacts are caused by the hydro-dam operators due to trapping of sediments behind reservoir walls. Artisanal fishers and coastal communities tend to be most negatively impacted by the upstream activities. Table 2-1 provides a tabular overview of the main sectors and stakeholder groups causing sediment load alterations and those negatively affected by it.

Table 2-13 Analysis of sectors and stakeholder groups causing river flow alteration and degeneration of water quality, as well as those impacted by such

River basin	Key Problem		Stakeholder groups																	
	Alteration of flow	Degradation of water quality	Agriculture and Forestry						Mining		Industry		Energy Production		Fisheries		Urbanisation	Transport		
			Small-scale farmers	Large-scale farmers	Pastoralists	Small-scale loggers	Industrial Loggers	Small-scale miners	Industrial mining	Light manufacturing industry	Agro-processing industries	Hydro-dam operators	Power station operators	Artisanal fishers	Industrial fishers	Town Planners	Ports	Roads	Coastal Communities	
Tana	X	X	C	I	C		C	I				C								
Athi-Sabaki	X	X		I			C	I	C							C			C	I
Pangani	X	X	C	I	C		C							I		C				I
Rufiji		X	C											I		I				
Rovuma																				
Zambezi	X		C	I	C									I		I				I
Pungwe	X		C		C			C						I		C				
Limpopo	X		C	I	C	I	C			C				I		C				
Incomati	X		C	I	C	I		C		C			C	I		C	I			I
Maputo		X			C					C				I		I	C			
Thukela	X	X	C		C			C		C			C	I		I	C			
Betsiboka	X		C			C	C							I		I			I	I
Tsiribihina			C			C	C							I		I				
Mangoky			C			C	C							I						
Fiherenana	X		C			C	C		C					I				I		I

Key: Hot spot basin C = Cause I = Impact Where both "C" and "I" are present indication is of cause and impact applicable in different parts of the basin

1.4.5 Problem area 4: Declines in Living Marine Resources

1.4.5.1 Overview of the problem in the WIO

Globally, it is now well established that the majority of marine wild capture fisheries are fully or overexploited. Fishing methods may impact on other non-target species, and contribute towards the loss or disturbance of natural habitats, further threatening the long term survival of species which depend upon these habitats for feeding, breeding or other critical life processes. Populations of many species, including the larger more charismatic marine mammals, seabirds, sea turtles, as well as endemic species have been affected by fisheries activities. The issue categories related to declines in living marine resources as identified from the MEDAs and included in this Main Area of Concern are described below:

Decline of populations of focal species

Focal species is an umbrella term that is usually used to refer to a collection of species of conservation concern, which may include endemics, flagships, indicators, keystones, targets, and vulnerable species. In this context it has been used to group the charismatic flagship and vulnerable species. The commercially important indicator and target species are dealt with in the subsequent section.

1.4.5.2 Decline in populations of marine mammals (excluding cetaceans)

(a) Problem Statement

There are five marine mammal species other than whales and dolphins found within the region, which include: one species of Sireniidae (*Dugong dugong*) which was found throughout the region, and four species of Pinnepeds (*Arctocephalus pusillus*, *Arctocephalus tropicalis*, *Mirounga leonina*, *Lobodon carcinophagus*), which are mainly found along the South African coast, but have also been reported as vagrants from other locations. Dugong are potentially the most threatened and vulnerable species within the WIO and now extremely rare. The population is estimated to be less than 500 animals, the majority of which are found in Mozambique (Bazaruto Archipelago). Recent surveys have also found potentially significant populations in northwest Madagascar (Ridoux *et al.* 2010), and Mayotte (Kiszka *et al.* 2007a, b, c) but the viability of these populations remains uncertain. Populations of dugong have declined due to hunting and incidental capture in commercial and artisanal fisheries (gillnets, trawlers and other set nets) and habitat loss (particularly seagrass beds) as a result of pollution and physical disturbance. In more recent years, an increase in tourism activities and boat traffic also pose a threat to these marine mammals through noise pollution and boat strikes.

Dugong populations around Mauritius and Rodrigues, which were once common in the lagoons, went extinct a long time ago, and no sightings have been reported in recent years (Turner and Klaus 2005). Only a few individuals having been recorded in Seychelles waters at Aldabra atoll (WWF EAME 2004). Comoros used to host a population of several hundred dugongs in Mohéli Marine Park, especially during the austral winter months when seagrass beds exhibit the fullest, but sightings are now rarer than before (WWF 2004, Muir and Kiszka 2011, ASCLME 2012a).

The largest remaining viable dugong population in eastern Africa is found in Bazaruto Bay, Mozambique, although this population is also now considered to be declining (Muir *et al.* 2004). Recent aerial surveys conducted between April 2006 and December 2007 estimated 247 animals (Cockcroft *et al.* 2008, Findlay *et al.* 2011). Dugongs sightings in other parts of Mozambique are now relatively rare (WWF 2004) and in adjacent Tanzania (ASCLME 2012c). There is a small resident population in the Rufiji-Kilwa-Mafia area, at Moa in Tanga region, and in the Pemba-Zanzibar channel, but estimates indicate no more than 100 individuals (ASCLME 2012c). There is possibly a viable dugong population remaining in Somalian waters, although there is limited recent information available (ASCLME 2012i), and in Madagascar (Ridoux *et al.* 2010), and Mayotte (Kiszka *et al.* 2007).

Dugong is still a desired source of meat and they are still targeted in Mozambique, Madagascar (Van der Elst 2012), Comoros (ASCLME 2012a) and Somalia (ASCLME 2012i). Hunting of large mammals has been intense in Somalia, leading to catastrophic declines hence the uncertainty regarding the remnant populations of dugong (ASCLME 2012i). Dugongs are also caught incidentally by commercial, artisanal and traditional fisheries. Entanglements in gillnets appear to be a major cause of dugong mortality in Mozambique (ASCLME 2012d), Tanzania (ASCLME 2012c) and Somalia (ASCLME 2012i). Habitat losses (seagrass beds) due to trawling for shrimp and noise pollution associated with trawling are also a concern.

The South African fur seal (*Arctocephalus pusillus*) is found along the south and southwest coasts of South Africa (Best 2007). Fishing activities have reduced fish stocks on which seals depend; the reduction in prey resources would have a negative impact on their populations. Furthermore, cape fur seals are often trapped and drowned in nets. Fishermen view seals as a pest that compete with them for fish and destroy their fishing gear in the process. Some fishermen retaliate by killing seals at sea by shooting or clubbing them (ASCLME 2012e).

(b) Transboundary Scope

Dugongs are listed as a 'Vulnerable' species on the IUCN Red List, and the South African fur seals, are listed as a species of 'Least Concern' on the IUCN Red List. The status listing of dugong is based on a reference site in Queensland, Australia, due to the lack of data on available on this species from other regions within their known distribution range. Some local populations within the WIO have already gone extinct and few of the remaining populations are considered viable. The dugong is therefore a transboundary issue of concern at both the regional and global scale. Seven of the 9 countries identified concerns related to marine mammals as 'Relevant', and 5 countries ranked the issues as being of 'High' importance in the Level 1 prioritisation exercise. In the Level 2 prioritisation, only 2 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern within the WIO region at this time.

1.4.5.3. Decline in populations of cetaceans

(a) Problem Statement

Over 32 species of whales and dolphins have been reported from the waters of the WIO region, and these include baleen whales, sperm whales, toothed whales and dolphin species. The whole of the Indian Ocean south to 55°S was declared as a Whale Sanctuary in 1979. Within the WIO region cetacean populations are still declining due mainly to hunting and incidental catches by various fisheries (commercial, artisanal and traditional). Habitat disturbance and loss, pollution, collisions and climate variability and change are other factors contributing to the decline in local populations. Noise pollution is an increasing problem which disrupts orientation, feeding and communication ability of cetaceans, causing interference which may lead to strandings and physical damage to the ear of the animals if they are close to the source noise.

All countries reported the presence of whales and dolphins within their EEZ. Species numbers varied hugely indicating that further research of this species group is required. The largest number of species reported was from the Seychelles where over 40 species of whale and dolphin have been recorded, although there may be some taxonomic uncertainties (ASCLME 2012g). Cetaceans are not a fisheries target species in the Seychelles but there are several incidents of poaching of dolphins every year but the number of occurrences is on the decrease (ASCLME 2012g).

Dolphin species are still targeted by fishermen in some parts of the WIO, particularly in the south-west region of Anakao, Madagascar, for consumption and sale of meat. The species targeted include the bottlenosed dolphin (*Tursiops truncatus*), the Indo-Pacific humpbacked dolphin, (*Souza chinensis*) and the long-nosed dolphin (*Stenella longirostris*) (Andrianarivelo 2001, Razafindrakoto *et al.* 2004, 2007, Cerchio *et al.* 2009). The annual catch at Anakao was estimated to be between 100 and 150 spinner

dolphins (*Stenella longirostris*), with smaller catches of large dolphin and Risso's dolphin (*Grampus griseus*) (Razafindrakoto *et al.* 2009, COUT and Cooke 1994).

Incidental catches occur as a result of various fisheries (commercial, artisanal and traditional) but there is little data on the scale of the problem throughout the region. The results of the retrospective analysis conducted by SWIOFP suggested that in the WIO, unlike other regions, the impact of industrial fisheries on marine mammals is low to negligible but that several artisanal fisheries impose considerable threats (van der Elst 2012). The capture of delphinids in artisanal gillnet fisheries in Zanzibar and several other locations in Tanzania, was found to be high enough to negatively impact local populations (van der Elst 2012). Although the impact of by-catch is probably lower than for hunting in Madagascar, drift nets and longlines catch coastal species of dolphins, and cetaceans are also accidentally caught by jarifa (shark nets) (ASCLME 2012f). Other significant mortality of marine mammals is reported from bather protection shark nets in KwaZulu-Natal in South Africa (van der Elst 2012).

Other concerns include the increase oil exploration activities, will result in an increase in the amount of noise pollution, and pose a threat to cetaceans around the Seychelles (ASCLME 2012g). Noise pollution around major ports and activities, particularly industrial shrimp trawling and seismic and sonar studies undertaken by the oil industry, also create a disturbance for these animals in Madagascar. Collisions between ships and cetaceans as well as harassment, whether intentional or accidental, is increasing (ASCLME 2012f). Whale and dolphin watching has become a very popular tourist attraction in Madagascar and Mauritius, and the number of boats offering this activity has exploded in recent years as fishers have transitioned out of fisheries into the tourism sector (Mautitius MEDA 2012).

(b) Transboundary Scope

While some species of cetaceans may form resident populations, other species are highly migratory and thus transboundary. A decline in the populations of cetaceans was identified as a 'Relevant' by 6 of the 9 countries, and 5 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, only 3 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the WIO LMEs.

1.4.5.3 Decline in populations of seabirds

(a) Problem Statement

There are eleven seabird families within the WIO region including, penguins (Spheniscidae), albatrosses (Diomedidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), tropicbirds (Phaethonidae), gannets and boobies (Sulidae), cormorants (Phalacrocoracidae), frigatebirds (Fregatidae), skuas (Stercorariidae), gulls and terns (Laridae). Seabird populations in the WIO are threatened by hunting and egg collection; accidental bycatch particularly in the longline fishery, but also by gillnets; and habitat destruction or loss as a result of human activities or climate change; the introduction of alien predators such as cats and rats also affect many seabird populations. Many tropical seabird species forage in association with tunas, which drive prey to the surface and thereby bring them within reach of the seabirds (van der Elst *et al.* 2012). The Procellariiformes (albatrosses and petrels) are the most susceptible to being accidentally caught in longline fisheries (Brothers *et al.* 1999). The depletion of tuna stocks and other small pelagics, as well as the implications of climate change on the distribution and abundance of these 'food' fish species, could also impact bird populations although these kinds of impacts are difficult to predict.

Enforcement efforts to control the amount of Sooty tern (*Onychoprion fuscatus*) eggs harvested commercially have failed and poaching is still an issue, especially on the outer islands, due to logistical and economical constraints (Feare *et al.* 1997, Rocamora and Skerrett 2001). Egg collecting also takes place in Madagascar and is considered to be a major factor in the decline of seabirds in coastal waters (ZICOMA 1999), although systematic study on this subject has yet been conducted

(ASCLME 2012f). Bird breeding populations have severely reduced due to predation of eggs, chicks and adult birds by introduced animals such as *Rattus* spp., *Felis catus*, *Tyto alba* and *Acridotheres tristis* (Rocamora and Skerrett 2001, ASCLME 2012f). Other bird species are threatened by habitat destruction and/or loss from land use changes such as coconut plantations (ASCLME 2012g). Albatrosses and giant petrels and other birds are sometimes accidentally caught by longlines when these birds dive after the bait on the fish hooks (van der Elst 2012). Mitigation measures to reduce seabird by-catch include night setting with minimum deck lighting, bird-scaring lines (tori lines) and weighted branch lines (IOTC 2009, van der Elst 2012).

(b) Transboundary Scope

Seabirds spend the majority of their life at sea and some species are highly migratory, and this is therefore a transboundary issue of concern. Eight of the 9 countries identified concerns related to seabirds as 'Relevant', only 3 countries ranked the issues as being of 'High' importance. In the Level 2 prioritisation, only 1 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the ASCLMEs.

1.4.5.4 Decline in populations of turtles

(a) Problem Statement

There are five species of sea turtle known to frequent the waters of the WIO region (Marquez 1990, Ratsimbazafy 2003, Seminoff 2004) all of which are included on the IUCN Red List, and on Appendix I of CITES which means that international trade in live specimens or their products, is prohibited. The species found include two 'Critically Endangered' species, the Hawksbill (*Eretmochelys imbricata*) and Loggerhead turtle (*Caretta caretta*), two 'Endangered' species, the Green turtle (*Chelonia mydas*) and Leatherbacks (*Dermochelys coriacea*), and one 'Vulnerable' species, the Olive Ridley turtle (*Lepidochelys olivacea*). The Green and Hawksbill turtles are the most widely distributed and the Green turtle is the most numerous within the WIO. Loggerhead and Leatherback turtles are most common in South African waters. Little is known about the distribution and abundance of the Olive Ridley turtle within the WIO, and it may be more of a vagrant to the region.

The main threats to turtles in the region include: hunting for meat, eggs and carapaces; habitat disturbance, loss and degradation of nesting beaches and foraging grounds (e.g. coral reefs and seagrass beds); pollution, marine litter, oil pollution, sedimentation, light and noise pollution; incidental capture in industrial and artisanal fisheries and; disease. Hawksbills and Green turtles are the most commonly exploited species in the region (Hughes 2010). Female turtles generally spawn at night and can be disturbed by the presence of lights on the beach, inducing them to retreat without laying. Electric lights can also affect new hatchlings, inducing them to approach the light instead of moving towards the horizon to the sea. Sea level rise may modify nesting beaches and rising temperatures may also affect embryo development, causing sex ratio bias toward females (Mortimer 2003). Although reporting of bycatch of sea turtles is generally poor, there are reports of catches by purse seiners, longliners, and gillnets. The most common species caught by the purse seiners were Olive Ridley, Green and Hawksbill turtles (van der Elst 2012).

There are two species of marine turtles which are encountered in the coastal waters of Mauritius (*Eretmochelys imbricata* and *Chelonia mydas*). Both species used to nest on Mauritius and Rodrigues but there is no evidence of nesting in recent times, which is thought to be due to the loss of nesting beaches. There are still nesting beaches on St. Brandon and Agalega. In Mauritius the Hawksbill was traditionally exploited for the carapace and eggs and the Green turtle was exploited for meat, eggs, fat and leather (ASCLME 2012h).

Four species of sea turtle are found in the Comoros including the Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*), Loggerhead turtle (*Caretta caretta*), and Leatherback turtle (*Dermochelys coriacea*) (ASCLME 2012a). Previously all the beaches of the Comoros were nesting sites, now only the Mohéli Marine Park has nesting beaches, and these are some of the most important

in the region. The main threats to sea turtles in Comoros include habitat loss, due to sand and stone mining on nesting beaches, discharge of groundwater and surface runoff, and poaching. Despite large public sensitization programs, environmental education in schools and surveillance by coastguards, poaching of Green turtle for its meat and eggs is still prevalent in Comoros. A traditional trade for turtle meat is still active in Anjouan and Moheli. However in some places, such as Itsamia's village, the population is well educated on the importance of turtle conservation and the whole community is supporting anti-poaching activities.

(b) Transboundary Scope

All marine sea turtles are listed on the IUCN Red list and CITES Appendix I, and five of these highly migratory species are found in the region, indicating that this is a transboundary issue of concern at both the regional and global level. Recent results of satellite tagging studies have confirmed that turtles migrate between countries within the region (SWIOFP 2012). All 9 countries identified concerns related to sea turtles as 'Relevant', and 8 of the 9 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 6 of the 9 countries assigned the issue an 'Overall rating' score that was above average, indicating that this might be a priority transboundary issue of concern. There was a discrepancy between the national and regional results, as the Regional 'Overall rating' score, was below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the ASCLME region.

Decline in populations of commercial fish stocks

Globally marine wild capture fisheries are in decline, and this is also true for a number of the commercially important fish stocks within this region. The majority of countries identified a decline or uncertainty related to populations of commercial fish stocks in their MEDAs. The most common cause for the declines is overexploitation, which is an issue of concern for all countries, and Illegal, Unregulated and Unreported (IUU) fishing.

1.4.5.5 Decline in populations of sharks and rays

(a) Problem Statement

Shark and ray fisheries and bycatch are prevalent throughout the region (Kizska and van der Elst 2012). All elasmobranchs (sharks and rays) and the related chimaeras are highly vulnerable to overexploitation due to their slow growth, late age at maturity, low fecundity and large size at birth. Globally, landings have been increasing at a rate of 2 % per annum and are now estimated at 700,000 to 850,000 tons of sharks per year (Camhi *et al.* 2009, Lucifora *et al.* 2011). This figure is likely to be an underestimate given that it does not account for illegal fin fishing (Clarke *et al.* 2006). In the western Indian Ocean (FAO fishing area 51), elasmobranch catches peaked at 180,000 Mt in 1996, partly associated with increased efforts targeting tuna (Smale 2008). Based on voluntary declared FAO records there is evidence that shark catches in the WIO have more than halved, and in 2009, elasmobranch landings were reported by 33 countries totalling 86,000 Mt (Kizska and van der Elst 2012). There are over 200 species of sharks and rays that have been reported in catches and 15 species of sharks (belonging to five families) that are regularly caught in the WIO (Kizska and van der Elst 2012, Smale 2008); the most common species being blue (*Prionace glauca*) and silky sharks (*Carcharhinus falciformis*) (Smale 2008). While it is known that sharks are taken both as bycatch and target species in several industrial and artisanal fisheries, knowledge on the extent of bycatch and level of exploitation of elasmobranchs are poorly documented (Kizska and van der Elst 2012). In the IOTC (Indian Ocean Tuna Commission) records, most elasmobranch landings in the region are not identified to species and are grouped as "sharks", and there is insufficient data to properly assess the status of stocks (IOTC SR14, 2011). Shark bycatch is commonly associated with the pelagic fisheries including the purse seine fishery and the pelagic longline fisheries, targeting other species such as tuna and swordfish, and fisheries associated with FADS (Kizska and van der Elst 2012). These fisheries mainly affect three main shark families including Lamnidae, Alopiidae and Carcharhinidae. The industrial shrimp fishery with shallow inshore and deeper offshore elements also catches significant amounts of elasmobranchs (Fennessy 1994).

Shark populations in RSA waters are declining, in particular blue and mako sharks. There is a shark fishery in South Africa which catches of elasmobranchs, taken in longline, trawl and line fisheries (van der Elst 2012). These are legally harvested elasmobranchs that are declared and subject to management regulations. Shark and ray bycatch is problematic in several of main commercial fisheries including: the large pelagic fishery, the midwater trawl fishery and, the line fishery. Sports and recreational fishers also target sharks; the shark-nets along the southern and eastern seaboard to protect bathing beaches also result in mortality. South Africa also offers non-consumptive resource use/tourism sector, in the form of shark cage-diving operations, although this is not thought to be a factor in the decline of shark stocks (South African MEDA 2012).

In the Seychelles, the local semi-industrial long-line fishery which started in the mid-1990s to target swordfish and tuna has resulted in an increased shark bycatch. In the late 1990 it was noted that some of the long-line vessels were increasingly targeting and finning shark in order to export this high-value commodity, and targeting has increased in recent years and there are currently three companies exporting shark fin (Kizska and van der Elst 2012). In 2007, a National Plan of Action (NPOA) for the conservation and management of sharks was produced. The NPOA indicated that the shark fishery is data deficient but that significant historical, anecdotal and fisheries-independent information suggest that inshore populations are severely depleted (ASCLME 2012g). Stocks of inshore sharks have also been described as being depleted in recent fisheries reports (FAO 2009).

In Somalia, elasmobranchs are heavily exploited in both the industrial and artisanal sectors (FAO 2005b), and represent 40 % of the artisanal catches. The principal groups are hammerheads (Sphyrnidae), grey sharks (Carcharhidae), mako shark (Lamnidae), houndsharks (Triakidae) and dogfish (Squalidae). Shark populations are also declining due to the unmanaged harvest of shark fins (Pilcher and Alsuhaibany 2000). Sawfish (Pristidae), which are classified as "critically endangered" on the IUCN Red List and on Appendix I of CITES are also caught as bycatch in shark gill net in Somalia.

While in Kenya there is no reported directed fishery for sharks, there is trade in shark meat and fins (Kizska and van der Elst 2012). The main species of sharks landed from licensed and non-licensed vessels calling at Port Louis consisted of blue (58.1 %) and short-fin mako sharks (38.9 %; Mamode 2011). In Tanzania, Madagascar, Comoros there are artisanal fisheries which target shark using different types of gill nets and longline (Kizska and van der Elst 2012). The catches of the artisanal fishery in Toliara in Madagascar, Hammerhead sharks (*Sphyrna* spp.) composed 29 % of sharks caught by number and 24 % of the total wet weight (McVean et al. 2006).

Most of the elasmobranchs taken in Mozambique waters caught as bycatch, and prawn trawlers catch the most significant amount of elasmobranchs, especially over the continental shelf. Bycatch reduction devices have been tested and over 75 % of hauls with exclusion grids caught fewer large rays than those without grids, while all hauls using grids caught no large sharks at all (Fennessy and Isaksen 2007). There is however still also opportunistic targeting, and Kizska and van der Elst (2012) reported the intense pursuit of mantas at Ligogo in 2010, where a large number of mantas *Manta alfredi/ birostris* and *Mobula kuhlii* were caught in gill nets.

In Mauritius, sharks are not targeted but they are caught as bycatch in the semi-industrial and industrial fishery. For the years 2009-2010 a total of 2,349 tons of sharks was transhipped at Port Louis, consisting mainly of blue (58.1 %) and short-fin mako sharks (38.9 %, Mamode 2011).

(b) Transboundary Scope

Relatively little is known about the elasmobranchs populations of the WIO region. Some of the species of the sharks and rays found are highly migratory while others tend to form more resident populations. It is known that the migratory sharks can show limited population genetic structural diversity, even at the global level (Castro *et al.* 2007). Significant (haplotypes frequency) differences may still be found in the populations of some species (e.g. whale sharks) between, for example, the Atlantic and the Indo-Pacific regions, highlighting the need for broad international approaches for management and

conservation (Castro *et al.* 2007). More significantly distinct genetic populations may exist for other species with less migratory tendencies, disjunct distributions or reproductive philopatry, (e.g. scalloped hammerhead shark *S. lewini*) (Duncan *et al.* 2006). With the exception of South Africa, few (if any) countries in the region have assessed the stocks of sharks and rays (van der Elst 2012). In addition, given that many of the species found within the region are listed on the IUCN Red List, this is a transboundary issue of concern within the region and globally. The targeting of sharks for their fins is also a global transboundary issue of concern. Eight countries identified concerns related to sharks and rays as 'Relevant', and 8 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 7 of the 9 countries assigned the issue an 'Overall rating' score that was above average. There was agreement between the national and Regional 'Overall rating' score, which was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern within the WIO.

1.4.5.6 Decline in populations of large pelagics

(a) Problem Statement

Large pelagics, such as tuna and tuna-like species including billfishes, are apex oceanic predators. These species make up nearly 50 % of the total landed catches within the WIO (Cochrane and Japp 2012). The fisheries targeting these species are diverse and include small-scale or artisanal fisheries, sports fisheries, as well as by national and foreign industrial and semi-industrial fleets. Pelagic landings (excluding foreign fleet data per EEZ) have boomed over the last decade (Cochrane and Japp 2012). Factors that have increased the national catches include the deployment of Fish Aggregating Devices (FADS), which have increased landings by artisanal and sports fisheries in the region. Landings in Seychelles waters alone increased four-fold between 1995 and 2005, due to increased investment in the national fleet and the setting up of joint ventures to supply the cannery. Many other countries have not significantly increased their national catches of large pelagics, but there have been significant increases in the landings by foreign vessels.

Tuna catches are largely made up of skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacores*), followed by bigeye tuna (*T. obesus*). Catches of large pelagics other than tunas are much lower than for the main tuna species and consist mainly of swordfish (*Xiphias gladius*) and the Indo-Pacific sailfish, (*Istiophorus platypterus*) (Cochrane and Japp 2012). Catches of bigeye, skipjack and yellowfin tuna have all declined in recent years although this may be related to the expansion of piracy in the WIO and the resulting drop in fishing effort. The swordfish stock has been overfished in the past decade and now appears to be highly depleted in the SWIO compared to other regions within the Indian Ocean.

The latest report by the Indian Ocean Tuna Commission (IOTC-SC14 2011) included stock assessments for the priority species. Maximum Sustainable Yield (MSY) has been determined for 5 of the 15 large pelagic fish species (Albacore, Bigeye, Skipjack, Yellowfin and Swordfish). The status of the stocks for the other 10 species listed in this report (Longtail tuna, narrow barred Spanish mackerel, Bullet tuna, Frigate tuna, Kawakawa, Indo-Pacific king mackerel, Black Marlin, Blue Marlin, Striped Marlin and Indo Pacific Sailfish), excluding sharks, are classified as 'Uncertain' as there is "*no quantitative stock assessment available due to the lack of a fishery data for several gears*". There is a particular concern about the stock status of yellowfin (*Thunnus albacores*) and big eye (*T. obesus*) tuna (IOTC-SC14 2011), and recommendations have been made to reduce landings to the MSY levels. The Indian Ocean Swordfish (*Xiphias gladius*) are caught mainly using drifting longlines (95 %) and gillnets (5 %).

Landings of swordfish in the Indian Ocean slowly increased in tandem with the level of coastal state and distant water fishing nation longline effort targeting tunas between 1950 and 1980. Swordfish were mainly a bycatch of industrial longline fisheries before the early 1990's with catches slightly increasing from 1950 to 1990 proportionally to the increase in the catches of target species (tropical and temperate tunas). Data indicate that stocks in the southwest Indian Ocean have been overfished in

the past decade and biomass remains below the level that would produce Maximum Sustainable Yield (MSY).

Other billfishes, such as the Indo-Pacific blue marlin (*Makaira mazara*), black marlin (*M. indica*) and Striped marlin (*Tetrapturus audax*) are caught almost exclusively under drifting longlines (~50-98 %) with remaining landings being caught by gillnets, troll and hand lines. These species are usually considered as bycatch by the industrial fisheries. Stock assessments have not been completed for marlin species, but landings (nominal CPUE) have all exhibited declines since the fishery commenced. Other factors which may influence the stocks of these highly migratory species include changes in seawater temperatures, but there is currently insufficient data to be able assess its importance (Anon 2009).

There is concern about the stock status of yellowfin (*Thunnus albacores*) and big eye (*T. obesus*) tuna from the Seychelles. A recent stock assessment conducted by the IOTC working party on Tropical Tuna in 2009, incorporating recently obtained data from the Regional Tuna Tagging Programme-Indian Ocean (RTTP-IO) revealed that the stock of yellowfin tuna has been over-exploited with catches averaging 343,000t (1992-2002 period). It was recommended that catches should not exceed the MSY (250,000 and 300,000t) levels estimated by the current assessment (Cochrane and Japp 2012).

Large pelagics (and demersal sharks) in South Africa are targeted by the longline fisheries and a pole fishery for tuna. The longline catch is dominated by five species (yellowfin tuna, bigeye tuna, blue shark, longfin tuna and mako shark) which make up 75 % of landings, although up to 61 species may be retained. Other non-directed bycatch recorded from this fishery include sharks, killer whales (depredation) and marine birds (Grantham *et al.* 2008). While this is a relatively small fishing sector, the South African EEZ and surrounding waters are also heavily fished by foreign tuna fleets which access the ports for servicing and fish transshipments.

(b) Transboundary Scope

Large pelagics are heavily targeted within the WIO by a diverse range on fisheries, ranging from small-scale artisanal fisheries to large commercial fishers, as well as recreational fishers, from within the region and beyond. Industrial fishers in the WIO tend to be distant water fishing fleets from Asia and Europe that target a wide range of migratory fish, such as tuna, kingfish, bonito, and mackerel, most of which are sold in the export market. Because of the highly migratory nature of many large pelagic species, several of the target stocks are shared between the EEZ of the countries within the region, and this is a transboundary issue. All 9 countries identified concerns related to large pelagics as 'Relevant', and 7 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 7 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern within the WIO LMEs.

1.4.5.7 Decline in populations of small pelagics

(a) Problem Statement

Small pelagic fisheries may target small tuna-like species including horse mackerel and mackerel, (Scombridae), barracuda (Sphyraeidae), Jacks (Carangidae), sardines (Clupeidae), anchovies (Engraulidae). They are targeted mainly by the artisanal and industrial fisheries, including shrimp trawlers using a variety of fishing gear (e.g. bottom-set gill nets, beach seine nets and purse seines). The purse-seine fisheries for small pelagics typically targets scads, sardines, small mackerels (Lucas *et al.* 2009). The artisanal coastal net fisheries (beach seine, small purse-seines, cast nets, ring nets) target small and medium pelagic fish species for own consumption and local sale in all countries within the SWIO region (Lucas *et al.* 2009, Cochrane and Japp 2012). The species targeted are variable, but they are often an important for food security among the artisanal fishers in the region. As these species may form large shoals in coastal waters, they are also often an important food fish for other species, such as seabirds.

An artisanal purse seine fishery in Tanzania that mainly targets sardine and anchovy, which together form 30-50 % of total fish landings (ASCLME 2012c). In Kenya, ring nets, cast nets and seine nets are used to catch medium and small pelagic species (Maina 2012).

Artisanal fisheries in Madagascar use cast nets and gill nets to catch medium and small pelagic fish species including small Scombridae, such as the eastern little tuna, *Euthynnus affinis*, the wahoo, *Acanthocybium solandri*, the narrow-barred Spanish mackerel, *Scomberomorus commerson*, the Indian mackerel, *Rastrelliger kanagurta* and *Auxis* spp., Sphyraeidae, Carangidae, sardines (Clupeidae), anchovies (Engraulidae), Hemiramphidae, Belonidae and others (ASCLME 2012f). Small pelagic fishes are also targeted by shrimp trawlers in all shrimp fishing zones, and there is a significant decline of small pelagic fisheries in Madagascar (ASCLME 2012f).

In South Africa, species mixing between juvenile anchovy (*Engraulis encrasicolus*) and juvenile sardine (*Sardinops sagax*) causes an “early season” fishery problem (before separating into discrete shoals), presenting fishery management issues such as discarding and dumping (ASCLME 2012e). Seabirds which feed on anchovy and sardine must compete with purse-seine fisheries for food and as a result, some have suffered large decreases in the past 50 years (Crawford *et al.* 2007).

(b) Transboundary Scope

Stocks of some small or medium pelagic species are known to straddle the boundaries between national EEZs and the high seas or both and some species are known to undergo migrations across national borders (Cochrane and Japp 2012). The stock structure of many small and medium pelagic species in the Indian Ocean has yet to be defined (Cochrane and Japp 2012). Small (and medium) pelagic species are not targeted in all countries but where they are targeted they are often important for food security (Cochrane and Japp 2012). So while this is a transboundary issue of concern, it is also a shared concern within the region between those countries that target these species. Only 7 of the 9 countries identified concerns related to small pelagics as 'Relevant', and 5 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 5 of the 9 countries also assigned the issue an 'Overall rating' score that was above average, indicating that the majority of countries consider this to be a priority transboundary issue of concern in the WIO. The Regional 'Overall rating' score was however below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern in the WIO region at present.

1.4.5.8 Decline in populations of deep demersal fish species

(a) Problem Statement

Exploitation of deepwater species is a relatively recent development in the WIO (Clark *et al.* 2006). Deep water fisheries may involve dropline/long-line fishing (200-400 m depth) targeting deepwater snappers and other associated fishes; and conventional line fishing (mainly hand-line, less than 200m depth) targeting a range of reef-associated fishes, and deepwater trawling, which could be considered the most concerning due to the associated habitat damage (Floros and Schleyer 2012). In the 1990's there was a shift in trawl effort towards deeper water and industrial deep-sea operations targeting deepwater species such as orange roughy (*Hoplostethus atlanticus*), cardinal (*Epigonus telescopus*), Alfonsino (*Beryx splendens*), deep water dory (*Allocyttus verrucosus*) and others (FAO 2007, 2009). Rich deepwater resources (mostly demersal species) were discovered, particularly on the South West Indian Ocean Ridge and on deep-sea seamounts. Efforts in or adjacent to the South African EEZ were largely short-lived with few economically commercial stocks identified (Japp and James 2005). The exploitation of this area has been documented in FAO technical reports and by Japp (2006). Many deep-water species have life history strategies that are vulnerable to exploitation (slow-growing, aggregating behaviour etc), and without proper and sustainable management, they have typically followed a 'boom and bust' cycle. After very high initial catches per unit effort, the stocks are depleted rapidly over short time scales (5 years) and the areas are either closed to fishing or no longer supported commercial fisheries (Clark *et al.* 2006). These fisheries are typically associated with hard grounds and sensitive deep-water coral habitats and other benthic flora and fauna (Clark *et al.* 2006,

Rogers *et al.* 2009). The fishing industry, as represented by the Southern Indian Ocean Deep-sea Fishers' Association (SIODFA), has since attempted to limit the impact of trawling by voluntarily halting trawling in eleven deep-sea areas of the southern Indian Ocean. SIODFA have established benthic protected areas (BPA) where bottom trawling, mid-water trawling and dredging is forbidden to SIODFA members (van der Elst 2012). This will probably help to protect of some benthos, although the areas are not monitored.

In Madagascar, continental shelf and slope surveys carried out in the 1970s, in the Northwest identified almost 20 species of commercially important deepwater demersal fish. In 2007, a pilot fishing for alfonso *Beryx splendens*, was launched by a South African company using deep trawling techniques. The gear used on these trawls are able to deflect rocks weighing several tonnes and destroy large areas of underwater habitat, particularly on seamounts and continental slopes and shelves (ASCLME 2012f).

Demersal fisheries in the Seychelles are carried out by both the artisanal and commercial fisheries. Important demersal species include red snappers, groupers, job fish, and emperors (Nageon de Lestang 2011). The two main fishing grounds for the demersal handline fishery are the Mahé Plateau and the Amirantes Plateau at depths from 25 - 70 m. Other fishing areas include the offshore banks and around the southern Group of coralline islands. Experimental drop-line fisheries for certain deepwater species resulted in the rapid removal of stocks (*P. filamentosus*) (Grandcourt 2008).

(b) Transboundary Scope

Not all of the countries have developed deepwater demersal fisheries, and knowledge about these stocks is limited (van der Elst 2012). However as coastal populations expand and nearshore fisheries declines, there is growing interest in these deeper offshore fish resources, within EEZs and beyond. There has been an expansion of these fisheries targeting these resources in the high seas, and more countries are considering developing fisheries which specifically target offshore resources (Clark *et al.* 2006, Cochrane and Japp 2012). Only 6 of the 9 countries identified concerns related to deepwater demersal as 'Relevant', and only 4 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 3 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern.

1.4.5.9 Decline in populations of reef and demersal fish

(a) Problem Statement

Reef and nearshore demersal fish are heavily exploited throughout the WIO (Heileman 2012). These resources are largely exploited by artisanal fisheries as they are typically open-access, and are within relatively easy reach of the shore, thus requiring minimal investment. Population growth and coastal migration have increased pressure on these resources. Increased wealth and the expansion of coastal tourism in some countries have also fuelled the demand for more fish. There are currently 738 marine fish included on the IUCN Red Data List for the WIO, which includes 492 species of (68 %) and 83 families teleost fishes, which are dominated by coral reef species (van der Elst 2012). Many of the preferred reef-associated fishes are becoming increasingly rare throughout the region, and some species are now recognised as being of international concern for conservation, including many species of grouper (Serranidae), the humphead wrasse, *Cheilinus undulatus* (Labridae) and the double-headed parrotfish (*Bolbometopon muricatum*) (Scaridae) (van der Elst 2012). Overfishing of reef and demersal fishes may cause an imbalance in the functioning of the wider reef ecosystem. Overfishing of herbivores can result in the smothering of corals with algae, and overfishing of keystone predators can lead to outbreaks of nuisance species (e.g. sea urchins *Diadema* spp.) (McClanahan and Obura 1996). Overfishing can also have impacts higher up the food chain. As resources become progressively more depleted there has been an increase in the use of more destructive and non-selective fishing methods, involving the use of dynamite, plant derived poisons or smaller mesh size nets, such as mosquito nets.

An estimated 60,000 coastal residents depend on the small-scale fisheries in Kenya for their livelihood. Over-fishing has been compounded by an increase in the use of destructive fishing methods which has led to a 50 % decrease in demersal coral reef fish yields through the 1990s. Rabbit fish and scavengers, which now make up nearly 40 % of the small-scale fishers' landings, declined by 40 % in the 1990s. Population growth, along with high levels of poverty in the coastal region has resulted in a 34 % increase in the number of fishers between 2004 and 2008 and further over-exploitation (ASCLME 2012b).

The artisanal fisheries of Tanzania contribute more than 96 % of the total marine fish catches, of which reef and demersal fishery contributes approximately half (ASCLME 2012c). Fishing effort is concentrated on coral reefs, sea-grass beds and reef flats areas, and as a result of heavy fishing pressure the fishery is showing signs of over-exploitation (Tarbit 1984). Destructive fishing practices, most notably dynamite fishing, are common in coastal areas near urban centres such as Dar es Salaam, Tanga and Lindi. Dynamite fishing has contributed to the further decline in the productivity and catches of artisanal fishery. The seine net fishery is also destructive, as the fishers encircle the reef with nets and then scare the fish into the net by breaking the coral heads.

In the Comoros, the reef fishery produces 3000 tons per year. Overexploitation has meant that commercially important food fishes including jacks, groupers and parrot fishes are now very rare (ASCLME 2012a). There has been an increase in the use of destructive fishing methods including the use of dynamite and plant poisons (*Thephrosia candida*), which paralyzes and kills fish and the use of small mesh nets. Other destructive fishing techniques have caused further habitat damage and contributed to the decline in species includes reef walking, the creation of retention ponds for use during low tide, damage due to use of paddles, machetes or pitchforks, bow-nets which requires walking on the reef flat, use stone line or bottom line on the reef flat or on the outer edge of the reef flat.

In Mauritius, reef and demersal fish are exploited by the artisanal and bank fishery. The artisanal fishery provides employment to over 2,000 fishermen on Mauritius (and at least double that on Rodrigues). The main families of fish caught are Lethrinids, Siganids, mullets, Scarids and groupers. Total production in 2009 was 820 tonnes (ASCLME 2012h). Reef and demersal fish stocks are over-exploited and no substantial increase in fish production in these areas is expected in future (ASCLME 2012h).

(b) Transboundary Scope

Reef and shallow water demersal fisheries are targeted in all countries, and are generally multi-gear and multi-species (Heileman 2012). These fisheries are predominantly artisanal, except for Madagascar, Mozambique and South Africa, where there are also semi-industrial and industrial fisheries. Several of the priority species are widely distributed in the SWIO region and could be shared or transboundary, but there is little or no information on the identity and spatial and temporal distribution of the stocks (Heileman 2012). Many of the priority food-fish species have been listed on the IUCN Red List, which indicates that there is concern about their status. All 9 countries identified concerns related to reef and demersal fish as 'Relevant', and all 9 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 7 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern within the WIO.

Decline in populations of commercial invertebrates

High coastal population densities within the ASCLMEs results in intense exploitation of nearshore resources by recreational and subsistence fishers. Many coastal invertebrate stocks are overexploited as a result, with significant impacts on both target and non-target species having been recorded.

1.4.5.10 Decline in populations of molluscs (bivalves, gastropods)

(a) Problem Statement

As with many of the fisheries for invertebrates, bivalves and gastropod mollusc resources are usually exploited in nearshore habitats, most often by reef gleaning or snorkelling. Molluscs are often collected opportunistically as additional catch alongside other fishing methods. The main molluscs targeted are the edible and ornamental species. Several gastropod and bivalve mollusc species are listed in Appendix II of CITES, or in Annex 2 of the Nairobi Convention. These include the giant clams (*Tridacna* spp.), pearl oysters (*Pinctada* spp.), the queen conch (*Strombus gigas*), the triton (*Charonia tritonis*) and (*Trochus niloticus*) among others. Many of these species are now becoming rare on the region's reefs.

Many tons of mollusc shells are exported to neighbouring countries (Madagascar, Kenya and Tanzania) (ASCLME 2012a). *Charonia tritonis*, which feeds on the corallivorous crown-of-thorn starfish (*Acanthaster planci*), is now rare in the Comoros. Even though there is a ministerial decree, which prohibits the collection of shells, licences are regularly given to exporters without any real control over the quantities or species exported. All the places more or less frequented by tourists offer shellfish for sale. The rarity of these molluscs is an indication of over-exploitation (ASCLME 2012a).

In Madagascar, no national legislation exists concerning the exploitation of gastropods and between 1989 and 1991, one Indian exporter from Toliara annually exported 8,000 kg of ornamental shells and 50 tonnes of industrial shellfish (WWF 1993). In 1997, it was reported that 138 species of gastropods were for sale in shellfish markets at Toliara. Bivalves are also exploited as food species such as clams (*Anadara antiquata*), oysters and mussels. Several species of food bivalves are overharvested (ASCLME 2012f).

High rural population densities, pervasive poverty, a lack of development and very limited control over natural resource use along the coastal sections of the underdeveloped former homeland areas such as Kwa-Zulu, Transkei and Ciskei, have resulted in the stripping of coastal shellfish and other natural resources for subsistence consumption (ASCLME 2012e).

(b) Transboundary Scope

Mollusc fisheries are not targeted in all countries and generally the fishery is artisanal. There is little knowledge about these fisheries as they are typically not monitored, even though several of the species are listed on Appendix II of CITES. Only 7 of the 9 countries identified concerns related to molluscs as 'Relevant', and only 2 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, only 2 of the 9 countries assigned the issue an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the WIO.

1.4.5.11 Decline in populations of cephalopods

(a) Problem Statement

Cephalopods are members of the Phylum Mollusca, and there are over 16 species within the region, which are all active predators that trap prey using their tentacles. There are fisheries that target squid, cuttlefish and octopus, the most widespread of which is the artisanal octopus fishery (van der Elst 2012). Declines in octopus fisheries landings were reported by several countries due mainly to overexploitation and habitat damage. According to the South West Indian Ocean Fisheries Commission (SWIOFC) the octopus fishery is classified as 'Overfished' in the SWIO region (FAO-SWIOFC 2012). This fishery is usually open access, requires little financial investment, and is often done by young people and women as it requires minimal investment. The most common fishing technique employed throughout the region is to use a long metal spike, or harpoon, with a crook end to lure the octopus from the den in the reef rock, break open the den and to spear the octopus once caught. This method of fishing may be supplemented by the use of oil, to help smooth surface ripples

and increase visibility through the water column (Klaus pers obs.), or by the use of lime to stun the octopus and make it exit the den (ASCLME 2012a). Reef walking causes habitat damage, particularly in coral dominated habitats, and the fishing technique also leads to further breakage of the corals (Klaus pers. obs.).

In Mauritius, there are fisheries targeting both squid and octopus, both of which are important artisanal fisheries, particularly on Rodrigues. The octopus fishery (*Octopus cyanea*) provides a livelihood to over 2000 people but is heavily overfished. Catches in Rodrigues have declined by more than 75 % over the past 20 years, from 800 tons in 1994 to approximately 200 tons in 2006 due to overexploitation, habitat degradations and lack of management control (Sauer *et al.* 2011).

Cephalopods represent a significant fishing resource in Tanzania (octopus, cuttlefish and squids). The common octopus, *Octopus vulgaris* is the cephalopod species with the highest landings in Tanzania particularly among the artisanal fleet. Traditionally, this species has been caught by the artisanal fleet using spears, traps and hand collection during low tides. Regulation has been proposed to include a minimum legal capture of an individual octopus weighing not less than 500 g. Production and export data have revealed that catches of octopus are declining rapidly from 430,000 kg in 2000 to 57,000 kg 2007, representing a 87 % decrease in 7 years, which is attributed to overfishing stimulated by high prices of octopus in international markets (ASCLME 2012c).

In south west Madagascar, the octopus fishery (*O. cyanea*) is heavily overexploited. Between 1994 and 2002 production increased from 50 tonnes to more than 700 tonnes. The fishing grounds cover 400 km of coast from Fanambosy and Morombe reefs, and involve some 60 fishing villages. By 2005, there were declines in catches and the Ministry of Fishery announced a closed season between December 15 and January 31 and imposed a minimum size limit of 350 g. An initiative then showed that a longer closure maximized the size of octopus, taking advantage of international markets that prefer sizes above 500 g (Humber 2006, ASCLME 2012f).

(b) Transboundary Scope

Cephalopod fisheries targeting squid, octopus and cuttlefish occur in all countries, and are mainly artisanal in nature with the exception of South Africa. Octopus fishing is a particularly important livelihood in a number of the countries. Recent studies using microsatellite DNA analysis have demonstrated that some cephalopod stocks (e.g. *O. cyanea*) are genetically indistinguishable within national population, they are divergent within the region, and specifically for this study between Rodrigues and Madagascar (Shaw 2011). This suggests that these populations are not exchanging migrants (i.e. through gene flow through larval dispersal) on a large scale or regular basis (Shaw 2011). Prevailing current flows across the region from east to west, and the biology of the species (i.e. pelagic larval stage), would support the potential for larval gene flow from Rodrigues to Madagascar. Future studies employing further molecular marker loci should be able to address this question of unidirectional gene flow. Only 8 countries identified the issue as being 'Relevant', and from the Level 1 prioritisation 7 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation, only 2 of the 9 countries allocated an 'Overall rating' score that was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern.

1.4.5.12 Decline in populations of sea cucumbers

(a) Problem Statement

Sea cucumber fishing is not a traditional fishery within the WIO, but it has rapidly and significantly increased in importance given the export value of the product Conand (2008). The fishery spread as a result of foreign demand for sea cucumbers, which grew in tandem with the economic growth in China and the Eastern region. Sea cucumbers are typically targeted by fishers using snorkel and mask or SCUBA equipment or collected as bycatch by spear fishermen and other gleaners. The gear and boats may be provided by dealers who purchase the processed product, while the collectors carry out the processing and drying at the landing beaches. Fishers typically target the six highest value species

(*Holothuria nobilis*, *H. fuscogilva*, *H. scabra*, *Thelenota ananas* and *Actinopyga mauritiana*) (Conand 2008). Sea cucumber resources in all countries in the WIO are presently either 'Over-exploited' (at least for the main commercial species) or 'Fully-exploited' (FAO-SWIOFC 2011). The fishery is characterised by a "boom and bust" nature, in that it often starts rapidly without any formal monitoring or management and then crashes just as fast, and this characteristic is common not only within this region but globally.

Most of the sea cucumber resources in the central and the southern regions of Mozambique are depleted, with the exception of those in the Bazaruto Archipelago National Park (Conand 2008). There has been a fishery for sea cucumber in Kenya and Tanzania since the 1990s, exploiting a range of species, and overexploitation is a concern (ASCLME 2012b, Tanzania MEAD 2012). Sea cucumbers are an important export product around Madagascar and natural populations are now overexploited (Conand 1998, Conand et al. 1997). The exploitation of sea cucumbers in Mauritius started on a trial basis in late 2005 and was continued by six licensed operators with exports of around 80 tonnes (Conand 2008). Stocks were rapidly depleted, particularly around Rodrigues, and the fishery is now closed. In Comoros, the sea cucumber fishery stopped soon after it had commenced due to two deaths from diving accidents. Now the harvesting and processing is controlled by Chinese immigrants (Conand 2008). In the Seychelles, the fishery was an open-access fishery until 1999. Since then management regulations have been put in place and only 25 licences are issued each year. There has been an upward trend in the catches, while the catch per unit effort (CPUE), expressed in numbers of sea cucumbers collected per diver per day, shows mostly a downward trend (Ameruddy and Conand 2008). There was a particularly high increase in catches between 2004 and 2005, although the number of fishing licenses (25) remained the same. This was most likely due fishers working as a group from a mothership, which meant they could stay longer at sea (Conand 2008).

(b) Transboundary Scope

Sea cucumber fishing is now widespread in the Indian Ocean. This is limited knowledge about whether the stocks in the region are shared, but given the prevalence of the fishery within the region this is a shared transboundary issue. Eight of the 9 countries identified the issue as being 'Relevant'. From the Level 1 prioritisation 8 countries also ranked the issue as being of 'High' importance. In the Level 2 prioritisation, 4 countries allocated an 'Overall rating' score which was above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern within the ASCLMEs.

1.4.5.13 Decline in populations of prawns and shrimp

(a) Problem Statement

Prawns and shrimp are targeted by both industrial and artisanal fisheries in shallow water throughout the WIOs, and in shallow (Fennessy 2012) and deep water along the mainland coast (Groeneveld 2012a). The same species are found and exploited along the entire East African coast to Kenya and also off the Indian Ocean islands (especially Madagascar). The main target species in the mainland countries are *Penaeus indicus* and *Metapenaeus monoceros* which together currently contribute around 90 % of landed shallow water trawled prawn catches (Fennessy 2012). Other commercially-valuable shallow prawn species (*P. monodon*, *P. semisulcatus*, *P. latisulcatus* and *P. japonicus*) contribute a smaller portion of trawl catches, with the exception of Mozambique from the early 1990s to the mid-2000s when the latter two species were specifically targeted at night. The deep water trawl fisheries, which is active in Mozambique and South Africa, target deep-water knife (or pink) prawns (*Haliporoides triarthrus*), several other deep-water prawns (*Aristeus virilis*, *Aristeus antennatus*, *Aristaeomorpha foliacea*, *Plesiopenaeus* and *Heterocarpus* spp.), and other crustacean species (Groeneveld, 2012a). Other countries with deep-water prawn fisheries include Madagascar, Kenya, and Tanzania, although these fisheries operate intermittently with fewer boats. There have been both scientific research trawls in Kenya, Tanzania, Mozambique, Madagascar, Mauritius and Comoros (Groeneveld 2012a).

The status of the stocks of the main commercial species are unknown in many countries, although a retrospective analysis of the shallow water fishery data from five countries along the East Africa coast indicates that stocks are compromised (Fennessy 2012), and various reasons are suggested including: recruitment over-fishing (due to heavy small-scale exploitation of juveniles in inshore waters before they recruit to the trawl fishery); growth over-fishing (caused by trawling of prawns too early in the season); general over-fishing (due to excessive trawling effort); habitat degradation (due to reduced river flow and destruction of mangroves); reduced profitability of the trawl sector (due to low market prices, caused by foreign mariculture, and increased fuel prices). Trawling gear can cause substantial habitat damage in nearshore areas, particularly seagrass beds, and these fisheries often result in bycatch of fish and more vulnerable species that frequent these habitats such as sea turtles and elasmobranchs (van de Elst 2012). The catches are a valuable source of foreign currency, particularly in Mozambique and Madagascar (Fennessy 2012). Small-scale (traditional) prawn fisheries have expanded as a result, leading to user-conflicts with the industrial trawl fishery. In Madagascar, the industrial trawl fishery has withdrawn from some areas as a result; in some instances the trawling companies purchase prawns from the small-scale sector. User-conflicts maybe exacerbated by the trawlers catching and discarding large amounts of bycatch of fish species which form part of artisanal fisheries' catches

In Mozambique shallow water prawn fishery is the most commercially valuable marine resource and the second most important species by volume, accounting for 29 %, followed by the deep water shrimp at 8 %, which were worth 46 million US dollars, and 12.5 million US dollars respectively in 2009 (USAID 2010). Commercial vessels operate mainly on the Southern Sofala Bank, Maputo Bay, Limpopo River, and Angoche. The artisanal beach seine fishery in Mozambique harvests adults and juveniles and catches of juveniles outweighs those of adults (ASCLME 2012d).

In Madagascar, artisanal and traditional fisheries joined the industrial shrimp fishing after some years of delay. With fairly stable industrial catches in the early 1990s, a first decline in the industrial catch was observed in 1999 and a significant drop from 2002, which is a major concern (ASCLME 2012f). In Kenya, there are both small scale and commercial fisheries for Penaeid prawn (*Penaeus indicus*, *P. semisulcatus*, *P. monodon*, *P. japonicas*, and *Metapenaeus monoceros*), and deep water prawns (*Heterocarpus woodmasoni*). Commercial trawlers compete with the small scale fishers who share the same fishing grounds and this leads to conflicts. Trawling methods are destructive to the habitats leading to a reduction in productivity (ASCLME 2012b).

(b) Transboundary Scope

Prawn and shrimp stocks may be shared between some of the countries within the WIO, particularly those along the East African mainland coast, although further studies are required to be able to confirm this possibility. The preferred habitats (soft, muddy, turbid, shelf substrata for adults; shallow, muddy estuaries for postlarvae/juveniles) are widely separated by unsuitable habitats and there is limited information about the potential for transboundary larval transport. SWIOFP genetic studies have yet to elucidate the extent or otherwise of connectivity between populations (Fennessy 2012). Eight countries identified the issue as being 'Relevant' so this issue is a shared transboundary issue as well. From the Level 1 prioritisation 6 countries ranked the issue as being of 'High' importance. In the Level 2 prioritisation 5 countries allocated 'Overall rating' scores which were above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern in the WIO.

1.4.5.14 Decline in populations of lobsters

(a) Problem Statement

Several species of lobster are targeted within the WIO by commercial and artisanal fisheries. The commercial fisheries tend to target deepwater species using traps and trawls (Groeneveld 2012a, b). These fisheries include industrial trap-fishery for spiny lobster, *Palinurus gilchristi* (South Africa, south coast); and experimental trap-fishery for spiny lobster, *P. delagoae* (South Africa, east coast); and industrial trap-fishery for spiny lobster, *P. delagoae* (Mozambique) (Groeneveld 2012a, b). Only

the trap-fishery for *P. gilchristi* off southern South Africa is presently active, as a stable and well-managed sector of the South African fishing industry since 1974. There are annual landings of approximately 1000 t/year all of which are exported. Both the fisheries for *P. delagoae* are less stable. In deep water traps, slipper lobsters *Scyllarid elizabethae* are also caught as bycatch (Groeneveld 2012a, b). The deep water trawl fishery for prawn and shrimp also targets deep-water lobsters (*Palinurus delagoae*) and red crabs (*Chaceon macphersoni*) (Groeneveld 2012a, b). The artisanal fisheries tend to target spiny lobsters (*Palinurus* sp. and *P. homarus*), using tangle nets, traps, spearguns or reef gleaning methods using snorkelling or SCUBA diving (WIOFish 2011, van der Elst 2012). The lobster fisheries are valuable but monitoring is limited (with the exception of South Africa) and information on stocks is insufficient. According to the Scientific Committee of the South West Indian Ocean Fisheries Commission (SWIOFC), the status of lobster stocks in the region range from over exploited (Kenya) to recovering (Seychelles).

In the Comoros, several species of spiny lobster are found on reefs: *Panulirus japonicus*, *P. ornatus*, *P. versicolor* and *P. longipes*. The latter is the most coveted and most exploited species in the Comoros. Lobster are not currently under threat of overexploitation in the Comoros. However there is potential that future tourism growth will increase fishing pressure (ASCLME 2012a).

In Mozambique, an industrial trap fishery for *Palinurus delagoae* by licensed Japanese and local vessels operated between 1980 and 1999, and achieved annual landings of up to 400 t/year. As in South Africa, this fishery also landed slipper lobster *Scyllarides elizabethae* and red crab *Chaceon macphersoni* as a retained bycatch. The fishery was unstable, with declines in catches, and is currently inactive (ASCLME 2012d).

(b) Transboundary Scope

There is large body of research on the biology, life history and fisheries of *P. gilchristi* and *P. delagoae*, but little is known about *P. barbarae*, *S. elizabethae*, *C. macphersoni* and the deep-water *Heterocarpus* spp. Some stocks appear to be sub-regional (shared by South Africa, Mozambique and possibly Madagascar) (Groeneveld 2012b), this was not demonstrated by a recent population genetic study on *P. delagoae* (Groeneveld 2012b). While this means that more information would be required to justify a shift in fisheries management strategy, from national to sub-regional or regional management plans, in most cases, this is a shared transboundary issue of concern between the countries in the WIO. This issue was identified as being 'Relevant' by 7 of the 9 countries. From the Level 1 prioritisation 6 countries ranked the issues as being 'High' importance. In the Level 2 prioritisation, only 3 of the 9 countries allocated 'Overall rating' scores which were above average. However, the Regional 'Overall rating' score was above average, indicating that the countries consider this to be a priority transboundary issue of concern.

1.4.5.15 Decline in populations of crabs

(a) Problem Statement

The exploitation of crabs is common but poorly researched fishery in several of the countries in the WIO region. The industrial lobster trap fishery, also targets the deep water red crabs (*Chaceon macphersoni*), although other crab species are also sometime caught and discarded. The artisanal fishery targets portunid crabs, mud or mangrove crabs and more rarely coconut crabs. The most commonly targeted species by the artisanal fishery is the mangrove crab *Scylla serrata*, which is now also being farmed. The farming of this species is further contributing to the decline of some wild populations due to the harvesting of crablets for use in mariculture (ASCLME 2012b). Shallow-water swimming crabs (*Portunus pelagicus*), of blue swimming crabs, also support many small-scale fisheries throughout the region, and they too are likely to be regional or sub-regional resources.

The coconut crab *Birgus latro* is the largest land crab in the world (up to 3 kg). It is captured by fishermen in the Comoros to use as bait for fishing traditional coastal fish (mullet, parrot fish, triggerfish), and it is now rare on the islands. The species is protected under Appendix II of the Nairobi Convention.

In the Seychelles, several hundred baited hoop (tangle) nets on a longline are set offshore in water 30-80m depth for spanner crabs *Ranina ranina* (van der Elst 2012). Information on the bycatch from from this fishery is limited, discards include gravid females and sub-legal individuals which are returned to the water, although survival is low.

In Mozambique, the mud crab and the blue swimming crab (cf. *Portunus pelagicus*) are targeted. The crabs are caught with drag-nets, but the most common method to catch them is by walking in the sand at low tide with a spear. Both the method of netting and spearing of crabs result in a relatively high catch of juvenile individuals as well as egg carrying females being caught and killed. Crab production and export values indicate a decline in stocks (ASCLME 2012d). An experimental fishery for *C. macphersoni* off Mozambique has recently started (2009).

There is an artisanal fishery for crabs in Kenya, which targets portunid crab species in mangroves (*Scylla serrata*) and the swimming portunid crabs (*Charybdis spp.*), as well as *Parasesarma catenata* (Brachyura: Sesarmidae), *Epixanthus dentatus* (Decapoda: Oziidae), *Thalamita crenata* (Latreille) and Hermit crabs e.g. *Clibanarius laevimanus*. Populations of the mud crab, *S. serrata*, which are targeted by the artisanal fishery are declining in Kenya, crablets are being harvested from the wild for the mariculture sector with little regard for resource status.

(b) Transboundary Scope

The only crustacean species for which there is large body of research is the lobster, there is only limited information available about crab species targeted within the region (Groeneveld 2012a,b, van der Elst 2012). Declines in crab populations were identified as being a 'Relevant' issue by 7 countries. From the Level 1 prioritisation, 5 countries ranked the issues as being 'High' importance, mainly related to concerns about mud / mangrove crab *Scylla serrata*. In the Level 2 prioritisation no countries allocated 'Overall rating' scores which were above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a priority transboundary issue of concern within the WIO LMEs.

1.4.5.16 Excessive bycatch and discards

(a) Problem Statement

Excessive bycatch and discards is an issue of concern for both the artisanal and industrial fisheries in the ASCLMEs. Non-selective gears used by artisanal and industrial fisheries often result in bycatch of non-commercial species including vulnerable species such as marine mammals, turtles and elasmobranchs as well as juvenile fish. A comprehensive Retrospective Analysis on the relationship between vulnerable biodiversity and fisheries in the WIO, which was completed through SWIOFP, presents the current knowledge on the extent of bycatch within the WIO (van der Elst 2012). An analysis of 250 fisheries in the WIOFish database, as part of this study, revealed a close relationship between the level of bycatch and the harvesting type. While the assessment revealed inconsistencies in the scoring of bycatch, the study also found that the fisheries considered to be low bycatch fisheries were largely artisanal, as little of the catch is in effect discarded or unwanted. Conversely, industrial trawl fisheries were considered to have the highest bycatch scores. Although this relationship did not always hold for all fisheries, and some artisanal fisheries were revealed to be responsible for substantial bycatch (van der Elst 2012).

Analysis landing data showed that industrial fisheries do not impact as substantially on marine mammal populations as in other regions, but that there are significant interactions with artisanal fisheries. Delphinids and turtles for example, as well as being targeted in some countries, are also significantly impacted by artisanal gillnet fisheries (in Tanzania, and Madagascar). Significant mortality of marine mammals, turtles, and elasmobranchs is reported from bather protection nets in KwaZulu-Natal. Depredation by marine mammals is a problem that impacts on longline fisheries throughout the WIO and the species responsible. The study found that the highest depredation rates by

cetaceans are often in areas with the highest swordfish catch rates, suggesting that cetaceans congregate in areas of high swordfish abundance (van der Elst 2012).

Both artisanal and industrial fisheries pose a threat to turtles, particularly by the pelagic longline fishery in South Africa, shallow prawn trawl fisheries, although the use of turtle excluder devices (TEDS) is progressively reducing the problem. There are reports of incidental capture or entanglement with gear of seabirds (longline, trawl and gillnet fisheries), loss of foraging opportunities due to depleted fish stocks and direct competition with fisheries targeting low trophic level fish. However, incidental mortality of seabirds within the WIO from fishing appears to be lower than for temperate species, due to differences in their foraging strategy (van der Elst 2012). Studies on the status of elasmobranch in the region have been minimal and few if any shark management plans are in place. There are high levels of bycatch associated with longline, trawl and line fisheries. Included are blue and mako sharks as well as the smaller *Squalus mitsukurii*, *Holohalaelurus regain*, *Scyliorhinus capensis* and *Raja straeleni* (van der Elst 2012).

Twelve non-elasmobranchs species of fish are Red Listed by IUCN, with exception of the coelacanth, few of these species are under domestic protection, let alone regional management. Several fisheries are investigated and seen to report capture of these vulnerable species, especially artisanal and recreational fisheries. Linefishing in association with reefs can target these threatened species such as *E. tukula*, *E. lanceolatus*, *E. albomarginatus*, *P. laevis*, *P. areolatus*, *C. undulatus* and *B. muricatum* as well as *L. chalumae*. A topic of concern is the effect of uncontrolled trawling on the seabed with removal of non-target species and the impacts on seabed ecology and its ability to support the very fisheries being trawled. There is also a poor understanding of fishing impact on seabed communities should be one area of focus in trawl effect appraisals.

In Somalia the offshore trawling grounds, especially those targeting prawns are showing signs of overexploitation with excessive bycatch and discards. A significant fraction of shrimp bycatch is composed of juvenile fish and on average, only 32 % of the bycatch is retained, with a discard rate of up to 1.8 tonnes per trawler per day (KMFRI 2003). A number of industrial fisheries in South Africa have problems with excessive bycatch and discards: discarding of non-tuna species such as the oilfish *Rivettus pritioides* is a growing problem in the tuna longline sector; there is a seasonal bycatch problem on the west coast with juvenile horse mackerel. The prawn trawl fishery (deep and shallow) has a major bycatch concern; and species mixing between juvenile anchovy (*Engraulis encrasicolus*) and juvenile sardine (*Sardinops sagax*) is an “early season” fishery problem resulting in discarding and dumping (ASCLME 2012e). Further details on the evidence of the impacts of fisheries on biodiversity is included in the reports by van der Elst (2012) and by Kiszka (2012).

(b) Transboundary Scope

Less selective fisheries gear types result in higher levels of bycatch, regardless of whether the gear is used by industrial commercial fisheries or artisanal fisheries. There is however more variation in the discard rates because in the artisanal fisheries, more of the species tend to be retained and consumed. Even with destructive fishing practices, such as use of dynamite or poisons in the reef fisheries, the majority of the catch is retained, regardless of the size or species. Both industrial and artisanal fisheries were also found to impact vulnerable focal species in the WIO (van der Elst 2012, Kiszka 2012). The bycatch rate for some artisanal fisheries was considered to be high enough impact local resident populations of delphinids (in gill nets) and sea turtles (shallow prawn fishery) for example (van der Elst 2012). Several of the most threatened species caught incidentally as bycatch within the region are highly migratory (e.g. sea turtles), and several of these species are also listed on the IUCN Red List, as well as CITES Appendix I. So this is a transboundary issue of concern at the regional level but also globally. All countries identified the issue as being 'Relevant'. From the Level 1 prioritisation 8 countries ranked the issues as being 'High' importance. In the Level 2 prioritisation 7 countries allocated 'Overall rating' scores which were above average. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern within the WIO.

1.4.5.17 Expansion of mariculture industry (biosecurity, diseases in wild stocks, exotics, habitat implications, water quality)

(a) Problem Statement

Mariculture activities are expanding rapidly throughout the countries of the WIO region in response to the increased demand for seafood and other products, both nationally and internationally, and the economic development potential this sector provides. Farming of blue-green algae, seaweed, sea cucumber, clams, pearl oyster, prawn, crab and finfish are all currently active in the region. The potential for this sector to generate employment for coastal communities is seen as an opportunity to both reduce fishing pressure on wild caught stocks and reduce poverty, although the employment opportunities created have not always been accessible to people from local coastal communities due to capacity constraints. For example, clam and pearl oysters farms that were set up in Seychelles offered little employment; the prawn farm on Coetivy Island employs 350 people, but only 18% are native Seychellois (ASCLME 2012g). Other constraints that have been identified include limited research capacity and finance in many countries in the region. In Mozambique, private sector investment has proved a successful alternative to donor funding. The expansion of this sector, at the present time, in the absence of adequate planning and technical capacity, can create serious long term environmental problems which include: the permanent loss of natural habitats such as mangroves and seagrass beds, the release of contaminated and or nutrient enriched wastewater, the introduction of non-native species or diseases into wild populations and, the overexploitation of wild-caught juvenile population for use as seed stock or feed (Andrew *et al.* 2011). There are some examples of responsible management in the sector, prawn farming in Madagascar and in the abalone industry in South Africa, which could potentially be emulated in the region (Shipton 2011c-d).

New experimental mariculture activities have been set up in Kenya along the south coast. This a developing sector and there are 8 finfish farms, 6 crab farms and 4 prawn farms, all of which are currently producing for domestic consumption. There has however been inadequate coordination, which has resulted in land-use conflicts, problems of theft, poor water quality and other problems reported from the sector. The destruction of mangroves to make way for prawn farming, as well as the potentially harmful use of wild caught crablets, highlights some of the unsustainable practices currently taking place.

Mariculture is a developing sector in the Malagasy economy with research and pilot projects ongoing in mud crab, sea cucumber, blue-green algae, oyster and eel. Commercial large scale farming of prawn for export and domestic consumption, as well as small-scale production in seaweed is also established. Prawn farming has been very successful in providing employment for rural communities, supplying 4,325 permanent and 30,000 part time jobs in 2003, and export revenues worth an estimated \$62 million USD (Madagascar CLA, 2012). The main impact of farms on the environment is the periodic draining of wastewater ponds. The water is rich in phosphates, nitrates and organic matters (and may also contain pathogens, antibiotics and pesticides). During the last five years, diseases have emerged in wild populations of shrimp, although the link to aquaculture has not yet been confirmed (ASCLME 2012f). Unguja Island, Zanzibar has become an important site for seaweed farming, and it is reportedly negatively affecting seagrass beds (de la Torre e Castro and Ronnback 2004, Eklof *et al.* 2005).

(b) Transboundary Scope

Many of the countries within the WIO region have or are in the process of developing or expanding mariculture activities and this is therefore a shared transboundary issue. Farming can impact could result in the further loss of critical habitats within the region (e.g. seagrass beds and mangroves). The introduction of species and pathogens into the region, could also become a biosecurity issue were the species or pathogens to escape and spread. Within the WIO, all countries identified concerns related to the expansion of mariculture industry (biosecurity, diseases in wild stocks, exotics, habitat implications, water quality) and identified all 9 countries identified the issue as being 'Relevant'. From the Level 1 prioritisation, 6 countries ranked the issues as being 'High' importance. In the Level 2

prioritisation, however, only 4 of the 9 countries allocated an 'Overall rating' score which was above average. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider this to be a high priority transboundary issue of concern.

1.4.6 Problem area 5: Climate change/variability and extreme events

The issues of concern that were identified by the countries related to unpredictable environmental variability and extreme events are causes which contribute to, and indeed exacerbate, many of the other issues that were identified. These include: Climate change and extreme weather events, Sea level change, Ocean acidification, Changes in seawater temperatures, Changes to hydrodynamics and ocean circulation, Changes in productivity (shifts in primary and secondary production) and Geohazards (tsunamis, volcanic eruptions, earthquakes). These are analysed in more detail in the following section.

1.4.6.1 Climate change and extreme weather events

There have been several major climatic events within the Indian Ocean basin during the past 10 to 15 years that have heightened awareness about the vulnerability of the countries in this region to climate related hazards and extreme weather events. The impacts of climate change and variability are examined in the following sections.

(a) Changes in seasonal rainfall patterns and river flows

Shifts in seasonal patterns of rainfall in terms of the distribution and volume of precipitation have already been reported by all WIO countries, with associated impacts upon river flows and sediments into nearshore marine habitats. For example, Kenya has already experienced notable changes in rainfall patterns and river flows, which are impacting upon flood plains, deltas and coastal ecosystems (ASCLME 2012b). In Tanzania, there is predicted to be an increase in rainfall throughout the year except between the months of June to August according to the IPCC scenarios (ASCLME 2012c). In Madagascar, rainfall patterns have shifted and precipitation has increased in the south and decreased in north; there has also been a decline in rainfall in coastal regions (ASCLME 2012f). Similarly, in Somalia heavy rains and flooding are resulting in both soil erosion and desertification (ASCLME 2012i). During heavy rain in Mauritius, river flooding is a common occurrence, and large amounts of debris and soil are discharged into the lagoon. Frequent discharge of pollution and nitrates from agriculture and coastal hotels also give rise occasionally to algae bloom and red tides (ASCLME 2012h).

(b) Increased frequency of climate extremes as a result of climate change

Climatic extremes such as floods and droughts may become more common as a result of climate change. In Somalia, there is expected to be an increased frequency of recurring droughts. Droughts are also expected to become more frequent and severe in Mauritius and in Seychelles (ASCLME 2012h0, ASCLME 2012g). Climate change scenarios in the Seychelles predict a marked variation in the seasonal rainfall patterns, whereby the dry season would be drier and warmer, resulting in more acute droughts while the rainy season would be wetter causing more flooding and landslides (ASCLME 2012g).

There is compelling evidence indicating that El Nino Southern Oscillation (ENSO) events may occur more frequently due to global warming leading to higher average rainfall over the Seychelles during an intense El Nino and abnormally low rainfall during an intense La Nina impacting severely on the country (ASCLME 2012g). The effects of climate change in South Africa are predicted to be east coast wetting, including an increase in the intensity of rainfall and associated risk of extreme events, flooding, and high volume runoff, most especially where there is strong topographical forcing (ASCLME 2012e).

The frequency of extreme events has increased in the recent past in Kenya. Flood events in the recent past occurred in 1997-1998, 2003 and 2006 and droughts occurred in 1999-2001, 2005 and 2008-2009 (KMD 2009). There has also been an increase in the frequency of extreme events such as floods

and droughts in Mozambique. In Somalia, a one time-unheard of incidence of frozen rains with devastating effects was experienced in 2005 (Galair 2007).

(c) Cyclones and Tropical Storms

Many of the countries in the WIO are regularly affected by cyclones and tropical storms. These extreme weather events are often accompanied by heavy rains, which can result in flooding of rivers and low lying areas, and extreme waves and storm surges, which can impact the shallow nearshore habitats and coastal areas. With global climate change, it is anticipated that the frequency and intensity of tropical storms and cyclones will increase and the average wave climate and the southerly swells will also change, leading to higher wave heights; in combination these events may lead to increased coastal erosion.

Mozambique has been impacted by more than 35 cyclones since 1946, and these increase the vulnerability of the coastal zones, and cause deterioration of the conditions for coastal populations. Expected intensification of winds will increase wave energy, which could have a significant influence on the development of shallow water ecosystems, including coral reefs, mangroves and seagrass beds which will be reduced or eliminated at the limits of their sustainability zones (ASCLME 2012d). In Madagascar, it is anticipated that increased wind speed may make coastal deserts and dune systems more dynamic, and may lead to the silting of back mangroves and shallow ecosystems such as lagoons and reef. Floods following heavy rains may also impact low-lying areas such as basins and the slums of cities, and flooding may affect river levels and coastline (ASCLME 2012f).

In Mauritius, tropical cyclones will most likely become more intense and higher waves will be formed, removing large quantities of sand from the beach and lagoons (ASCLME 2012h). Although the Seychelles is outside of the normal cyclone paths, it has been subject to cyclonic impacts through intense rain and the swells generated due to the cyclone can create a potential risk to maritime users within the Seychelles EEZ (Seychelles MEDA). Similarly, Tanzania is not a cyclone prone area, however historical records show that the coast has in the past been hit with several cyclones (ASCLME 2012c). In South Africa, although cyclones only contribute to a small percentage of the total rainfall, they can result in excessive flooding and it is suggested that global climate change may result in an increase in long shore wind strengths (primarily during the summer) along the southern and south-east coastlines (ASCLME 2012e).

(d) Extreme storm surges

Mauritius is already subject to significant wave and storm surges generated from long swells far south of the island. Storm surges during periods of strong winds have become an almost annual occurrence. The maximum wave run up levels on the beaches show a peak elevation of 2 to 3m above mean sea level with some up to 4 m along the southern coast (ASCLME 2012h). Madagascar is located in an area where the average wave height varies from 4 m in the south to 0.5 m in the north. Exceptional wave heights are encountered (especially during cyclones) which can generate violent sea conditions. There is no projection of the average wave height in Madagascar, however, an average increase of wave height, following increase average speed of wind surface, can be expected (ASCLME 2012f). Enhanced coastal flooding in the Seychelles associated with severe storms or abnormal high tides, would contribute towards erosion of shoreline and tourist beaches, and it is possible that several low-lying coral islands and sand cays could disappear (ASCLME 2012g).

(e) Ocean temperature increases

Air and sea temperatures are likely to increase within the region. Mauritius anticipates abnormally hot days and nights and more frequent heat waves. Tanzania predicts that the air temperature will increase by 2.5 – 2.9°C during the warmest months of December – February (Mwandosya *et al.* 1998). In Seychelles, the country is already experiencing warmer weather. The results of the expected change in the air temperature given by both SRES A2 and B2 scenarios for the 2100 period through the models tended to vary between 0.63 to 3.67°C. In Somalia, coastal communities are experiencing stronger winds and longer periods of higher temperatures. Fishermen have complained that it is harder to store the fish which they rely on for income and food in these higher temperatures (Galair 2007).

(f) Sea level rise

The change in sea level is expected to be at the average global rate of about 1.2 mm/yr over much of the 20th century, with significantly faster (5.5 mm/yr) change albeit for shorter term to affect the region. The IPCC projects a sea level rise of 0.35 meters [+ 0.21 to + 0.48 m] in global average and the same mean elevation for the Indian Ocean by the year 2100 (Petit 2008). From 1995 to 2003, Madagascar showed a sea level rise, between 7.2 and 21.6 mm on all coastal zones of the island (Raholijao and Ramiandrisoa 2007). There have however been variable changes in sea level reported at national and regional level and analysis of some tide gauge series shows that the mean sea level around Madagascar seems to hold with the trends observed in the region: an increase at Antsiranana and a decrease at Hell-Ville (ASCLME 2012f).

Around Mauritius, a study (Ragoonaden 2006a, b) has shown that a very slow fall in sea level (- 0.10 mm/yr) occurred in the average annual changes from 1986 to 2003 and the fall at Rodrigues was - 0.32 mm/yr during the same period. However, during the last few years an accelerated sea level rise has been observed. The same pattern has been noted in Rodrigues and other islands in the West Indian Ocean. This is a matter of serious concern in the event that the trend continues. Model reconstructions of long-term sea level trends (1955-2003) in Tanzania, show a general rising trend (0.4 to 2.0 mm/yr) increasing southwards. In South Africa, results show that, generally, sea level is rising around the South African coast in agreement with current global trends, but there are regional differences in the rate of sea level rise: the west coast of South Africa was rising by +1.87 mm/yr, the south coast by +1.47 mm/yr and the east coast by +2.74 mm/yr (Mather *et al.* 2009).

In Seychelles, it is predicted that several low-lying coral islands and sand cays could disappear. There would be enhanced coastal flooding, primarily associated with severe storms or abnormal high tides, resulting in erosion of shoreline and tourist beaches and threatening coastal infrastructure and biodiversity (ASCLME 2012g). In Mozambique, the main areas vulnerable to the effects of sea level change are the coastal zones along the whole extent of the country, mainly the major cities of Maputo, Beira and Nampula that have the largest populations, causing deterioration of the conditions of life for most of the people that live there (ASCLME 2012d). If sea levels rise even a small amount, most coastal cities in Somalia will be at risk of flooding. A rise of 1m will flood most of the coastal towns including Mogadishu, Bosaso and Kismayo. This is potentially very serious as over half of the population lives in the large coastal cities. Mogadishu alone houses one sixth of the population (ASCLME 2012i).

Coastal environments and habitats are vulnerable to sea level rise and coastal flooding could cause flooding of estuaries, seagrass beds and mangroves. In South Africa, it is suggested that sea level rise as a consequence of global warming could result in the elimination of many intertidal areas, particularly estuarine habitats as these become constricted between the rising water level and existing developments and structures (ASCLME 2012e). Soft coasts will be increasingly eroded and sea level rise is also expected to have a negative impact on coastal wetlands such as saltmarshes and mangroves, since these communities depend on a tidal cycle of inundation and exposure, and may not be able to retreat upshore.

(g) Ocean acidification

Ocean acidification occurs as a consequence of increased dissolved CO₂ concentration in ocean water. This causes a decrease in the pH value of the sea water and it is expected that the pH which was 8.104 in the 1990s will decrease to 7.949 in 2050. Ocean acidification causes a delay of growth rates of corals and other species on carbonate basis and a weakening of the carbonate skeleton. Under the current forecast of CO₂ levels in the atmosphere, in 2100, the growth rate of scleractinian corals will be significantly compromised (Kleypas and Langdon 2006, Kleypas *et al.* 2006, Lough 2008). The acidification effects are firstly felt in cold waters, but subsequently in tropical waters.

Not much work has been carried out in WIO related to ocean acidification. Brief studies conducted in the Seychelles in late 1990's suggest that the pH level around the coastal hotspot areas around the main island of Mahé to be within the normal expected range as defined by regional guidelines

(ASCLME 2012g). In Kenya, it is suggested that ocean acidification will have adverse effects on plankton communities, more particularly calcifying Coccolithophorids, planktonic Foraminifera and Pteropods species (ASCLME 2012b). Mauritius is concerned about the threat to coral reef growth around the island thus reducing the supply of sand to the lagoon and beaches and South Africa also suggests that offshore coral reefs could be affected by ocean acidification (ASCLME 2012h). The importance of these potential effects, in Madagascar is unknown, but the hypothesis is that the acidification will contribute to the decline of coral reefs and other species with carbonate skeletons or shells (ASCLME 2012f).

(h) Increase in seawater temperature

In Kenya, there has been an increase of mean Sea Surface Temperature (SST) from 27.2°C to 28.2°C since 1980. The SST within the Somali Current has also warmed by 0.46°C since 1987 and 0.18°C since 1982 (Heileman and Scott 2009). Increased SST causes coral bleaching and during 1997-1998 the El Nino Southern Oscillation (ENSO) caused extensive coral bleaching throughout the western Indian Ocean with coral bleaching observed in Madagascar, Mozambique, Somalia, Tanzania and South Africa; in Mauritius about 50 % of the corals were bleached compared to Seychelles where coral mortality was almost 100 % in some areas (CORDIO 1999). In Madagascar, it is also suggested that high temperatures would have impacts on highly migratory species such as cetaceans, sea turtles and tuna (Anon 2009). Given the importance of these species in wildlife conservation and fishing, such impacts would be a potential concern, but sufficient data to assess its importance are lacking.

(i) Changes to hydrodynamics and ocean circulation

The Mozambique Channel is a sensitive area for air-sea interactions on inter-annual time scales. The Indian Ocean “Dipole” (IOD) impacts climate in northern Mozambique and is characterised by intensified easterlies and large changes in equatorial circulation. The northern tip of the Channel is characterized by a strong anticyclonic curl associated with strong convergence. There is however a major gap in knowledge related to ocean atmosphere interaction is with regard to the determination of the extent to which atmosphere drives the ocean circulation. Off the coast of Somalia there is some inter-annual variability in the monsoon wind patterns which causes seasonal variation in the Somali Current. Although this variability has not been studied it could affect shelf circulation, the marine ecosystems and the fisheries productivity (Heileman *et al.* 2008).

There has been a warming of the Agulhas Retroflexion area to the south of South Africa, possibly due to a poleward migration of the oceanic westerly winds, with an increase of the leakage of Indian Ocean waters into the South Atlantic and beyond (Biaostoch *et al.* 2008). This will have potential consequences for the global thermohaline overturning circulation.

(j) Changes in primary and secondary production

The impacts of climate change and variability are already being felt globally. Along the equator, more stable water stratification is expected with climate change which could result in reduced advection of nutrients from the deeper water to the upper photic zone and it is anticipated that climate change will also affect nutrient cycling. This is likely to result in changes in productivity which might have subsequent effects on the distribution of pelagic fishes, recruitment and fish biomass thus potentially affecting the fishing industry, issues of concern expressed by Seychelles and Mauritius.

(i) Changes in primary productivity (species shifts and declines in productivity)

Climate change is expected to lead to a shift in the timing and intensity of synoptic weather systems. These shifts in the weather system may affect the monsoon winds which drive the large coastal upwelling system up the east coast of Somalia affecting primary productivity in the region (ASCLME 2012i). In Madagascar, a hitherto unknown phytoplankton bloom was found to occupy the Madagascar Basin in late austral summer. This bloom however failed to develop in 1998, the second year of a two-year ENSO episode, when anomalously weak Southeast Trades failed to deepen the mixed layer as in other years (ASCLME 2012f).

Climate change may also affect specific species of plankton resulting in species shifts. In Madagascar, the large autumn phytoplankton bloom was previously driven by nitrogen-fixing cyanobacteria (*Trichodesmium* spp.). In 2005 the autumn bloom was however dominated by diatoms, the cells of which host another nitrogen-fixing cyanobacterium called *Richella intracellularis*, with *Trichodesmium* of lesser importance. In Kenya, it is suggested that ocean acidification will cause a potential loss of productivity as it will have adverse effects on plankton communities more particularly calcifying Coccolithophorids, planktonic Foraminifera and Pteropods species (ASCLME 2012b).

(j) Changes in trophic dynamics and secondary production

It is believed that evidence from climate change in marine communities will first appear in the zooplankton with respect to species range and population. In recent years there has been a shift in stock biomass of anchovy and sardine from the west to the east coast South Africa, possibly related to climate change (Crawford *et al.* 2008) and in Kenya, it is suggested that increasing sea surface temperatures will lead affect vertical migration of fish and other macro-invertebrates (Stempniewicz *et al.* 2007). There is also concern that a low primary productivity will lead to a decrease in the fish catch. Low productivity affects the demersal fish catch as the absolute amount of organic matter reaching the seafloor depends on the level of primary and secondary production in the surface waters. Several fish species feed directly on zooplankton (mackerels and some tuna-like species) and a decrease in the zooplankton production will affect the fish production. In Kenya, it is suggested that vertical migration of fish and other macro-invertebrates to deeper water (Stempniewicz *et al.* 2007) will directly reduce the available food to piscivorous birds in particular and invertebrate feeders in general, leading to erratic breeding success and lower population recruitment. The anticlockwise shift in the distribution of anchovy and sardine observed in South Africa has already led to a mismatch in the distributions of breeding localities and prey for several seabirds in southern Africa.

(k) Geohazards (tsunamis, volcanic eruptions, earthquakes)

WIO region is subjected to the following geohazards the extent and magnitude of which vary from country.

Tsunami

Countries within the WIO were exposed to the tsunami wave as a result a volcanic eruption off the coast of Indonesian in December 2006. Countries that made specific reference to this event in their MEDAs included Somalia, Kenya, Tanzania, South Africa. In Somalia the tsunami wave hit most parts of the Somali coast, destroying several coastal fishing villages, killing about 300 fishermen, and resulting in the loss of fishing gear and fishing boats. Extreme waves of this kind have never been experienced in the past, neither storm surges of disastrous scale (ASCLME 2012i). Measurements in two recent tsunamis demonstrated that the tsunami reached its maximum amplitude in the entire WIO at Port Elizabeth (ASCLME 2012e). Rare events such as tsunamis also create waves that impinge on the Tanzanian coast and islands (ASCLME 2012c).

Volcanic eruptions

Mauritius expressed concerns related to risks associated with volcanic eruptions although there have not been any recent eruptions on Mauritius (ASCLME 2012h). There are two volcanoes in the WIO region which have been recently active. These include Piton de la Fournaise on Reunion Island, which has erupted every year for at least the last 10 years, and is the most active volcano in the region. The other active volcanoes in the WIO include Karthala and La Grille on Grand Comoros, the former of which has already also recently erupted. There are other volcanoes in the WIO but these have remained inactive, including those of Madagascar (Ambre-Bobaomby, Nosy-Be, Ankaizina, Itasy, Ankaratra).

Earthquakes

Mozambique has recently been affected by an earthquake that resulted in landslides and affected the stability of coastal areas (ASCLME 2012d).

1.5 Analysis of regional root causes and impacts

1.5.1 Introduction and methodology

Following identification and prioritisation of the main transboundary issues as presented in the preceding sections, the next step in the TDA process was to identify the causes. This was considered to be important as it allows formulation of policy interventions that are aimed at addressing the root cause of degradation of the coastal and marine environment in the WIO region. The process of identification of causes was achieved through a Causal Chain Analysis (CCA) which explored the cause and effect pathways, from the environmental impacts and socio-economic consequences back to their direct causes (economic sectors and associated human resource use practices), through to the underlying causes (social, political, and legal) and finally, the root causes that determine the behaviour of those sectors. This approach is beneficial since once the important causes of each prioritised issue are identified, policy measures can be designed to target actions that will restore and prevent further degradation of the environment. Interventions that are designed to remedy the root causes of problems, or the causes closest to the root causes, will often be common to several causes. Target actions designed to address the common causes will in theory be most cost effective in addressing a specific problem or issue.

The aim of this section of the joint TDA is to present the cause and effect pathways for the high priority transboundary issues of concern within the WIO countries, in order to assist in the formulation of appropriate management interventions that will be integrated into the common Strategic Action Programme (SAP) for addressing impacts of transboundary issues in the WIO region. As outlined in the previous sections, the CCA process started at the national level before the results were consolidated and validated at the regional level. In this section, the method used to construct the chains including the resulting chains for all priority transboundary issues of concern within the WIO is presented. The CCA results for each of the priority issues are presented using the same format, which includes impact chain analysis (environmental impacts, ecosystem services, socio-economic impacts), and causal chain analysis (direct causes, sectors, resource use practices, underlying social, economic and legal causes and root causes).

During the National CCA meetings, the participating countries identified their top ranking issues through the prioritisation process described in the earlier sections of the TDA. Causal Chain Analyses (CCA) were then completed for between three to five of the highest ranked issues within each of the three Main Areas of Concern. The chains were constructed for each issue using problem trees (spider diagrams) in two parts: the first part of the problem tree examined the impacts and the second part examined the causal chain. To construct the impact chains, the working groups first identified the environmental impacts caused by the issue, then considered which ecosystem services were going to be most likely affected by that environmental impact and the resulting socio-economic consequences in terms of economic impacts (welfare), social impacts (wellbeing) and ecological impacts (sustainability) aspects and finally, which of the stakeholder groups they thought would be impacted. To assist in this process, each working group was provided with a standard list of ecosystem system services and some generic lists of environmental and socio-economic impacts (TEEB 2011, Raymond *et al.* 2009, De Groot *et al.* 2002, MEA 2005, Daily *et al.* 2009; UNEP/Nairobi Convention Secretariat 2009b). To construct the causal chains, the working groups were asked to identify the direct or immediate causes of the issue; the sectors and resource use practices that contributed to the direct causes; the underlying legal, social, economic and political causes and then finally the root causes. Each link in the chain was forged by asking the question 'Why? For example, why a particular resource use practice had persisted. This process was repeated until all root causes were identified. Once the CCAs were completed, the national results were captured and transferred into a tabular format. The national results were consolidated into generic chains in form of tables and problem trees. These were then validated by the participants during the Regional TDA-III Meeting that was held from 9th to 10th May 2012 and Regional TDA-IV Meeting that was held from 24th to 27th July 2012 in the case of the ASCLME TDA (Scott 2012a-b). In the case of the WIO-LaB TDA, Regional TDA meetings were also held on 25th -26th August 2008.

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

The following section provides details on the specific issues related to coastal and marine water and sediment quality degradation in the WIO region. The priority issues that were identified through national and regional processes undertaken as part of the WIO-LaB and ASCLME TDA are (i) microbial contamination from land- and marine-based sources, (2) high suspended solids and turbidity due to human activities, (3) chemical pollution from land-based and marine-based sources, (4) solid waste and marine debris including plastic litter from land-based and marine based sources, (5) eutrophication and nutrient over enrichment in coastal waters, (6) degradation of the quality of groundwater and surface freshwater resources, (7) pollution of coastal waters due to oil spills due to drilling, exploitation, transport and shipping activities. For each of these issues, details are presented on the extent of the problem including the impacts, underlying causes and root causes.

1.5.2.1 Microbial contamination from land- and marine-based sources

(c) Impact Chain Analysis

In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater and sewage, contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing and industrial effluents mainly from food processing industries. Most countries in the WIO region identified microbial contamination of their coastal waters as an issue of concern. Microbial contamination refers to the presence of pathogenic organisms (protozoa, bacteria and viruses) of either human or animal origin in the aquatic environment. Usually these occur as a result of inappropriate disposal of un- or under treated municipal wastewater, contaminated surface and sub-surface runoff from populated areas, contaminated runoff from agricultural areas used for livestock rearing, and industrial effluents (often food processing) (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009). The ecosystem services that are impacted due to microbial contamination from land-based and seas-based sources include:

Provisioning Services – food (e.g. fish); drinking water; biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms).

Regulating Services – biological control, disease control and water treatment especially water purification.

Supporting/Habitat Services—maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding); photosynthesis and primary production and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle and bequest, intrinsic and existence.

Microbial contamination of coastal waters can have serious socio-economic impacts, and presents a risk to human health through direct contact or ingestion of contaminated seafood. These consequences can affect local communities, tourists, industry and aquaculture operations. The reduced quality (and economic value) of seafood, whether cultured or wild harvested can have serious economic consequences. The loss of the recreational value of coastal waters, due to high levels of faecal bacteria (typically used as indicators of microbial contamination), is evident throughout the coastal zone of the WIO region. Concentrations are often higher in areas in close proximity to larger urban centres (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). In many areas, the situation is accompanied by unpleasant aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

Microbial contamination can have severe socio-economic consequences in coastal waters, such as human health risks associated with recreation or ingestion of contaminated seafood, and reduced quality of seafood products cultured or harvested in a contaminated area. These consequences affect stakeholders across society, from local communities to international tourists, and industrial and aquaculture operations, all of which utilise the marine environment for recreation and collection and culture of seafood. Loss of the recreational value of coastal waters due to unacceptable levels of faecal bacteria is evident throughout the WIO region. Areas of concern are usually associated with larger urban centres where insufficiently treated or untreated waste and wastewater are some of the most important land-based sources of pollution. In many areas, the situation may be exacerbated by unacceptable aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

(d) Causal Chain Analysis

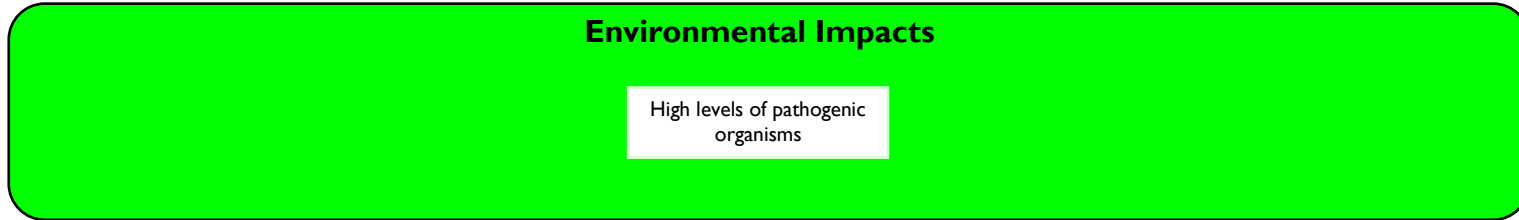
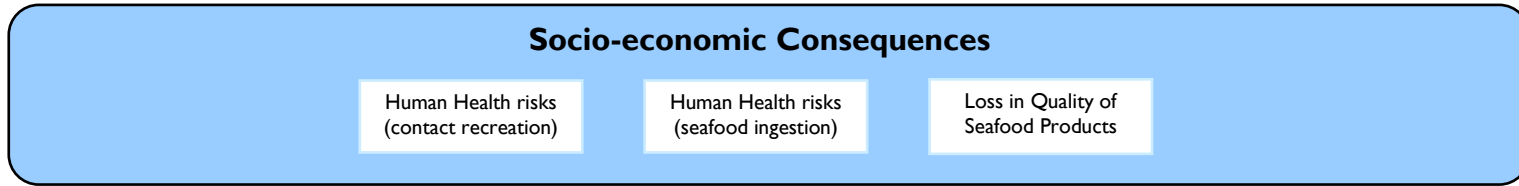
The problem tree for microbial contamination in the WIO region, specifically linked to land-based activities, is presented in Figure 2-5. As indicated, the key sectors contributing to microbial contamination are urbanisation and tourism (e.g. municipalities and tourist developments responsible for municipal waste and wastewater disposal), agriculture (in particular livestock rearing), industry (specifically food processing) and transportation (referring to waste disposal facilities in harbours and ports).

The main **Underlying Causes** can be summarised as follows:

- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of microbial contamination of coastal and marine environment in the WIO are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

IMPACTS AND CONSEQUENCES



DIRECT CAUSES AND UNDERLYING SECTORS

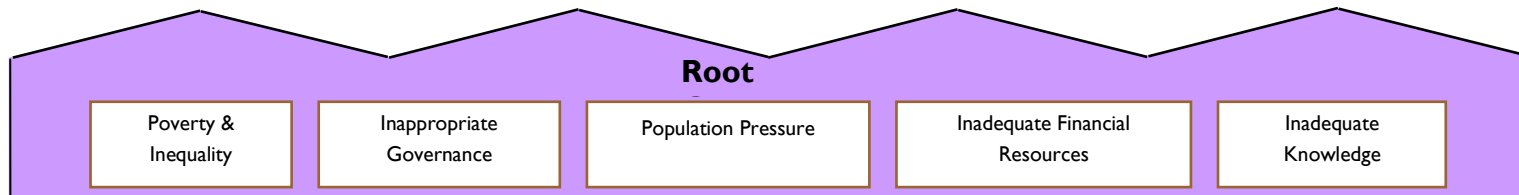
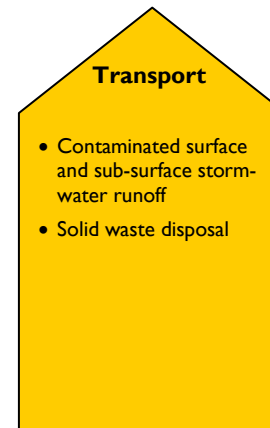
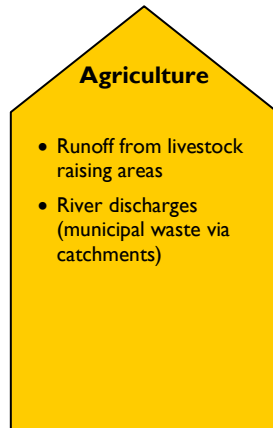


Figure 2-5 Causal chain analysis for microbial contamination.

1.5.2.2 Eutrophication or nutrient over enrichment in coastal waters

(a) Impact Chain Analysis

Eutrophication occurs when there is elevated organic matter loading in coastal waters due to the increased availability or supply of nutrients, usually as a result of inappropriate disposal of municipal wastewater, sewage or nutrient-enriched agricultural run-off. Wastewater containing high levels of inorganic nutrients (e.g. nitrogen and phosphate) or a high organic content (with high biological or chemical oxygen demand, BOD or COD) can also contribute towards eutrophication and the creation of 'dead zones'. Although such areas have not yet been reported in the WIO region, it is possible that such areas could occur in the future with increased nutrient enriched run-off. Harmful or nuisance algal blooms which can, but not always, occur as a result of nutrient enrichment, can be problematic in some areas. In the WIO region eutrophication is often more apparent in closed coastal waters and in estuaries where higher levels of organic nutrients are concentrated due to poor water circulation. Nutrients such as nitrate, nitrite, phosphates and silicates are necessary for the growth of phytoplankton. These inorganic substances are constantly lost from marine surface waters as they are taken up by phytoplankton during primary production, and also because of gravitational sinking. Nutrients are naturally brought up to the surface by upwelling, when cold nutrient-rich deep waters are advected upwards, and there are several important areas of upwelling within the region. Nutrients may also be enhanced by circulation patterns around seamounts (Harris 2011, Keating *et al.* 1987). Coastal waters in the WIO region are however also enriched by nutrients as a result of land-based sources, and this was raised as an issue of concern by the majority of countries. The ecosystem services that are impacted by eutrophication of coastal and marine waters in the WIO region include:

Provisioning Services – food (e.g. fish); freshwater; biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms)

Regulating Services – biological control (e.g. seed dispersal, pest and disease control); and water treatment (especially water purification).

Supporting/Habitat Services—maintenance of genetic diversity (gene pool protection); maintenance of life cycles including nursery, spawning, breeding, feeding; photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); and bequest, intrinsic and existence.

Elevated nutrient levels in coastal waters can generate artificially enhanced primary production (e.g. algal and phytoplankton growth) and an increase in the amount of organic material in the water column. Nutrient enrichment also promotes rapid growth of certain benthic species (e.g. macroalgae), and causes shifts in community composition (e.g. phase-shifts). Changes in the composition of benthic communities that occur as a result of nutrient enrichment include shifts from coral to algal dominated habitats and shifts from seagrass to algal dominated habitats (Hughes *et al.* 2007; Waycott *et al.* 2009).

(b) Causal Chain Analysis

The key sectors or stakeholders contributing to eutrophication in coastal waters include municipalities responsible for waste disposal, industries that generate high nutrient loads in their wastewater and agriculture through inappropriate use and disposal of fertilizers, as shown in the eutrophication problem tree (see **Error! Reference source not found.**). Environmental impacts of eutrophication include:

- Nuisance, opportunistic or harmful algal blooms affecting both aesthetics and biodiversity;
- Discolouration of coastal waters, affecting light-dependent benthic species;
- Smothering of benthic communities (e.g. during die off of algal blooms);

- Mortalities of marine biota (e.g. caused by anoxic conditions generated on decomposition of organic matter); and,
- Modification of marine biotic species composition.

A broad range of stakeholders are potentially affected by eutrophication, from local communities to larger sectors such as fisheries, aquaculture and tourism, which bear socio-economic consequences including loss of aesthetic value, risks to human health in terms of contact recreation and ingestion of contaminated seafood and loss of artisanal and/or commercial fisheries and aquaculture. Within the WIO region, there is some evidence of anthropogenic sources of nutrient enrichment that impact on coastal ecosystems through harmful or nuisance algal growth. Along the Kenyan coast, Uku (1995, 2005) and Uku and Björk (2005) have reported an abundant growth of epiphytic algae on seagrass and the dominance of the green algae (*Ulva* and *Enteromorpha* sp.) in areas adjacent to dense tourism development, where epiphytic cover reaches up to 69% in the more developed areas. Nuisance algal growth, affecting the recreational and aesthetic value of coastal resources, has also been reported in Mauritius where high nitrate concentrations introduced into lagoon systems through agricultural return flows have been associated with algal proliferation in the lagoons of Belle Mare/Palmar. As a result, many hotels have had to remove algal deposits from the shoreline on a weekly basis (Dulymamode *et al.*, 2002). At Flic en Flac, black anoxic sands, smelling of hydrogen sulphide, have been observed at the low water mark and are associated with organic enrichment from wastewater discharges (Prayag *et al.*, 1995). Also in Mauritius, domestic sewage released to coastal waters from urban areas and poorly planned housing developments on reclaimed wetlands is a cause of eutrophication and algal blooms that lead to the smothering of coral reefs. Algal blooms are observed annually at Trou aux Biches and isolated cases have been reported at Bain des Dames near Port Louis. Higher levels of nitrate and phosphate associated with proliferation of algal growth have been recorded at both Belle Mare and Flic en Flac (Prayag *et al.*, 1995; Botte, 2001). Nutrient enrichment of lagoon waters also results in increased algal growth over coral, thus affecting their biology and the coral reef ecosystem as a whole (Botte, 2001). High concentrations of phosphates have been reported from Mauritius from surveys conducted as part of the implementation of WIO-LaB water quality monitoring programme (Anon. Mauritius, 2009). In Seychelles, Jones *et al.*, (2002) have reported eutrophication/algal blooms as a major issue in some of the sensitive areas around the coast of the Seychelles, although the report did not include any quantified scientific evidence of this.

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

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

In Tanzania, raw sewage is released directly into estuaries and other coastal habitats and nutrients also enter the marine environment as fertilizer run-off from areas of intensive farming through mouths of major rivers and streams (ASCLME 2012c). Coastal waters in Kenya also receive nutrient inputs from untreated wastewater or sewage, agricultural run-off (ASCLME 2012b). In Mozambique, agricultural activities within the coastal region and hinterlands result in the contamination of coastal and marine waters with pesticides and fertilizers. High levels of BOD and COD, and low content of dissolved

oxygen have been detected downstream of the factories and the presence of water hyacinth and *Pistia* is a clear evidence of nutrient rich water (ASCLME 2012d). Rivers draining the Madagascan Highlands are a major source of nutrients in coastal waters due to the use of fertilizers and accelerated soil erosion as a result of deforestation in river basins (Lope 2009). Some lagoons have variable but high concentrations of nutrients such as ammonium, nitrate and nitrite. The periodic draining of wastewater ponds in fish farms in Madagascar is another source of nutrient enrichment as this water is rich in phosphates, nitrates and organic matters and may also contain pathogens, antibiotics and pesticides, and can cause eutrophication and harmful algal blooms (HABs) (ASCLME 2012f).

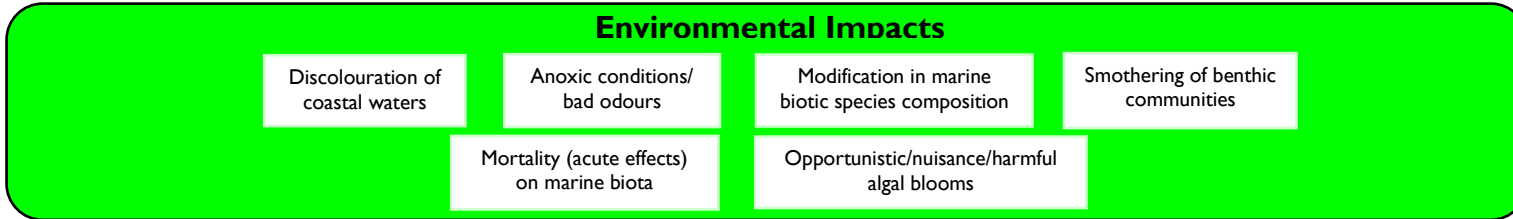
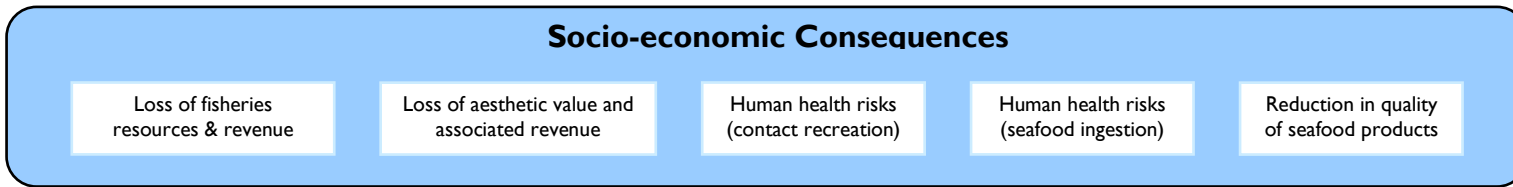
Agricultural practices in Mauritius (both intensive agriculture and small scale market gardening, and livestock rearing), poses a serious threat to coastal ecosystems and give rise to algal blooms and red tides (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009). Mass fish mortality events have become quite common in recent years and this has been attributed to discharge of untreated effluents as well as pesticides and uncontrolled use of fertilizers from coastal agricultural activities. High nitrate concentrations introduced into lagoon systems through agricultural return flows have been associated with algal proliferation in the lagoons of Belle Mare/Palmar, and many hotels have had to remove algal deposits from the shoreline on a weekly basis (Dulymamode *et al.* 2002). At Flic en Flac, black anoxic sands, smelling of hydrogen sulphide, have been observed at the low water mark and are associated with organic enrichment from wastewater discharges. High levels of nitrate and phosphate and associated proliferation of algal growth have been recorded at both Belle Mare and Flic en Flac (Prayag *et al.* 1995). Nutrient enrichment of lagoon waters also results in increased algal growth over corals, affecting their biology and the coral reef ecosystem as a whole. High concentrations of phosphates (relative to other WIO countries) were confirmed from sampling conducted as part of the WIO-LaB project (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009).

The main **Underlying Causes** of nutrient enrichment or eutrophication of coastal waters in the WIO region can be summarised as follows:

- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of pollution due to oil spills are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

IMPACTS AND CONSEQUENCES



DIRECT CAUSES AND UNDERLYING SECTORS

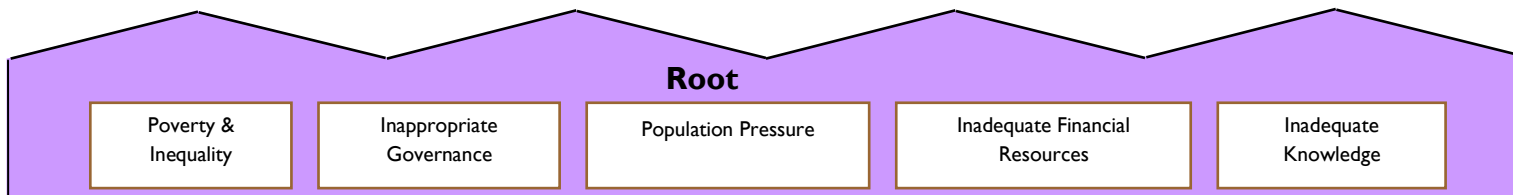
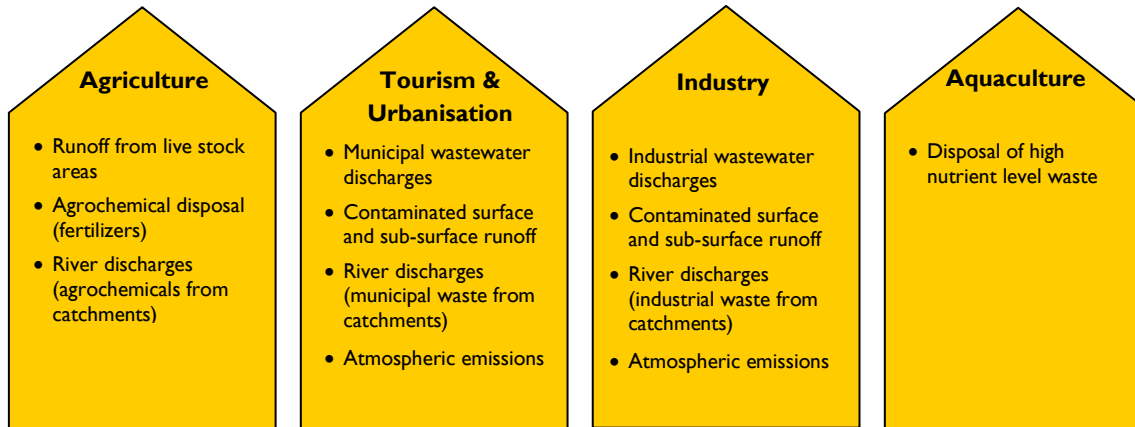


Figure 2-6 Causal chain analysis for eutrophication and nutrient enrichment.

1.5.2.3 High suspended solids/sediments and turbidity due to human activities

(a) Impact Chain Analysis

High concentrations of suspended solids/sediments causes increased turbidity and deposition of sediments in coastal waters in WIO region. This problem has been associated with the river discharges and surface runoff, discharge of municipal and industrial wastewater discharges and dredging of ports and harbours. High suspended sediments load enter the coastal waters due to river discharges. Major rivers such as Maputo, Incomati, Limpopo, Thukela, Save, Tana, Athi-Sabaki, Rufiji, Zambezi and Ruvuma, discharges large volumes of sediment to the WIO (Kairu and Nyandwi 2000). The high sediment load is usually associated with inappropriate land use activities in the river basins such as cultivation on steep slopes without application of soil conservation measures, livestock overgrazing, deforestation and mining activities. River sediment load input in the WIO is estimated to range 5-34 million tonnes per annum (UNEP/Nairobi Convention Secretariat, and WIOMSA 2009). Disposal of municipal and industrial wastewaters and effluents is considered an important source of suspended solids in coastal waters that are located within or close to urban areas (UNEP/Nairobi Convention Secretariat, and WIOMSA 2009). Also, within the marine waters, activities that mechanically disturb benthic sediments such as dredging and trawling, re-suspend sediment particles and increase water turbidity (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009, van der Elst 2012). The ecosystem services that are impacted by high levels of suspended solids and turbidity include:

Provisioning Services – food (e.g. fish, game fruit); freshwater supply; biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); and ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion).

Regulating Services – biological control and water treatment especially water purification.

Supporting/Habitat Services – maintenance of genetic diversity (gene pool protection); maintenance of life cycles including nursery, spawning, breeding, feeding; photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); and bequest, intrinsic and existence.

High concentrations of suspended solids can have various environmental impacts. For instance, suspended sediments can block light penetration through the water column thus reducing the photic zone with serious implications on the productivity of photosynthetic organisms (Yentsch *et al.* 2002). The settling sediment particles also smother benthic flora and fauna, and clog gills and feeding apparatuses of filter feeding marine organisms (Fabricus 2005, Woolridge and Done 2009). Sedimentation can result in the mortality of some species and lead to shifts in community structure and composition (Fabricus 2005, Ahamada *et al.* 2008). The loss of critical habitats such as mangroves, corals or seagrasses due to sediment loading can negatively impact fisheries and the livelihoods of people dependent on these resources (Ahamada *et al.* 2008).

Key environmental impacts linked to high suspended solid/sediment loads include smothering of benthic communities, suffocation of marine organisms and loss of productivity through reduced light penetration, mortality of marine biota, chronic and acute effects on marine biota, modification of marine biota species composition and structure and discolouration or increased turbidity of coastal waters. Consequences associated with the problem of high suspended sediment load and turbidity affect stakeholders across society, from local communities to large international tourism concerns. The social and economic consequences of increased suspension of solids in coastal waters include loss of aesthetic value, loss of commercial and/or artisanal fisheries resources and revenue, reduction in quality of seafood products and aquaculture and agro-processing industries are also affected.

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

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

In Mauritius, increased sedimentation and suspended solids (increased turbidity) have been reported in the lagoon at Rodrigues and in Grand Baie, respectively, resulting in the modification of ecosystems (Resource Analysis-EDC, 1999). In Grand Baie, increased suspended sediment load and turbidity has been associated with household wastewater discharges, while in Rodrigues it has been due to soil erosion in the highlands. Some of the bays are completely silted and channels have had to be constructed to facilitate the movement of boats. Sedimentation has also damaged coral ecosystem by smothering and this has affected artisanal fishing activities (Anon. Mauritius, 2009).

In Mozambique, poor land-use, including deforestation of the coast and hinterland areas, are the main contributors to sedimentation, high concentration of suspended solids/sediments and high turbidity in the coastal waters. As a result, the ports of Maputo and Beira require regular dredging. Past surveys have shown that between $1.2 \times 10^6 \text{ m}^3$ and $2.5 \times 10^6 \text{ m}^3$ of sediments are dredged from the ports of Maputo and Beira annually (FAO, 1999).

In Seychelles, the main islands of Mahe, Praslin and La Digue have experienced higher suspended sediment loads through discharge and reclamation projects. This together with global warming has contributed significantly to the coral mortalities in the island (Jones *et al.*, 2002). In Madagascar, high suspended sediment loads and turbidity are associated with the discharges river systems and significant impacts have been reported in coral reefs and mangrove forest areas (Mong *et al.*, 2009).

In Somalia, high suspended sediment loads and turbidity in coastal waters are due to rivers draining upstream river basins with poor farming practices and deforestation (UNEP 2009). Destruction of mangrove forests has also increased siltation and in some areas, smothering coral reefs and seagrass has been reported (ASCLME 2012i). Municipal wastes containing organic materials and suspended solids are also released directly into the sea as there is no capacity to treat municipal wastewaters in Somalia's coastal cities such as Kismayu and Mogadisho. Mining and dredging activities also increase high suspended sediment loads in Somalia rivers. Mining of coral reefs limestone for construction occurs in the south in Marka and Barawe and this activity has been known to degrade coastal landscape leading to coastal inundation, sedimentation and erosion (ASCLME 2012i).

In South Africa, sand mining activities along the coast has been reported to result in high suspended solid loading that destroys riparian and in stream habitats (ASCLME 2012e). In Tanzania, seagrass beds and coral reefs are threatened by excessive sedimentation and increased turbidity that leads to reduction of photosynthetic activities (Whitney *et al.* 2003, Wells *et al.* 2004, ASCLME 2012c).

(b) Causal Chain Analysis

The key sectors contributing to high suspended solid/sediment loading and turbidity of coastal waters in the WIO region are agriculture (linked to soil erosion in river basins/catchments), industry (particularly those discharging effluents containing high suspended solid loads/sediments), transportation (primarily linked to dredging activities) and mining especially open case mining and quarrying activities. The urban sector (e.g. local municipalities) also contributes through inappropriate disposal of municipal waste, while aquaculture sector contributes through the disposal of wastewater containing high loads of suspended solids. These factors are depicted in the problem tree shown in **Error! Reference source not found.** The main Underlying Causes can be summarised as follows:

- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
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The Root Causes of pollution due to oil spills are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

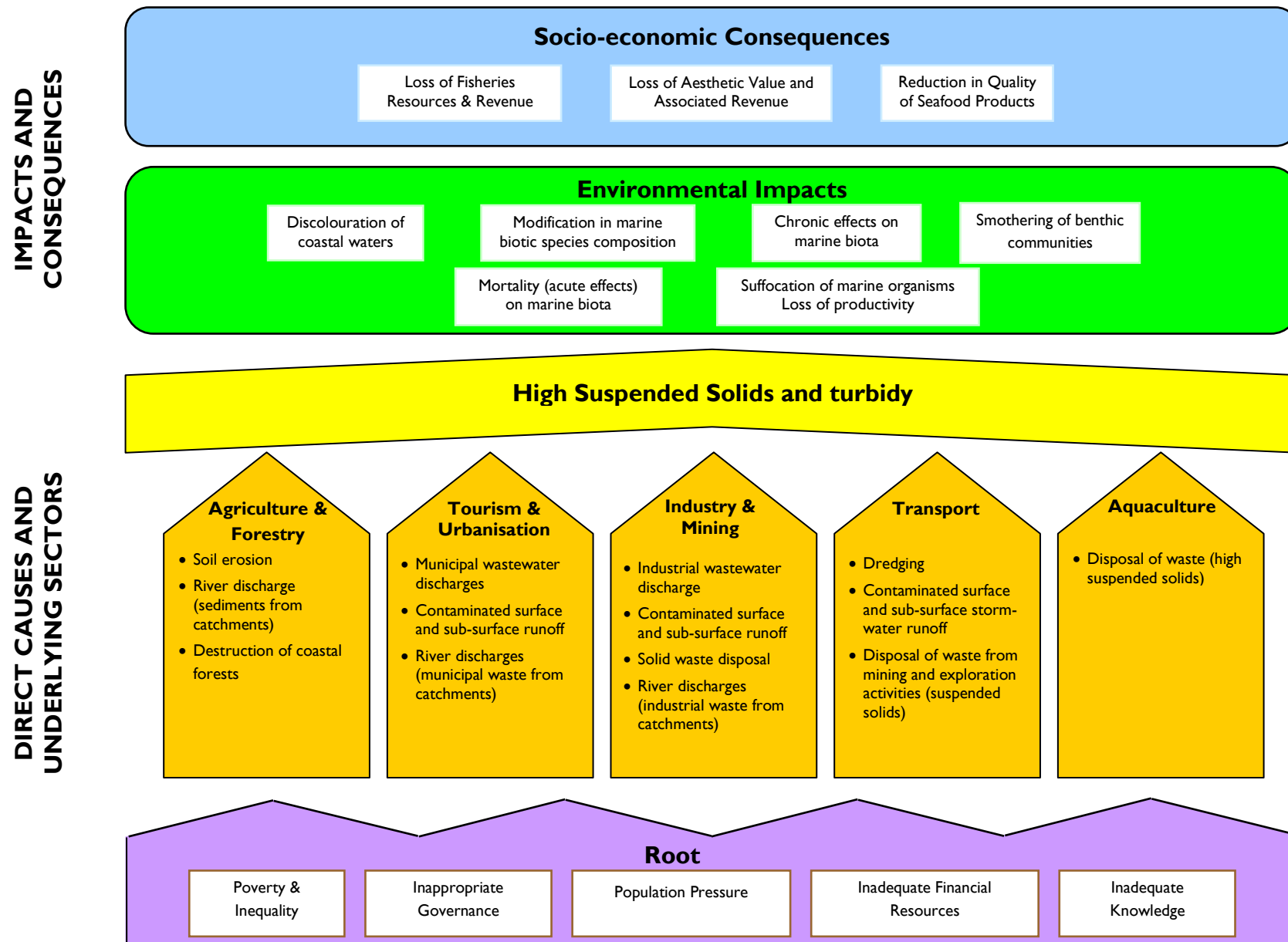


Figure 2-7 Causal chain analysis for high suspended solids and turbidity in coastal waters.

1.5.2.4 Chemical Pollution from land-based and marine-based sources

(a) Impact Chain Analysis

Chemical pollution of the coastal and marine waters in the WIO region is still low in view of low level of industrial development in most countries in the region. The problem is usually confined in few scattered hotspot areas located in the main urban centres in the region. In these hotspot areas, the main sources of chemical pollution are usually diverse and vary from one country to another but these usually include agrochemical discharges, release of sediment-bound heavy metals and hydrocarbons due to dredging operations in ports and harbours, discharge of industrial effluents and leachates from dumpsites (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). There is evidence of chemical pollution in some few hotspot areas located close to the main urban areas. For instance studies conducted in the Kilindini and Makupa creeks in Mombasa, Kenya revealed elevated levels of the heavy metals such as copper, cadmium iron and zinc (Kamau, 2001). Incidents of elevated levels of heavy metals in sediments and some fish species were recorded, but levels of lead and cadmium in most of the fish species analysed were generally within acceptable limits (FAO/WHO, 1986). Surveys conducted as part of implementation of the WIO-LaB regional monitoring programme in 2007 in the Sabaki estuary/Malindi Bay complex and Kilindini/Port Reitz Creek showed that the concentrations of cadmium, copper, lead and zinc in sediments are well above recommended WIO guidelines (Munga *et al.*, 2007).

In Mozambique, heavy metals, particularly lead, have been found within the Port of Maputo, in the mouths of Matola and Maputo rivers and in Nacala Bay (ASCLME 2012d). Agricultural activities within the coastal region also contribute towards chemical pollution through the release of pesticides and fertilizers residues. Pesticide residues found included 2,4,5-TCB, p,p'-DDT, p,p'-DDE, p,p'-DDD, lindane and HCB (Massinga and Hatton 1997). In Mauritius, industries such as steel mills, galvanizing, electroplating and battery factories have historically released their wastes directly into Grand River North West and St. Louis River which empty into coastal lagoons. Heavy metals, particularly chromium from the textile industries, zinc and lead from industrial effluent, sewage sludge and landfill leaches are also potentially problematic in the island particularly at Tombeau Bay and Poudre d'Or Estuary (Ramessur 2002). High heavy metal concentrations have also been reported in Madagascar and Tanzania, compared to other WIO countries (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009). In Somalia, there has been dumping ground for toxic and nuclear waste along the coast since the early 1980s. The waste materials have included uranium, radioactive waste, industrial chemicals and heavy metals such as cadmium and mercury (New Scientist 1992).

There is a diverse range of industries in the region that contributes to chemical pollution and these include manufacturing, textiles, tanneries, paper and pulp mills, breweries, chemical, cement, sugar and fertilizer factories. The ecosystem services impacted by chemical pollution in the WIO region include:

Provisioning Services – food (e.g. fish, game fruit); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); and ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion).

Regulating Services – biological control (e.g. seed dispersal, pest and disease control); and water treatment (especially water purification).

Supporting/Habitat Services – maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); photosynthesis and primary production and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); and bequest, intrinsic and existence.

The problem of chemical pollution has transboundary implications due to the fact that chemical contaminants can be transported by ocean currents leading to impacts on coastal and marine ecosystems throughout the region (see Table 4-1). In cases where bio-accumulation occurs especially in larger migratory species such as marine mammals and sharks, the contaminants can impact resources and thus communities far removed from the originating source. Chemical pollution can also affect one or more life stages of migrating marine organisms, which could impact on their distribution and abundance in a neighbouring country or region. The chronic or sublethal impacts associated with chemical contamination are often localised and contained within the vicinity of the source of origin. However, the issue can be considered transboundary where the issue is shared between one or more countries.

The specific direct environmental impacts linked to chemical pollution include: Discolouration of coastal waters; chronic effects that can alter growth, reproduction and other physiological processes of marine biota; acute effects that induce mortalities of marine biota; and modification of marine biotic species composition. The socio-economic consequences associated with chemical pollution which pose risks to human health affect stakeholders across society, from local communities to large tourist developments. The fisheries sector, both commercial and artisanal, as well as the aquaculture and seafood production industries, may also be affected. The specific socio-economic consequences include (i) loss of artisanal and/or commercial fisheries' potential; (ii) reduction in quality of seafood products cultured or harvested from a particular area; and (iii) human health risks associated with contact recreation or ingestion of contaminated seafood.

All nine countries in the WIO Region identified chemical pollution issue as being 'Relevant', only 2 of the countries ranked the issues as being of 'High' importance in the Level 1 prioritisation, a further 5 ranked it as being of 'Medium importance, and 2 ranked it as being of 'Low' importance. Only one country allocated an 'Overall rating' score that was above average compared with the scores for the other issues. The Regional 'Overall rating' score was also below average, indicating that the countries do not consider chemical pollution to be a high priority transboundary issue of concern in the WIO region at the present time.

(b) Causal Chain Analysis

The root causes of chemical pollution problems in the WIO region are generally cross-cutting and the following are considered to be the most relevant:

Population pressure - Population growth and expansion is one of the fundamental root causes of pollution in the region. The associated rapid urbanisation with changes in lifestyles characterised by high consumption rates, results in increased generation of waste. All countries in the WIO region have experienced rapid population growth and urbanisation in coastal areas and there has been increased production and disposal of solid wastes, domestic wastewaters and sewage, discharge of industrial wastewaters and effluent, particularly within the larger coastal cities.

Poverty and inequality - The WIO region is characterised by some of the highest poverty levels in the world, as evidenced by relatively low income per capita and low GDPs in the different countries. Consequently, a lack of adequate resources is one of the main reasons for inefficient and ineffective management of solid wastes, sewage, effluents and wastewaters in many of the countries in the region.

Inappropriate governance - Important building blocks for effective governance are not in place in many of the countries and the level of inefficiency varies from one country to another.

Inadequate knowledge and awareness – In most countries, most people are not empowered to play an active role in effective governance and management of coastal and marine natural resources.

Inadequate financial resources - Lack of adequate financial resources to implement and enforce legislation and promote use of appropriate technologies and practices to prevent or minimise

environmental impacts and socio-economic consequences of human activities in the coastal and marine ecosystems are a concern in many countries in the WIO region. Furthermore, lack of commitment by politicians in many instances, to address issues of environmental concern (including marine pollution) is reflected in the low priority given to such issues in the policies and budget allocations of most of the countries in the region. The socio-economic consequences of the impacts of pollution are also not properly communicated to politicians – knowledge that could change such behaviour.

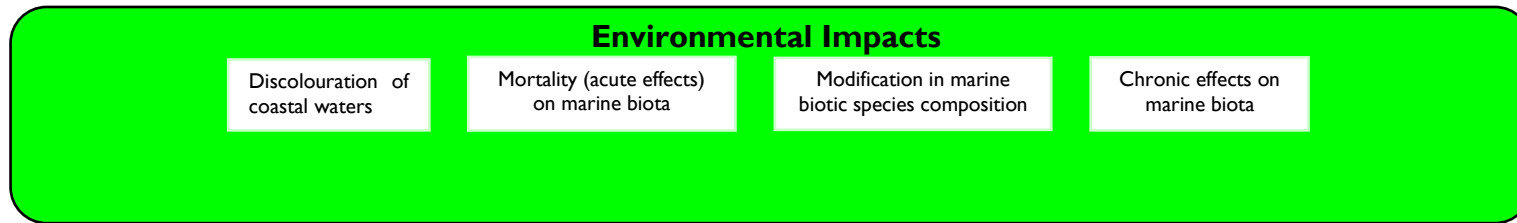
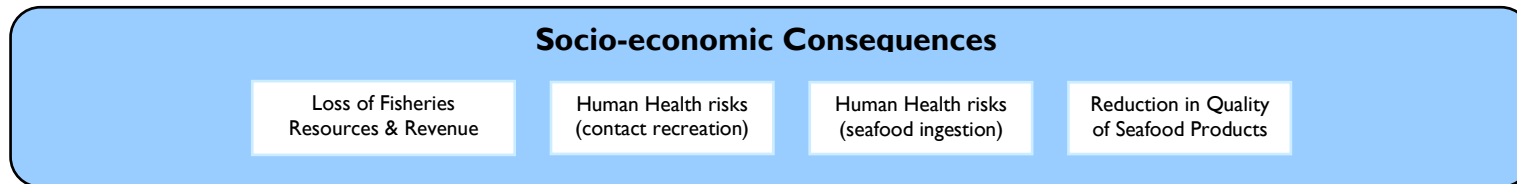
The three key sectors contributing towards chemical pollution of coastal- marine waters in the WIO region include industrial sector that contributes through disposal of toxic substances in wastewaters and industrial effluents, agricultural sector that contributes through discharge of persistent organic pollutants and transportation sector that contributes through dredging activities in ports and harbours that releases heavy metals and hydrocarbons bound in sediments. Probably to a lesser extent, the urban sector also contributes to chemical pollution through traffic emissions and the energy sector through burning of fossil fuels. However, the later contribution is deemed to be of minor significance in the region. Major industries contributing to chemical pollution in the WIO region include manufacturing, textiles, tanneries, paper and pulp mills, aluminium smelters, breweries, chemical, cement, sugar and fertilizer factories and oil refineries. Inappropriate utilisation, storage, transportation and disposal of agrochemicals including pesticides and fertilizers, are matters of increasing concern in most countries in the region. Furthermore, accidental spills of oil and chemicals in harbours or along coastal transport routes is another source of chemical pollution in coastal areas. These are summarised in the problem tree for chemical pollution provided in **Error! Reference source not found.**

The main **Underlying Causes** of chemical pollution in the WIO region can be summarised as follows:

- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for natural resources/materials.
- Increased internal market demands for natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of pollution due to oil spills are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

IMPACTS AND CONSEQUENCES



DIRECT CAUSES AND UNDERLYING SECTORS

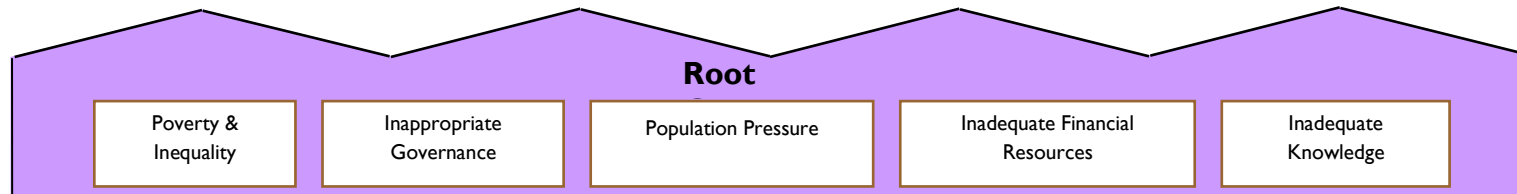
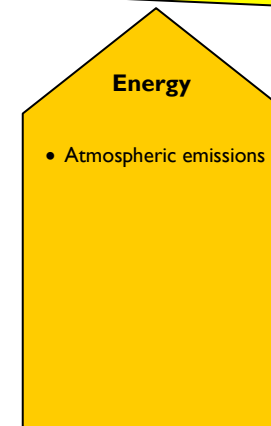
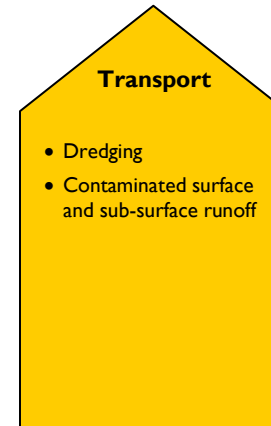
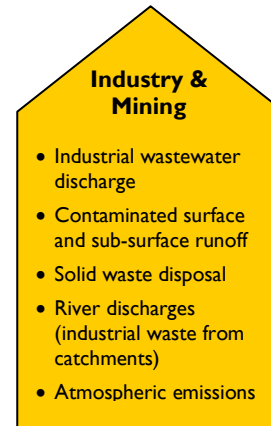
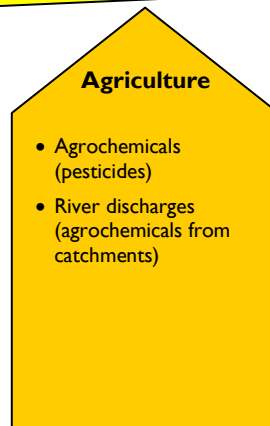


Figure 2-8 Causal chain analysis for chemical pollution in the WIO.

1.5.2.5 Degradation of ground and surface water quality

Impact Chain Analysis

Most countries in the WIO region are characterised by presence of coastal groundwater aquifers that are important sources of freshwater supplied to urban and rural centres. There are also numerous streams and rivers that are also important sources of freshwater for urban and rural water supplies and irrigation projects. However, in the recent past, the pollution of both the groundwater and surface water resources has increased due to discharge of municipal and domestic wastewaters and sewage, discharge of industrial wastewaters and effluents and also due to contaminated surface runoff in urban areas. The pollution of groundwater aquifers and surface water sources is limiting the availability of freshwater for various purposes. This is compounding the problem caused by water scarcity in most coastal areas in the region. The main environmental impacts caused by degradation of ground and surface water quality include degradation of estuaries, salinisation of soils, degradation of soil quality and decreased natural productivity. Lack of freshwater constraints public health and limits many development activities including tourism. The ecosystem services likely to be affected by degradation of ground and surface water quality include:

Provisioning Services - food (e.g. fish, game fruit); freshwater (e.g. for drinking, irrigation, cooling); and ornamental resources (e.g. artisan work, decorative plants etc.).

Regulating Services—wastewater treatment especially water purification; nutrient cycling and maintenance of fertility including soil formation; and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - maintenance of life cycles (including nursery, spawning, breeding, feeding); photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information and opportunities for recreation, tourism and lifestyle.

The socio-economic impacts caused by degradation of ground and surface water quality are reduction in quantity/quality of freshwater available for drinking and irrigation; reduction in agricultural productivity due to salt water intrusion; reduction in opportunities for tourism and leisure; reduction in aesthetics; reduction in future use values; loss of fisheries resources and revenue; loss of income generating livelihoods associated with tourism; increased unemployment; threats to public health; human health risk through ingestion of contaminated seafood; reduced productivity of workforce due to sickness and ill health; increased cost of living; reduction of foreign income revenues; loss of national revenues/GDP; reduction in wellbeing; reduced resilience; increasing poverty; impacts upon religious festival; and loss of social cohesion.

Causal Chain Analysis

The most important direct causes of degradation of ground and surface water quality are release of effluents from point and non-point sources, surface run-off from agricultural land and urban areas and inappropriate agricultural practices that causes soil erosion. However, rainfall variability, changes in land use and vegetation cover and deforestation also contributes to the problem in the region. The sectors that contribute to the degradation of ground and surface water quality are industry, agriculture and forestry, urbanisation, mining, tourism and natural environmental variability and change. The resource use practices and underlying (social, legal and political) causes that are contributing to the problem include the following:

Agriculture and Forestry: The agricultural sector is expanding as a result of the increased demand for food and agricultural produce in response to internal and external market demand. Various resource use practices are contributing to this issue including: (1) poor land use management and farming practices (e.g. lack of crop rotation), (2) increased use of agro-chemicals (fertilisers and pesticides), (3) increased surface run-off and (4) inadequate management and disposal of livestock waste. These practices may occur as a result of lack of education, knowledge and awareness, and lack of incentives for good practice.

There is also lack of agricultural extension officers within the region, and this contributes to limitations in compliance. Inadequate land-use planning and weak regulatory frameworks together with limited monitoring and enforcement capacities further compound the issue.

Urbanisation: Increased urbanisation results in increased (5) disposal of municipal wastewater, (6) construction activities, (7) seepage from pit latrines, (8) leachate from waste disposal sites and (9) surface water run-off. Increasing numbers of people are attracted to urban areas by the employment opportunities. Many urban areas have inadequate drainage systems or lack the infrastructure needed to manage and treat increasing volumes of wastewater. This is largely due to inadequate planning and investment in infrastructure, but is also due to inadequate waste water management legislation or weak enforcement of regulations.

Tourism: The tourism sector is expanding as a result of the economic growth potential and employment opportunities linked to global economic market demand. The expansion of this sector results in increasing (10) disposal or seepage of wastewater in the absence of adequate wastewater treatment infrastructure and (11) uncontrolled or poorly regulated construction activities, and (12) increased surface run-off. Weak national regulatory frameworks, insufficient planning and policy development occur as a result of lack of capacity for planning, as a well as lack of capacity for monitoring and enforcement especially of EIA regulations.

Industry: (13) Inappropriate disposal of effluents and increased (14) surface run-off occurs due to the expansion of industries. There is lack of drainage systems and effluent treatment systems including waste disposal infrastructure. Most companies exhibit poor compliance and countries have difficulties in identifying polluting industries due to inadequate monitoring capacities. Underpinning these practices is lack of capacity for planning for industrial development, weak national regulatory frameworks and lack of capacity for enforcement of legislation.

Mining: The (15) processing of mine wastes, washing of mine tailings and associated surface run-off occurs as a result of the expansion of this sector in response to the global market demand. There is poor planning and a lack of enforcement of legislation.

Climate change and natural environmental variability: Degradation of ground and surface water quality occurs due to algal blooms, droughts and floods as a result of climate variability and change.

The **Underlying Causes** of the degradation of ground and surface waters can be summarised as:

- Inadequate investment in infrastructure/poor maintenance.
- Rural poverty increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Limited knowledge and lack of technology and best practices.
- Lack of alternative sustainable livelihood opportunities.
- Low compliance with existing regulations.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Weak national planning and regulatory frameworks.
- Wealth creation and corruption.

The **Root causes** of degradation of ground and surface water quality include: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [H] Climate change and natural processes.

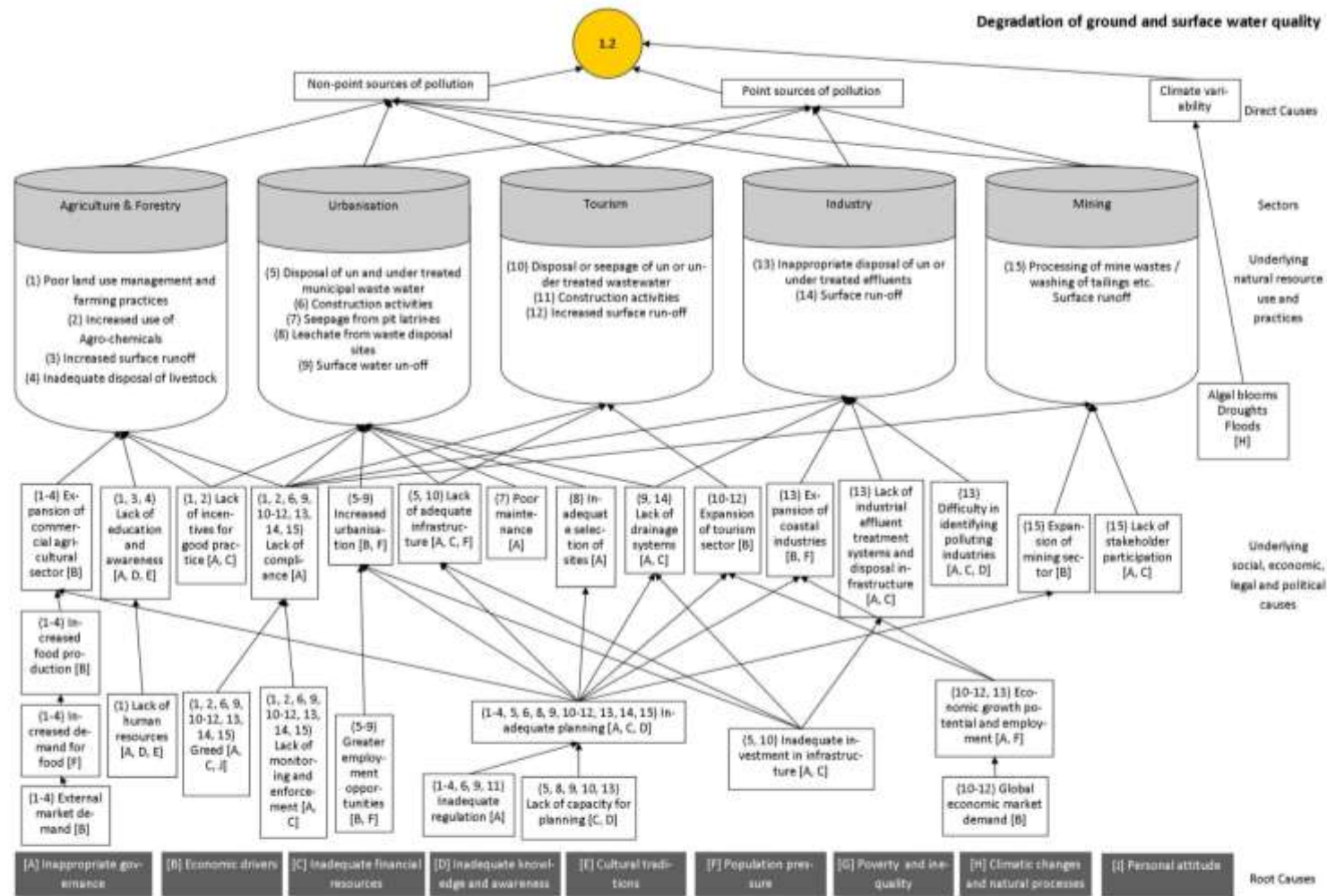


Figure 2-9: Causal Chain Analysis for the degradation of ground and surface water quality.

1.5.2.6 Microbiological contamination from land-based and marine sources

(a) Impact Chain Analysis

Microbial contamination is a common problem in most countries in the WIO Region and especially in coastal waters found in close proximity to urban centres. The environmental impacts caused by microbiological contamination from land-based sources (domestic, industrial, agriculture and livestock) and marine-based sources (mariculture, shipping) are algal blooms; eutrophication and anoxic conditions ("dead zones") increase in the incidences of diseases in marine organisms; high levels of pathogenic organisms; decreased natural productivity; loss of biodiversity; mortality of fish and macro-benthos; reduction in water quality (smells and colour). The ecosystem services likely to be affected by the environmental impacts resulting from microbial contamination include the following:

Provision Services—food (e.g. fish, fruits); freshwater; medicines and pharmaceuticals (e.g. biochemical products and test organisms) and ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion).

Regulating Services—Waste treatment especially water purification; nutrient cycling and maintenance of productivity; biological control for instance disease control.

Supporting Services—maintenance of life cycles including nursery, spawning, breeding, feeding grounds; maintenance of genetic diversity (gene pool protection); photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; social relations and sense of place.

The socio-economic impacts caused by microbiological contamination from land-based and marine-based sources include reduction in opportunities for tourism and leisure; reduction in aesthetics; reduction in future use value; loss of fisheries resources and revenue; loss of income generating livelihoods associated with fisheries / tourism; Increased unemployment; reduced quality of seafood products; threats to public health; human health risk through contact recreation; human health risk through ingestion of contaminated seafood; reduced productivity of workforce due to sickness and ill health; increased cost of living; reduction of foreign income/revenues; loss of national revenues/reduction in GDP; reduction in wellbeing; reduced resilience and increasing poverty.

(b) Causal Chain Analysis

The most important direct causes of microbiological contamination are release of effluents from point sources, release of effluents from non-point sources and surface runoff from agricultural land and urban areas. The sectors responsible for microbiological contamination are urbanisation, tourism, transportation and shipping, and agriculture and forestry. The resource use practices and underlying (social, legal and political) causes are as follows:

Urbanisation: Increased urbanisation contributes towards the issue of microbial contamination in coastal waters through (1) disposal of un- or under treated municipal waste water, (2) surface run-off and (3) seepage from pit latrines. Waste water treatment and disposal facilities are under-capacitated or out-of-date and are unable to cope with the expanding urban populations. This is due to a lack of planning but is also due to lack of investment in waste water infrastructure.

Tourism: The expansion of the coastal tourism contributes to the issue of microbial contamination through (3) disposal of un- or under treated municipal waste water and (4) surface run-off. There is lack of proper planning for tourism development, and increased volume of waste water generated by the expansion of the tourism sector. There is also low compliance within the industry and capacity for EIA and enforcement of existing regulations is weak.

Agriculture and Forestry: (6) Free roaming livestock contribute to the issue of microbial contamination through surface run-off, and there is no way of controlling the waste. There is also lack of treatment facilities to process agricultural waste.

Transportation and Shipping: (7) Disposal of liquid wastes from ships at sea occurs due to lack of compliance with international maritime legislation, due to lack of awareness, carelessness and lack of capacity for the countries to enforce such laws in their EEZ. There is also lack of adequate provision of facilities for collection, treatment and disposal of liquid wastes at ports as a result of a lack of investment.

The main **Underlying Causes** of microbiological contamination can be summarised as follows:

- Increased internal market demands for (use of) natural resources/materials.
- Increased external market demands for (use of) natural resources/materials (tourism).
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Low compliance with existing regulations.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Limited knowledge and lack of technology and best practices.
- Inadequate investment in infrastructure/poor maintenance.
- Wealth creation and corruption.
- Rural poverty increased coastal migration and urbanization.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of microbial contamination in coastal waters are as follows: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality, [H] Climate change and natural processes and [J] Personal attitude.

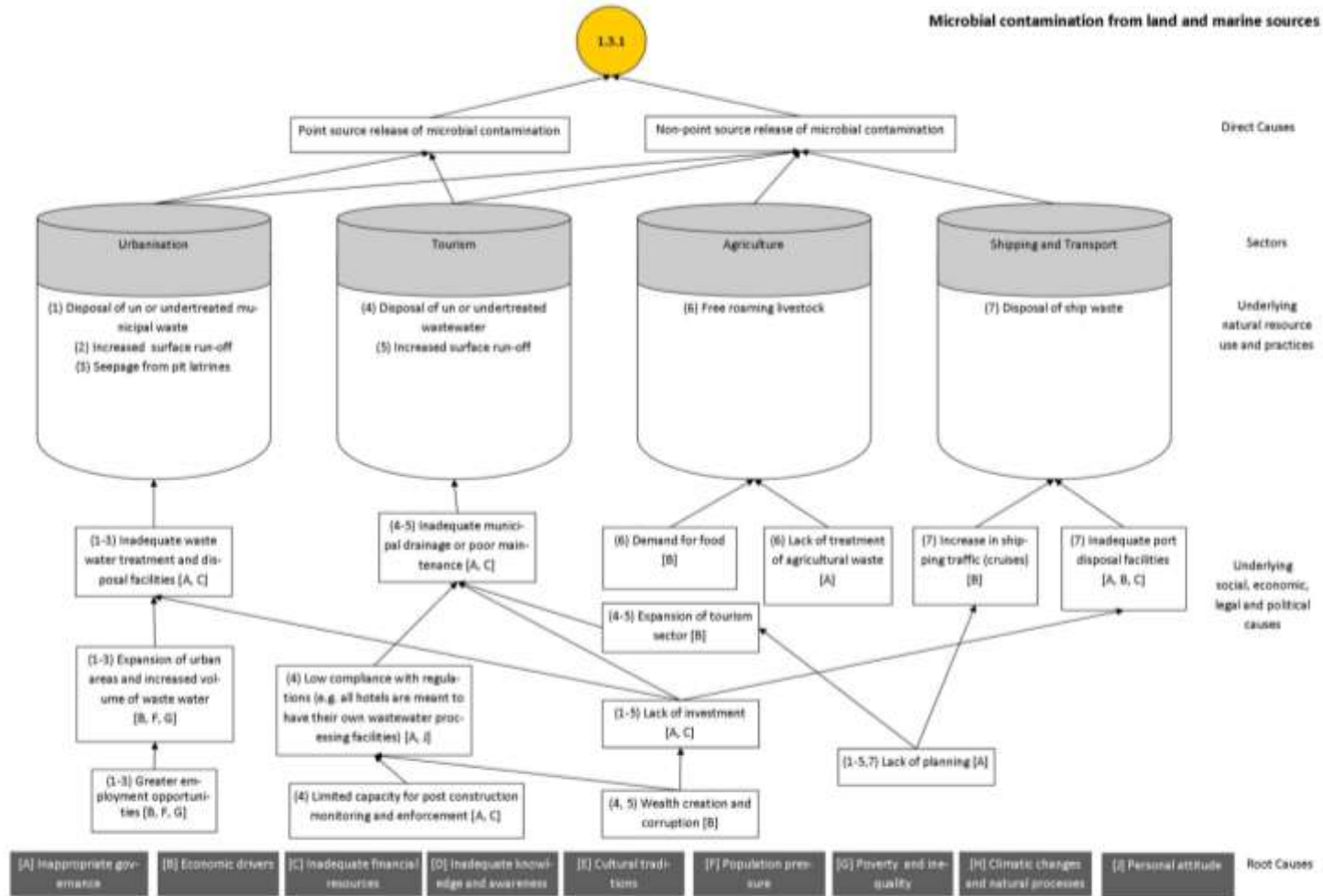


Figure 2.10: Causal Chain Analysis for microbiological contamination from land-based and marine-based sources.

1.5.2.7 Solid wastes/marine debris including plastic litter from shipping and land-based-sources

(a) Impact Analysis

The environmental impacts caused by solid wastes/marine debris including plastic litters from marine and land-based-sources include decline in turtle populations; degradation of floodplains; degradation of deltas; degradation of saltmarshes; degradation of estuaries; damage to sand beaches; damage to rocky shores; degradation of mangroves; degradation of coral reefs; degradation of seagrass beds; loss of biodiversity; mortality of fish and macro-benthos; declines in seabird populations and declines in marine mammal populations. The ecosystem services impacted by solid wastes/marine debris including plastic litter include:

Provision Services—food (e.g. fish, game fruit); freshwater (e.g. for drinking, irrigation, cooling); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); and ornamental resources (e.g. artisan work, decorative plants, pet animals).

Regulating Services—regulation of water flows; erosion regulation/prevention; nutrient cycling and maintenance of fertility (including soil formation); and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services—maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding); photosynthesis and primary production; and secondary production.

Cultural and Amenity Services—aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; and social relations.

The socio-economic impacts caused by solid wastes/marine debris (plastic litter) from shipping and land-based-sources include reduction in opportunities for tourism and leisure; reduction of aesthetics; reduction in future use value; loss of income generating livelihoods associated with tourism; increased unemployment; threats to public health; human health risk through contact recreation; reduction of foreign income/revenues; loss of national revenues/GDP; reduction in wellbeing; reduced resilience; increasing poverty; and loss of social cohesion.

(b) Causal Chain Analysis

The most important direct causes of solid wastes/marine debris including plastic litter marine and land-based-sources are inappropriate disposal of solid wastes, solid waste and plastic litter transported by surface runoff and rivers flowing through urban areas, dumping of solid wastes from ships, discarded fishing gear, among others. Plastic litter is also transported by ocean currents from South East Asia. The sectors responsible for solid wastes/marine debris (plastics etc.) from shipping and land-based-sources are urbanisation, tourism, transportation and shipping, fisheries and aquaculture, agriculture and forestry, and industry. The resource use practices and underlying (social, legal and political) causes are as follows:

Urbanisation: (1) Inappropriate disposal of solid waste occurs due to inadequate municipal waste collection and disposal systems, resulting from lack of planning for increased urbanisation and the increased volume of waste generated. The issue is compounded by lack of awareness and understanding of the impacts of solid wastes on the environment, and limited social attachment to coastal environment in some countries. There is often inadequate legislation on solid waste management, limited monitoring and enforcement capacities and disputes over land ownership for waste disposal sites due to other political priorities. The (2) dumping of garbage occurs due to lack of waste collection system but also due to weak enforcement capacities. Increased volumes of (3) solid wastes carried in surface run-off and (4) river run-off occurs due to inadequate planning of urban areas and inadequate maintenance of waterways.

Fisheries and Aquaculture: (5) Dumping solid waste and garbage overboard from small and large vessels occurs due a lack of education and awareness, underpinned by inadequate monitoring and enforcement capacities. (5) Discarded and lost fishing gear result from inappropriate fishing practices, and a lack of awareness and education and also due to lack of capacity.

Tourism: (7) Inappropriate disposal of solid waste occurs due to inadequate municipal waste collection and disposal systems. There is lack of proper planning for tourism development and increased volume of waste generated by the expansion of the tourism sector and weak enforcement of regulations due to other priorities. (8) Beach littering occurs due the limited provision of bins and inadequate garbage collection and disposal systems, lack of education and awareness, and inadequate monitoring and enforcement capacities.

Industry: (9) Dumping of garbage by industries occurs due to the expansion of coastal industry without adequate municipal waste collection and disposal systems. There is inadequate planning for industrial development and increased volume of waste generated by the expansion of the industrial sector, as well as weak compliance and lack of or weak enforcement of existing regulations due to other political priorities.

Transportation and Shipping: (10) Throwing solid wastes overboard occurs due to lack of facilities for collection and disposal of solid wastes at ports, lack of awareness, carelessness and inadequate monitoring and enforcement due to lack of capacity. (11) Waste dumping at sea takes place due to a lack of compliance with international maritime legislation and lack of enforcement within the countries national EEZ due to capacity limitations.

The main **Underlying Causes** of the solid wastes/marine litter can be summarised as follows:

- Rural poverty increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of education, training and awareness.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of solid wastes/marine litter include: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality, [H] Climate change and natural processes, [I] Voluntary action fills the governance void and [J] Personal attitude.

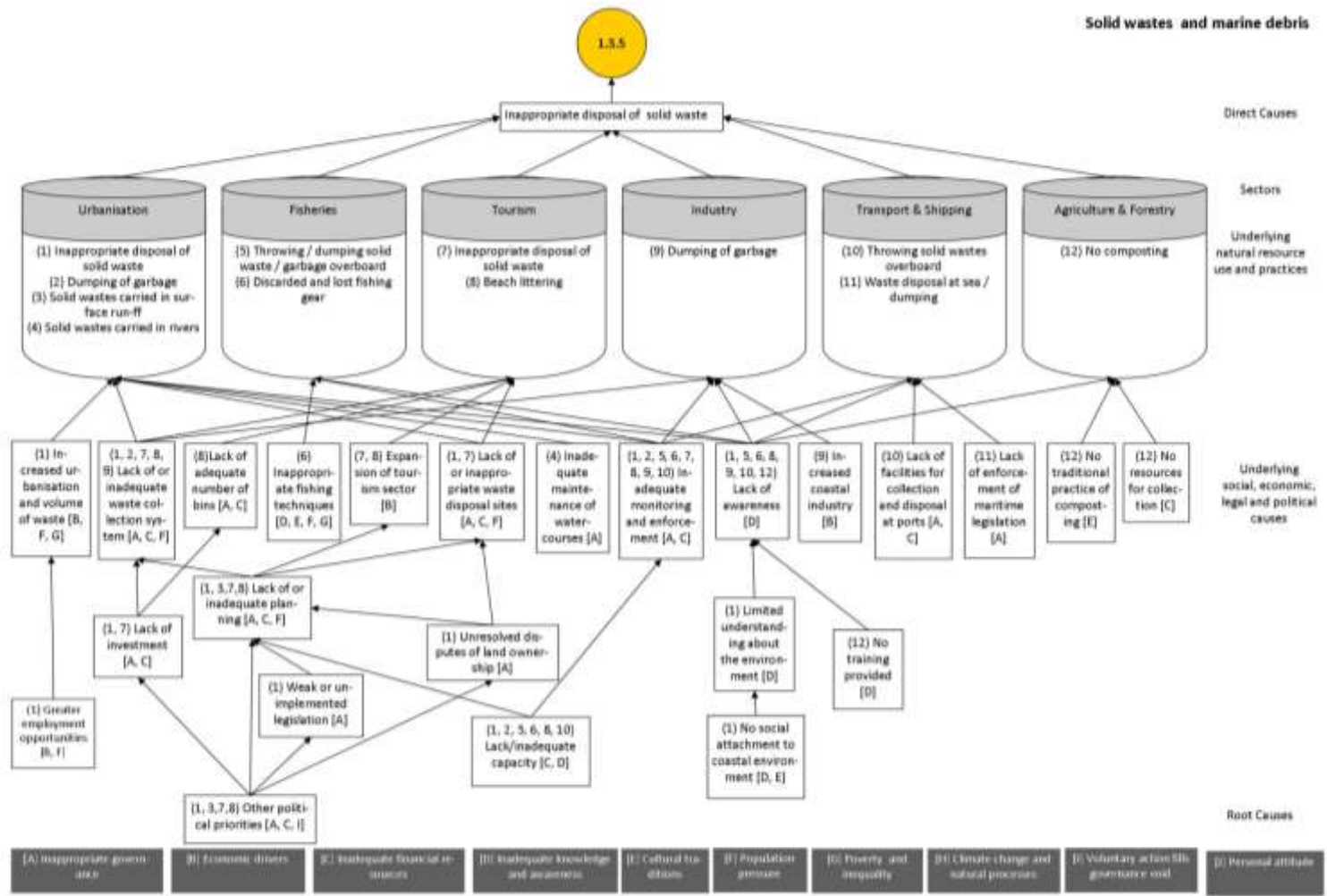


Figure 2.11: Causal Chain Analysis for solid wastes marine debris including plastic litter from shipping and land-based-sources.

1.5.2.8 Pollution due to oil spills associated with drilling, exploitation, transport, processing, storage and shipping activities

(a) Impact Chain Analysis

Chemical pollution due to oil spills is also common in the WIO region. Extensive mangrove forests in Mombasa and Maputo have been destroyed by oil spills (Munga, 1993; Richmond, 2002). Oil spillage has resulted in mangrove dieback especially in Makupa Creek where the effects of oil spills are still evident several decades after the last oil spill incident (Abuodha and Kairo, 2001). The main effects of oil spills on mangrove ecosystems include complete smothering of estuarine vegetation and organisms (Abuodha and Kairo, 2001). Seagrass habitats are similarly affected and studies in Kenya have indicated cases of complete smothering of these benthic plants, as well as their associated organisms (Abuodha and Kairo, 2001). The environmental impacts caused by oil spills that occurs during drilling, exploitation, transport, processing, storage and shipping are: loss of biodiversity; declines in marine mammal populations; bio-accumulation of toxins up the food chains; and reduction in water quality due to smell and colour. The ecosystem services impacted by oil spills include:

Provisioning Services – food (e.g. fish, game fruit); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); and ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion).

Regulating Services – biological control (e.g. seed dispersal, pest and disease control); and water treatment (especially water purification).

Supporting/Habitat Services—maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); and bequest, intrinsic and existence.

The socio-economic impacts caused by oil spills include: reduction in opportunities for tourism and leisure; reduction of aesthetics; reduction in future use value; loss of fisheries resources and revenue; reduction in fish availability; loss of income generating livelihoods associated with fisheries; loss of income generating livelihoods associated with tourism; increased unemployment; reduced quality of seafood products; threats to public health; human health risk through contact recreation; human health risk through ingestion of contaminated seafood; increased cost of living; reduction of foreign income/revenues; loss of national revenues/GDP; reduction in wellbeing; reduced resilience; increasing poverty; and loss of social cohesion.

(b) Causal Chain Analysis

The direct cause of oil spills is accidental release of oil during extraction, refining and transport. The sectors responsible for oil spills are: mining, transportation and shipping, industry and energy. The resource use practices and underlying (social, legal and political) causes are as follows:

Mining: The risk of accidental oil spills during (1) exploration and (2) extraction for production will occur due to the expansion of the oil sector in the region as a result of global economies and increased market demand. The risk is increased where there is insufficient national capacity to regulate and monitor foreign companies, especially those with inadequate internal environmental management policies. This often occurs as a result of insufficient allocation of funds for monitoring and checking compliance. The risk is exacerbated where there is also poor operational management (e.g. untrained personnel, a lack of proper equipment and maintenance and appropriate safety procedures) and a lack of capacity for handling cleanup operations due to limited education, knowledge, skills and training in the use of best practice.

Industry: (3) Oil spills during processing and storage occur due to the poor operational management of refineries, as a result of a the lack of proper equipment and maintenance, a lack of appropriate safety procedures, as a result of limited knowledge, and untrained personnel as a result of inadequate investment by the companies in providing skills based training in the use of best practices Weak national planning/regulatory frameworks further contribute to the continuation of these practices.

Energy: An increased demand for energy supply increases the risk of (4) oil spills from storage facilities. There is a lack of funds for monitoring and checking and a lack of capacity for handling cleanup operations. The risk of (5) oil spills at the point of energy generation increases due to poor operational management of facilities as a result of untrained personnel, lack of proper equipment and maintenance and lack of appropriate safety procedures as a result of limited knowledge, skills and use of best practices and inadequate investment. There are also weak national planning/regulatory frameworks.

Transportation and Shipping: The risk of an oil spill during transportation and shipping is due to the (6) proximity to major shipping lanes, combined with the increasing levels of shipping traffic within the region, in response to both global market demand and piracy within the northern part of the region. The (7) risk of a large scale oil spill within the WIO region increased due to the expansion of the oil industry within the region, and increased shipping traffic as a result of global economies and economic development pressure. Navigational resources within the region are inadequate due to lack of information on possible natural hazards and lack of proper planning and delimitation of shipping lanes. In addition, high risk, poorly maintained vessels are used for transport and personal negligence/carelessness is another contributory factor. The (8) risk of a large scale spill during loading, offloading occurs due to out of date / inadequate infrastructure at ports and negligence/carelessness. The risk of (9) small scale spills during cleaning/disposal of ballast water occur due to inadequate cleaning and waste disposal faculties at port and carelessness/negligence.

The main **Underlying Causes** of oil spills can be summarised as follows:

- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate investment in infrastructure/maintenance.
- Low compliance with existing regulations.
- Limited knowledge and lack of technology and best practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Weak national planning and regulatory frameworks.

The **Root Causes** of pollution due to oil spills are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

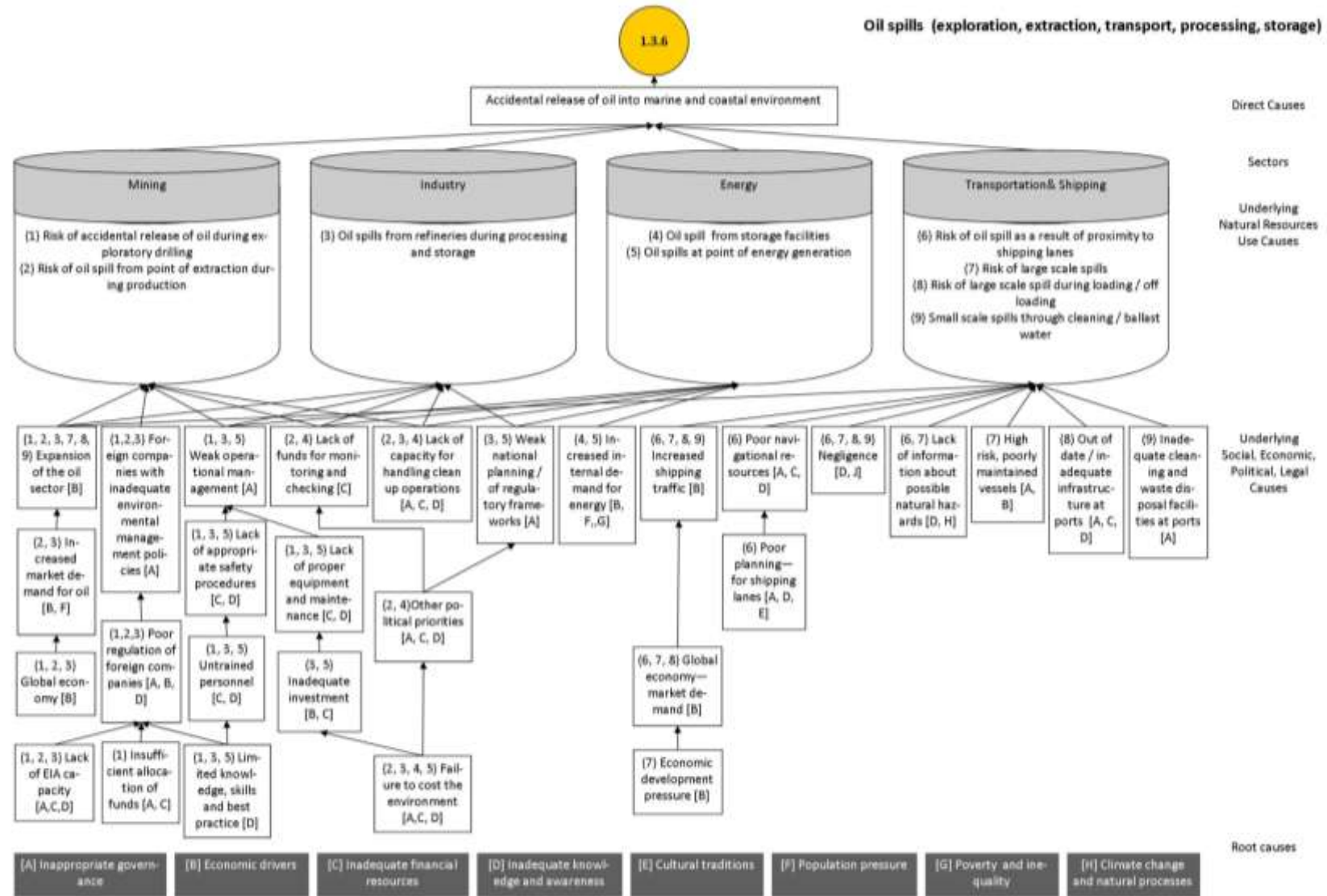


Figure 1.12: Causal Chain Analysis for pollution of coastal waters due to oil spills.

1.5.3 Problem Area 2: Physical Alteration, destruction of habitat and Community Modification

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

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

A summary of the main threats, impacts, and the underlying root causes of PADH in the region, for each of the five categories of PADH defined above are presented in Table 2-15 and 2.16. The following sections present a detailed root-cause analysis of each of these problem areas.

Table 2-15 Causes, environmental impacts and socio-economic consequences of PADH in the region.

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

Table 2-16 Direct causes and sectors responsible for the PADH in the WIO region.

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

The following section presents the impact and causal chain analysis for the top priority transboundary issues related to physical alteration, destruction and modification of habitats in the WIO region. The top priority issues identified by the WIO countries are as follows:

- Shoreline change due to modification, land reclamation and coastal erosion.
- Degradation and loss of upland watershed habitats (>10 m elevation).
- Degradation and loss of coastal forest vegetation and flood plain habitats.
- Degradation and loss of mangrove forest habitats.
- Degradation and loss of coral reef habitats.
- Degradation and loss of seagrass habitats.
- Introduction of exotic non-native species, invasives and nuisance species.

A summary of the impact chain analysis (environmental impacts, the ecosystem services affected by these impacts, and socio-economic consequences) and the causal chain analysis (direct causes, sectors and resource use practices, underlying social, legal and political causes, and root causes) is presented for each of these issues.

1.5.3.1 Shoreline change due to modification, land reclamation and coastal erosion

(a) Impact Chain Analysis

The environmental impacts caused by shoreline change due to modification, land reclamation and coastal erosion include: reduced water clarity and light availability for photosynthetic organisms; loss of biodiversity; increased risk of extinction of vulnerable species; loss of 'natural' shoreline protection and increased risk of coastal flooding; increased coastal erosion; changes to sediment composition (e.g. organic composition, particle size etc.); changes to sediment transport dynamics (accretion); modification of coastal hydrodynamics and changes in community composition. The ecosystem services likely to be affected by the environmental impacts resulting from shoreline change include:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion); freshwater (e.g. for drinking, irrigation, cooling) for which there is a medium link; and geological resources.

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. Natural drainage, irrigation and drought prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility (including soil formation) for which there are very strong links; and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; spiritual experience; information for cognitive development knowledge systems and education; and social relations.

The socio-economic impacts caused by shoreline change due to modification, land reclamation and coastal erosion are: increased risk of coastal flooding, increased risk to human life; loss of property; reduction in property/ real estate value; loss of infrastructure; increased costs of sea defence; change in livelihood; increased operation costs (e.g. due to increased travel costs for fishers etc.); loss of foreign revenues; reduction in GDP; reduction in income generating livelihoods (non-fisheries related e.g. tourism); reduction in income generating livelihoods (fisheries related); reduced resilience/increased vulnerability; loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; reduced

well-being; increased stress; loss of social cohesion; increase in social conflicts; and increased vulnerability to climate variability and change.

(b) Causal Chain Analysis

The most important direct causes of shoreline change are: shoreline erosion and coral reef degradation; physical removal of sediments; increased frequency and intensity of storm waves (e.g. cyclones, tsunami) and sea level rise. The sectors responsible for causing shoreline change are: urbanisation, tourism, industry, mining, transport and shipping, agriculture and forestry, energy and natural environmental variability. The contribution of these sectors is examined in more detail below.

Tourism: (1) Infilling of sea frontages to increase land for recreation due to the increasing demand for land for tourist developments. (2) Coastal development activities and the use of groins in front of hotels to retain beach frontages occur due to developers failing to comply with coastal set-back regulations and weak enforcement of these regulations. This arises due to lack of human resources (extension officers and environment inspectors) and lack of knowledge of staff. (3) There are also gaps in legislation relating to the construction of shoreline structures in front of private property (e.g. groins), as a result of unresolved legal issues related to land ownership in the coastal zone.

Transport and Shipping: (4) Dredging takes place as it is needed for maintenance of shipping lanes and economic development priorities. (5) Dredge spoils are sometimes used to reclaim land. There are weaknesses in the EIA process related to dredging, and this is due to lack of training in EIA procedures and lack of capacity.

Urbanisation: Unplanned coastal development occurs due to increased coastal population and non-compliance with coastal set-back regulations. (6) Sand-mining from coastal rivers and beaches for construction arises due to high local demand for sand for the construction industry. There is non-compliance with sand mining regulations as a result of weak enforcement. In addition, sand mining is a low skilled and low technology livelihood activity and there is a lack of alternative livelihoods for miners. (7) Infilling and reclamation to create additional land for development takes place due to a high demand for flat coastal land and lack of planning. (8) Destruction of natural barriers (mangroves, coral reefs, dunes, coastal vegetations) occurs due to the failure to mainstream climate change in coastal development planning.

Industry: Land clearing and deforestation of mangroves for salt pans occurs due to a high market demand for salt. There is non-compliance with regulations and clearing of mangroves to create additional space for salt pans due to weak enforcement of salt pan plot boundaries. This arises as a result of lack of knowledge and awareness in Government and lack of human resources particularly extension officers and environmental inspectors.

Agriculture and Forestry: (11) Increased runoff from agricultural land and (1) inadequate land use management occurs due to economic development priorities, lack of land-use plans and/or inability to enforce appropriate land use management practices due to the high percentage of private land ownership in some countries and lack of capacity and resources in other countries.

Natural environmental variability and change: Shoreline change due to modification, land reclamation and coastal erosion is due to changes in sediment dynamics, sea level rise, increased storm frequency (increased storm surges, waves and heavy rains) and ocean warming.

The main **Underlying Causes** of shoreline change due to modification, land reclamation and coastal erosion can be summarised as follows:

- Gaps in regulations/and lack of legal expertise.
- Unresolved legal issues related to land ownership.
- Lack of alternative sustainable livelihoods.
- Rural poverty, increased coastal migration and urbanization.
- Lack of awareness of the longer term implications in Government.

- Failure to mainstream climate change into planning and decision making.
- Lack of ICZM plan/ICZM plan not implemented.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Wealth creation and corruption/lack of transparency.
- Limited knowledge, lack of technology and understanding of best environmental practice.
- Lack of extension officers/environmental inspectors.
- Low compliance with existing regulations.
- Increased internal market demands for (use of) natural resources/materials.
- Increased external market demands for (use of) natural resources/materials.
- Lack of monitoring, control, surveillance and enforcement capacity.

The **Root Causes** of shoreline change due to modification, land reclamation and coastal erosion are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [G] Poverty and inequality and [H] Climate change and natural processes.

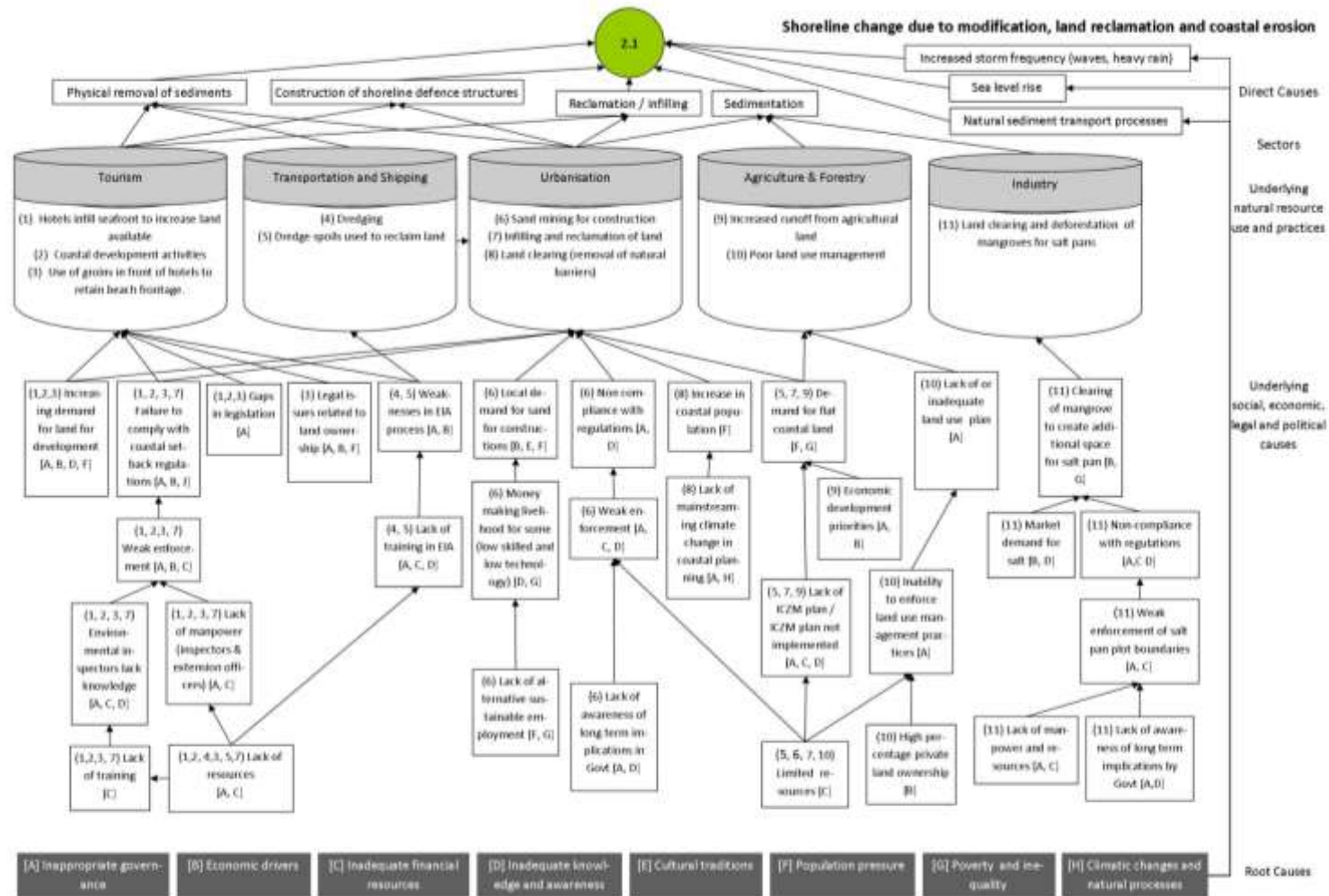


Figure 2-12: Causal Chain Analysis for shoreline change due to modification, land reclamation and coastal erosion.

1.5.3.2 Degradation and loss of upland watershed habitats (>10 m elevation)

(a) Impact Chain Analysis

The most severe environmental impacts caused by the degradation and loss of upland watershed habitats that are located at an altitude greater than 10 m above sea level are: reduced area of critical habitats (feeding, breeding, spawning); changes to sediment composition (e.g. organic composition, particle size etc.); changes to sediment transport dynamics (accretion); reduced water quality due to increased nutrients; reduction in freshwater inflow into coastal waters. Other severe impacts include: loss of biodiversity; increased GHG emissions through burning; changes to trophic structure; loss of 'natural' shoreline protection and increased risk of coastal flooding; increased coastal erosion; reduced water clarity and light available to photosynthetic organisms (turbidity); reduced water quality (chemical contaminants); modification of coastal hydrodynamics; changes in fisheries productivity; changes in primary productivity and phase shifts and changes in community composition. The ecosystem services likely to be affected by the environmental impacts resulting from disturbance, damage and loss of upland/watershed habitats (>10 m elevation) include:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) and; freshwater (e.g. for drinking, irrigation, cooling).

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. Natural drainage, irrigation and drought prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility (incl. soil formation); and biological control (e.g. seed dispersal, pest and disease control).

Supporting / Habitat Services -photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; spiritual experience; information for cognitive development knowledge systems and education and social relations.

The most serious socio-economic impacts caused by disturbance, damage and loss of upland watershed habitats are: reduced resilience /increased vulnerability; loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; loss of inspiration and materials for local artworks; reduction in availability of traditional handicrafts; reduced availability of traditional medicines; loss of habitats important for religious festivals and rituals; reduction in air quality (increase in respiratory diseases); reduced well-being; increased stress; loss of social cohesion; increase in social conflicts; increased unemployment; increased vulnerability to climate variability and change; reduced freshwater availability and; threats to public health. Other impacts include: loss of property; reduction in property/real estate value; loss of infrastructure; increased costs of sea defence; reduction in income generating livelihoods (fisheries related) and; reduced food availability/security due to degradation of soil quality.

(b) Causal Chain Analysis

Land use change has had significant impacts on the coastal and marine environment of many countries (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). Due to the high population density in the Comoros (300 inhabitants/km²), the lack of land use planning and the land tenure policy, there is uncontrolled land clearing and deforestation for agricultural purposes, and logging. Deforestation has led to increased siltation and reduction in groundwater supplies (ASCLME 2012a). In Kenya, construction activities, poor agricultural practices and deforestation in the river basins have intensified habitat destruction and soil erosion resulting in high sediment loads, and a reduction in the depth of the photic zone, thus limiting productivity of the marine ecosystems (ASCLME 2012b). Poor land use practices in

the Athi-Sabaki River Basin have resulted in the increased discharge of huge volume of sediments in Malindi Bay with far reaching ecological and socio-economic consequences (Kitheka et al., 2022). Massive sedimentation interferes with growth of mangroves and also smothers coral reefs and sea-grass beds (ASCLME 2012b; Kitheka et al., 2002 & 2003). The destruction and burning of vegetation in the Highlands of Madagascar causes massive erosion and an estimated 40 to 50 million tons of topsoil are carried to the seas every year (Rabesandratana 1984). This results in hyper-sedimentation in coastal zones (CNRE/CNRIT/IHSM 2000, ASCLME 2012f).

The most important direct cause of degradation and loss of upland watershed habitats is natural climate variability and change. Other direct causes are changes in land use and vegetation cover (e.g. grazing), physical habitat disturbance, removal and loss and cyclones. The sectors responsible for causing disturbance, damage and loss of upland watershed habitats are: urbanisation, agriculture and forestry and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

Urbanisation: (1) Expansion of urban areas can result in the loss of upland and watershed habitats as a result of poor planning, lack of land use management plans or failure to implement the plans due to lack of capacity, resources and knowledge.

Agriculture & Forestry: The (3) clearing of land for agriculture, (4) overgrazing and (5) poor land use management practices occur due to limited availability of suitable land, poor land use management practices including some traditional farming practices such as 'slash and burn'. These practices result due to lack of awareness, loss of traditional knowledge and lack of education and outreach. There is also lack of investment in extension officers due to other political priorities. Another cause is (4) unsustainable intensive commercial land uses for forestry, sugarcane and livestock.

Natural environmental variability and change: Disturbance to upland watershed habitats occurs as a result of increased temperatures, changes in rainfall patterns, cyclones and extreme weather events, flooding and erosion.

The main **Underlying Causes** of disturbance, damage and loss of upland watershed habitats can be summarised as follows:

- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Limited knowledge, lack of technology and understanding of best environmental practice.
- Open access resource/tragedy of commons.
- Lack of alternative sustainable livelihood.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Low compliance with existing regulations.
- Lack of extension officers / environmental inspectors.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Lack of awareness of long term implications in Government.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Unresolved legal issues related to land ownership.
- Weak national planning and regulatory frameworks.

The **Root Causes** of disturbance, damage and loss of upland watershed habitats are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality, [H] Climate change and natural processes and [J] Personal attitude.

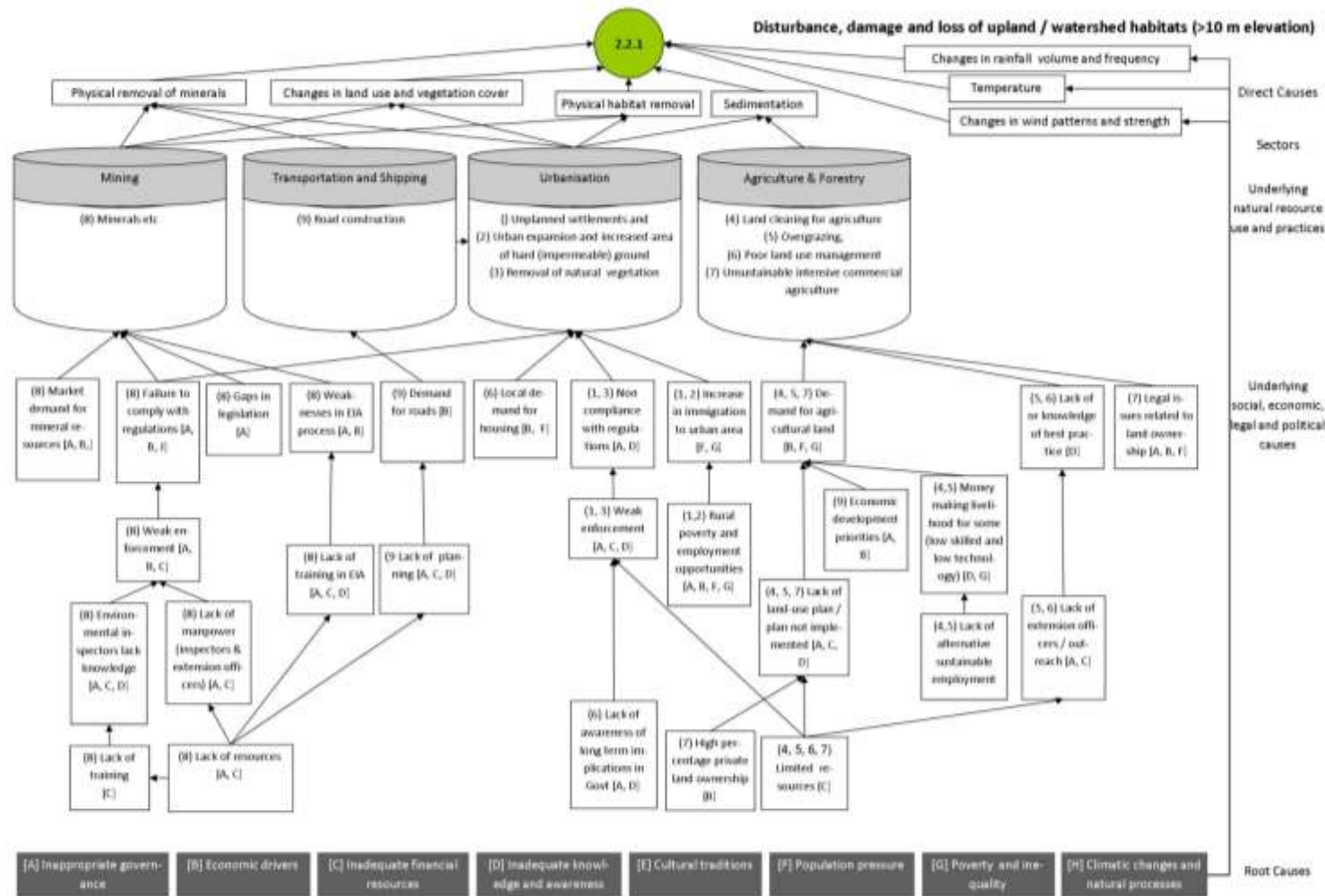


Figure 2-13: Causal Chain Analysis for disturbance, damage and loss of upland watershed habitats in the WIO region

1.5.3.3 Degradation and loss of coastal forest vegetation and flood plain habitats

(a) Impact Chain Analysis

The WIO region is characterised by presence of important coastal forests that are distributed in few remaining patches along the coast which have a high cultural significance to the local coastal communities who have traditionally used them for religious and spiritual rituals (Blackett 1994). The sacred values associated with these forests have contributed to their conservation and growth of forest tourism in the coast region. Coastal populations are highly dependent on forest resources for their daily needs (food, medicines, and general livelihoods). Degradation of coastal forests impacts upon these communities and the marine environment through clearing of buffer vegetation in environmentally sensitive areas close to shorelines which results in increased erosion and sedimentation (ASCLME 2012b).

Coastal forests are sources of fuelwood and charcoal-the main sources of energy for most people in the region. Lack of alternative energy for cooking has resulted in unsustainable harvesting and imposed severe demands on forest resources. In addition there is a major threat posed by the demand for land for export oriented production, including bio-fuels, which without careful management, will be detrimental rather than being beneficial to coastal livelihoods. The promotion of participatory forest management by the government and international NGOs such as WWF have focused on the empowerment of local communities to manage their own resources. Likewise, alternative sources of income generation, such as beekeeping, honey production, and tree nursery management have highlighted potential substitutes in this sector (ASCLME 2012c).

The islands also have important coastal forests, although there has been massive deforestation either historically or more recently, which has resulted in the decimation and almost entire loss of these habitats. On Mauritius and Rodrigues, the forests were cleared by early settlers and alien species were introduced, now little (40 km²) of the native forests remain (Turner and Klaus 2005). Madagascar has also lost much of its forests more recently due to illicit logging and agriculture (ASCLME 2012f). Poor agricultural and forestry practices such as burning and clearing of the forest are an issue of concern in Comoros (ASCLME 2012a).

The most severe environmental impacts caused by the disturbance, damage and loss of coastal forest vegetation and flood plain habitats located at an altitude less than 10 m above sea level are: increased risk of extinction of vulnerable species; loss of 'natural' shoreline protection and increased risk of coastal flooding; increased coastal erosion; changes to sediment composition (e.g. organic composition, particle size etc.); changes to sediment transport dynamics (accretion). Other impacts include: loss of biodiversity; loss of biomass 'carbon' sink; increased GHG emissions (through burning); reduced area of critical habitats (feeding, breeding, spawning); changes to epifauna and infauna; changes to trophic structure; reduced water clarity and light available to photosynthetic organisms (turbidity); loss of coastal vegetation; modification of coastal hydrodynamics; reduction in freshwater inflow into coastal waters; changes in fisheries productivity; changes in primary productivity and; phase shifts and changes in community composition. The ecosystem services likely to be affected by the environmental impacts resulting from the degradation and loss of coastal vegetation and flood plain habitats are:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) and; freshwater (e.g. for drinking, irrigation, cooling).

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. natural drainage, irrigation and drought prevention); erosion

regulation/prevention; nutrient cycling and maintenance of fertility (incl. soil formation); and biological control (e.g. seed dispersal, pest and disease control)

Supporting/Habitat Services -photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; spiritual experience; information for cognitive development knowledge systems and education and; social relations.

The most severe socio-economic impacts caused by disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) are: increased risk of coastal flooding; increased risk to human life; loss of property; reduction in property real estate value; loss of infrastructure; increased costs of sea defence; change in livelihood; increased operational costs (e.g. due to increased travel costs due to loss of landing sites for fishers, fishing grounds etc); loss of foreign revenues; reduction in GDP; reduction in income generating livelihoods (non-fisheries related e.g. tourism); reduction in income generating livelihoods (fisheries related); reduced resilience/increased vulnerability; reduced food availability / security due to the loss of coastal habitat; loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; loss of inspiration and materials for local artworks; reduced well-being; increased stress; loss of social cohesion; increase in social conflicts; increased unemployment; increased vulnerability to climate variability and change; reduced availability of raw materials (building etc); threats to public health and; increased poverty and inequality. Other impacts include: reduction in recreational space available for local community (e.g. beach barbeques); reduction in recreational space available for tourists; reduced food availability/security due to degradation of soil quality (salinisation); increased malnutrition and; loss of habitats important for religious festivals and rituals.

(b) Causal Chain Analysis

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

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

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

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

Tourism development indirectly causes the degradation of coastal forests through increased demand for wood materials used for curios, in the construction of tourist hotels and also through increased demand for agricultural products. For local communities, the loss of livelihoods and cultural values associated with forests further increases their poverty. Additional socio-economic impacts include the reduction in the touristic value of the forest due to deforestation that physically reduces forest areas. These communities become further vulnerable to natural calamities such as droughts or floods. Destruction of coastal forests and climate change also affect large animal communities that live in forests. The coastal forests of eastern Africa are recognized as being of global importance, earmarked as of the 25 world's hotspots of biodiversity due to the high concentrations of endemic plants and animal species in exceptionally small areas (Bruton and Cooper, 1980; Burgess and Clarke, 2000).

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

The most important direct causes of the disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) include physical removal of sediments, infilling and land reclamation, over extraction of non-living marine resources, coastal erosion, coral reef degradation, natural climate variability and change and sea level rise. Other contributory causes include construction of hard shoreline defence structures, beach replenishment/creation, changes in land use and vegetation cover (e.g. grazing), changes in the natural sediment transport patterns, physical habitat disturbance, removal and loss, oil spills and pollution (marine), Siltation, cyclones, increased frequency and intensity of storm waves (e.g. cyclones, tsunami etc.) and Light/noise pollution. The sectors responsible for causing disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) are urbanisation, tourism, industry, mining, transport and shipping, agriculture and forestry, natural environmental variability.

The resource use practices and underlying (social, legal and political) causes are as follows:

Tourism: There has been rapid and unmanaged transformation of the coast land and seascapes due to (1) uncontrolled tourism development, which has resulted in degradation of pristine coastal habitats. The growth of tourism within the region has been driven by international demand and economic development potential. Tourist developments are however inadequately situated due to failure to comply with coastal set-back regulations, deficiencies in EIA process, lack capacity for monitoring and enforcement of mitigation measures, and lack of transparency and corruption in planning processes. As a result of increased tourism, there has also been an increase in activities offered by local (2) tour guides who may lack awareness as a result of a lack of training and education.

Transportation and Shipping: (3) Construction of coastal infrastructure (harbours and launch sites) and (4) roads can result in the loss of critical coastal habitats and cumulative impacts downstream.

Urbanisation: Disturbance of coastal habitats occurs throughout the WIO region as a result of increased migration to the coast due to rural poverty. This has resulted in an increase in the number (5) unplanned settlements and (6) physical habitat damage from urban expansion. Urbanisation within the coastal zone also increases (7) light and (8) noise pollution, which threatens vulnerable species such as turtles, seabirds and shorebirds utilizing the coastal environment. Urban development increases (9) dumping of garbage on beaches and coastal habitats.

Mining: (10) Sand mining (sand-winning; mining for titanium, diamonds, fossil fuels and phosphate) is common in some coastal towns and fishing villages. Sand mined from beaches and dunes is used for building as there is a lack of an affordable alternative.

Agriculture and Forestry: (11) Removal of natural coastal vegetation to increase the amount of land available for agriculture occurs due to the increased demand for produce and due to non-compliance with regulations and a lack of awareness.

Climate and environmental variability: Disturbance, damage and loss of coastal vegetation and flood plain habitats can be caused by wind and wave action, sea level, and may be exacerbated by global climate change. Cyclonic waves can remove large quantities of sand from the beach and lagoons. Winds can result in dune systems becoming more dynamic.

The main **Underlying Causes** of disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) can be summarised as follows:

- Increased internal market demands for (use of) natural resources/materials.
- Increased external market demands for (use of) natural resources/materials.
- Low compliance with existing regulations.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Lack of awareness of the longer term implications in Government.
- Lack of ICZM plan / ICZM plan not implemented.
- Lack of capacity for Environmental and Social Impact Assessment (ESIA).
- Inadequate investment in infrastructure/poor maintenance.
- Rural poverty, increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Failure to mainstream climate change into planning and decision making.
- Lack of transparency / Wealth creation and corruption.
- Weak national planning and regulatory frameworks.

The **Root Causes** of degradation and loss of coastal forest vegetation and flood plain habitats (to 10 m elevation) are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [H] Climate change and natural processes.

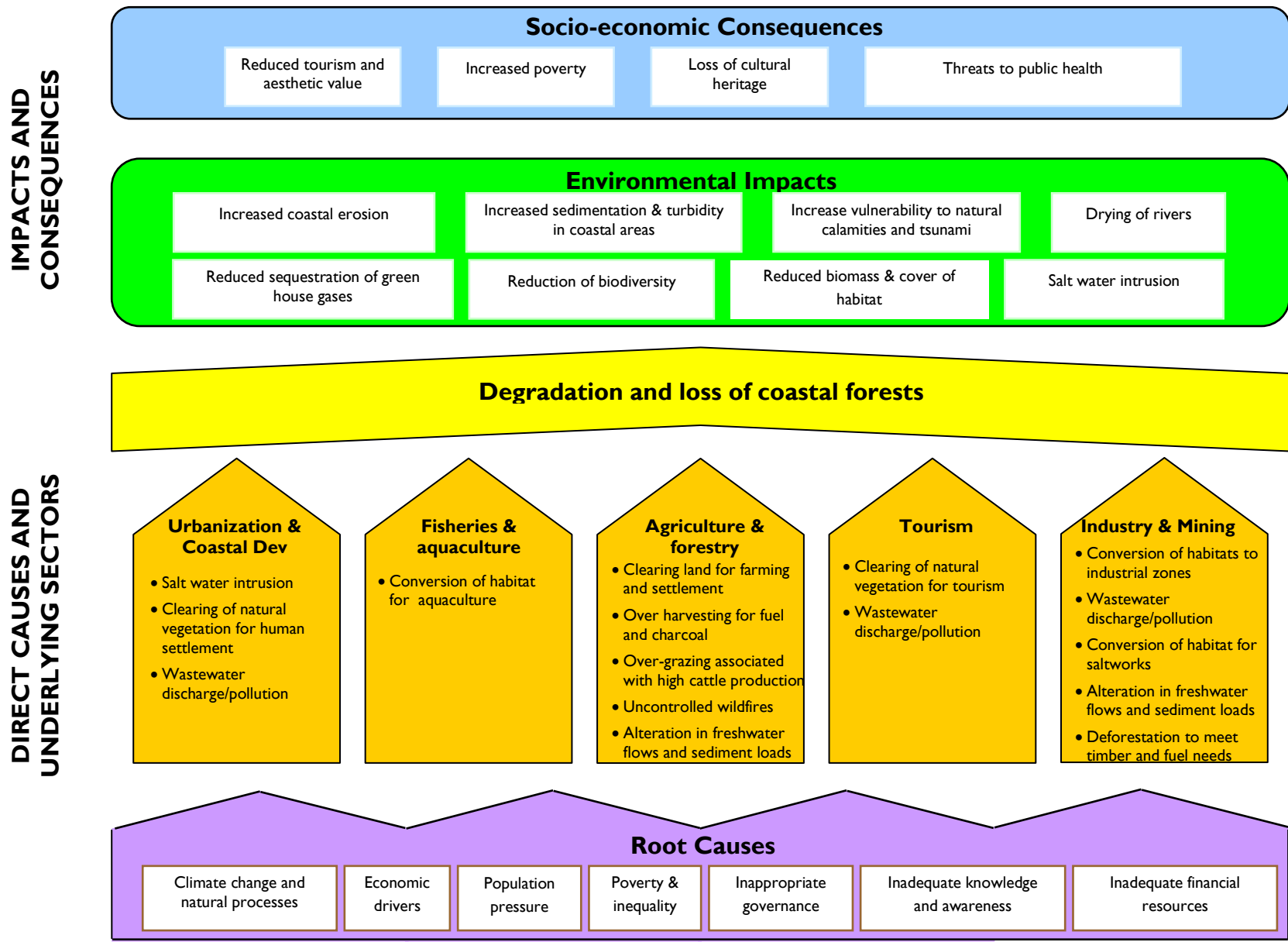


Figure 2-1 Causal chain analysis for the degradation and loss of coastal forests.

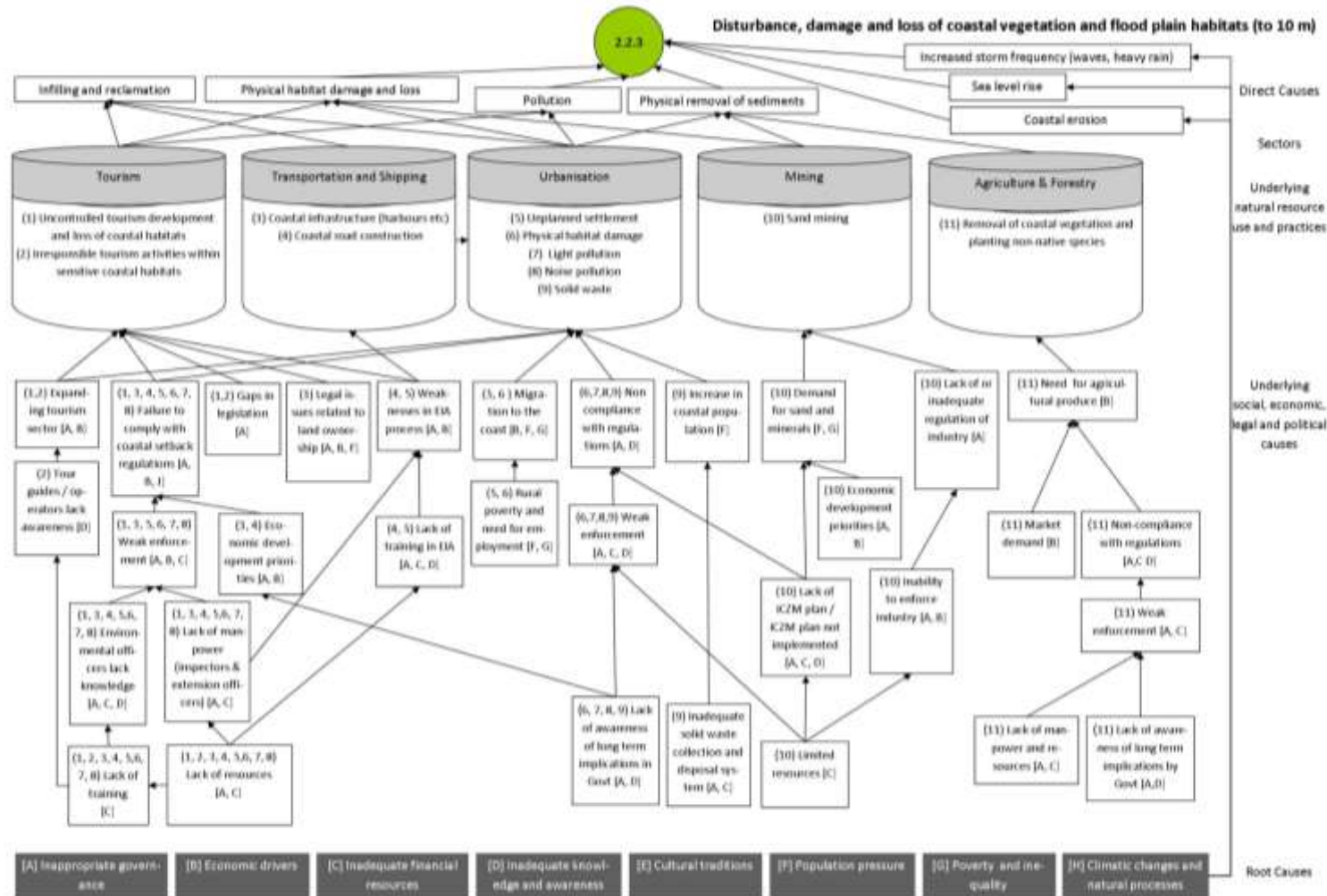


Figure 2-15: Causal Chain Analysis for the degradation and loss of coastal forest vegetation and flood plain habitats.

1.5.3.4 Degradation and loss of mangrove forest habitats

(c) Impact Chain Analysis

The most severe environmental impacts caused by the degradation and loss of mangrove forest habitats are: loss of biodiversity; reduced area of critical habitats (feeding, breeding, spawning); loss of 'natural' shoreline protection and increased risk of coastal flooding; increased coastal erosion and changes to sediment transport dynamics (accretion). Other severe impacts, which are likely to seriously degrade parts of the ecosystem are: increased risk of extinction of vulnerable species; changes to trophic structure; changes to sediment composition (e.g. organic composition, particle size etc.); reduced water clarity and light available to photosynthetic organisms (turbidity); reduced water quality (increased nutrients); modification of coastal hydrodynamics; changes in fisheries productivity and; phase shifts and changes in community composition. Less serious impacts are: loss of biomass 'carbon' sink; changes to epifauna and infauna; reduced water quality (chemical contaminants); increased salt water intrusion (and salinisation of soils); loss of coastal vegetation; creation of areas of 'hypoxic' areas (and smell); changes in primary productivity and changes in secondary productivity. The ecosystem services likely to be affected by the environmental impacts resulting from disturbance, damage and loss of mangrove habitats are:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) and; freshwater (e.g. for drinking, irrigation, cooling) - barrier to coastal flooding.

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. Natural drainage, irrigation and drought prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility (incl. soil formation); and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; spiritual experience; information for cognitive development knowledge systems and education; and social relations.

The most severe socio-economic impacts caused by degradation and loss of mangrove forest habitats are: increased risk of coastal flooding; increased risk to human life; loss of property; increased costs of sea defence; change in livelihood; increased operational costs (e.g. due to increased travel costs due to loss of landing sites for fishers, fishing grounds etc); reduction in recreational space available for tourists; reduction in income generating livelihoods (fisheries related); reduced resilience/increased vulnerability; reduced food availability/security; reduced food availability/security due to degradation of soil quality (salinisation); loss of landscape and seascape aesthetics; loss of inspiration and materials for local artworks; reduced well-being; increased stress; loss of social cohesion; increase in social conflicts; increased unemployment; increased vulnerability to climate variability and change; reduced revenue from fisheries; reduced availability of raw materials (building etc); reduction in quality of seafood and; increased poverty and inequality. Other impacts include: reduction in property/real estate value; loss of infrastructure; loss of foreign revenues; reduction in GDP; reduction in income generating livelihoods (non-fisheries related e.g. tourism); increased malnutrition and increased cost of living.

(c) Causal Chain Analysis

The underlying root causes of the loss and modification of mangroves in the WIO are associated with their value as an extractable natural resource as well as the multiple-use potential of the mangrove environment. As an extractable resource, mangroves are degraded or destroyed due to over-harvesting, which is a function of population density, poverty and socio-economic pressure in conjunction with resource desirability, poor resource management (i.e. ineffective governance), unequal distribution of resources.

In terms of the multiple-use potential of the mangrove environment, it suffers from increased sedimentation as a result of catchment degradation and land-use changes, assimilative capacity and desirability as a substrate for siting mariculture and solar salt production facilities. In addition, climate change related factors such as sea level rise and increased sedimentation have affected the fringing mangroves in Kenya, Tanzania and Mozambique (FAO, 2001). These have led to loss of mangrove cover, shortage of harvestable mangrove products (Abuodha and Kairo, 2001; Beetje and Bandeira 2007), reduction in fisheries, shoreline change (Kitheka *et al.*, 2003), pollution (Munga *et al.*, 2007), loss of livelihood and increase in poverty (UNEP *et al.*, 2004c; WWF, 2004).

Several studies have provided detailed problem analyses associated with over-exploitation of coastal and marine resources in Sub-Saharan Africa (see GEF/MSP, 2001), findings from which are presented in the problem tree for mangrove forest degradation (

Figure 2-). According to a recent assessment of global mangrove forests, the WIO region has lost approximately 8% of its mangrove cover in the last 25 years (FAO, 2007), on average approximately 3,000 ha per year. While causes of mangrove degradation may vary from one country to another, the major causes seem to be over-exploitation of mangrove wood products, conversion of mangrove areas to other land uses and pollution. These causes are described in detailed below.

The direct causes of disturbance, damage and loss of mangrove habitats include: overexploitation of living marine resources; infilling and land reclamation; coral reef degradation; oil spills and pollution (marine); natural climate variability and change and sea level rise. Other direct causes include: Changes in the natural sediment transport patterns; physical habitat disturbance, removal and loss; destructive fishing practices; chemical pollution; nutrient pollution; microbial pollution; suspended solids (turbidity); siltation/sedimentation; coastal erosion; cyclones; increased frequency and intensity of storm waves (e.g. cyclones, tsunami etc.) and disease and plague organisms. The sectors responsible for of disturbance, damage and loss of mangrove forest habitats are: industry, agriculture and forestry, tourism, urbanisation, and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

Agriculture & Forestry: Unsustainable harvesting of mangroves due to (1) overcutting occurs as a result of the increased demand for fuel and timber, loss and overexploitation of inland forests, and inadequate regulations. The (2) clearing of land for cultivation and (7) livestock grazing is due to the limited availability of suitable land, increasing demand for flat coastal land for agriculture purposes, due to immigration and expansion coastal populations and insufficient planning. (3) Inappropriate land use practices and (4) increased use of fertilizers and (6) increased sediment loads, is due to a lack of awareness and capacity in best practice techniques, as a result of a lack of education and knowledge, and lack of compliance. (5) Increased intensive farming is due to inappropriate subsidies, weak enforcement, and difficulties in enforcing existing regulations due to the high percentage of land ownership.

Fisheries & Aquaculture: (8) Destructive fishing practices due to lack of access to suitable technology, contribute towards the decline in mangrove forests. The (9) clearing of mangrove habitats for aquaculture ponds occurs as a result of market opportunity and lack of knowledge and awareness. (10) Overexploitation of mangroves by fisher communities for fuel-wood, timber and traps occurs due to lack of affordable alternatives for building traps, shelters or boats, and due to lack of access to an

alternative affordable fuel source. There is also a traditional preference for using mangrove wood for boat, trap and shelter construction due to the rot proof properties of the wood.

Urbanisation: The (11) clearing of mangroves occurs for aesthetic reasons (to improve the 'view') and for road construction purposes, in order to address development pressures for improved coastal access routes. The (12) inappropriate disposal of solid waste and (13) inappropriate disposal of un- or undertreated domestic wastewater occurs as a result of planned and un-planned coastal developments in proximity or in mangrove areas, where there is insufficient provision of waste water disposal infrastructure and inadequate solid waste collection and disposal systems. The lack of adequate waste disposal mechanisms is usually due to inadequate planning and investment.

Industry: The (15) disposal of un- or under treated industrial wastewater, and (16) solid wastes is due to inadequate provision of waste collection and disposal mechanisms. The (17) clearing of mangroves for the creation of salt pans is due to financial benefits that can be accrued from this industry; it occurs due a failure of companies to comply with existing regulations, and due to lack of enforcement as a result of insufficient capacities.

Tourism: (18) Physical damage and (19) clearing of mangroves to improve the 'view' occurs as a result of tourism developments. This is usually due to low compliance with existing regulations, lack of enforcement and lack of knowledge and greed.

Natural environmental variability and change: The disturbance, damage and loss of mangrove forest habitats occur due to increasing sea level rise, high frequency of storms, storm surges and waves.

The main **Underlying Causes** of degradation and loss of mangrove forest habitats can be summarised as follows:

- Increased internal market demands for (use of) natural resources/materials (timber).
- Increased external market demands for (use of) natural resources/materials (tourism).
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Low compliance with existing regulations.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Inadequate investment in infrastructure/poor maintenance.
- Lack of transparency/Wealth creation and corruption.
- Rural poverty, increased coastal migration and urbanization.
- Lack of education, training and awareness.
- Lack of awareness of longer term implications in Government.
- Lack of ICZM plan/ICZM plan not implemented.
- Weak national planning and regulatory frameworks.

The **Root Causes** of degradation and loss of mangrove habitats are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions,[F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

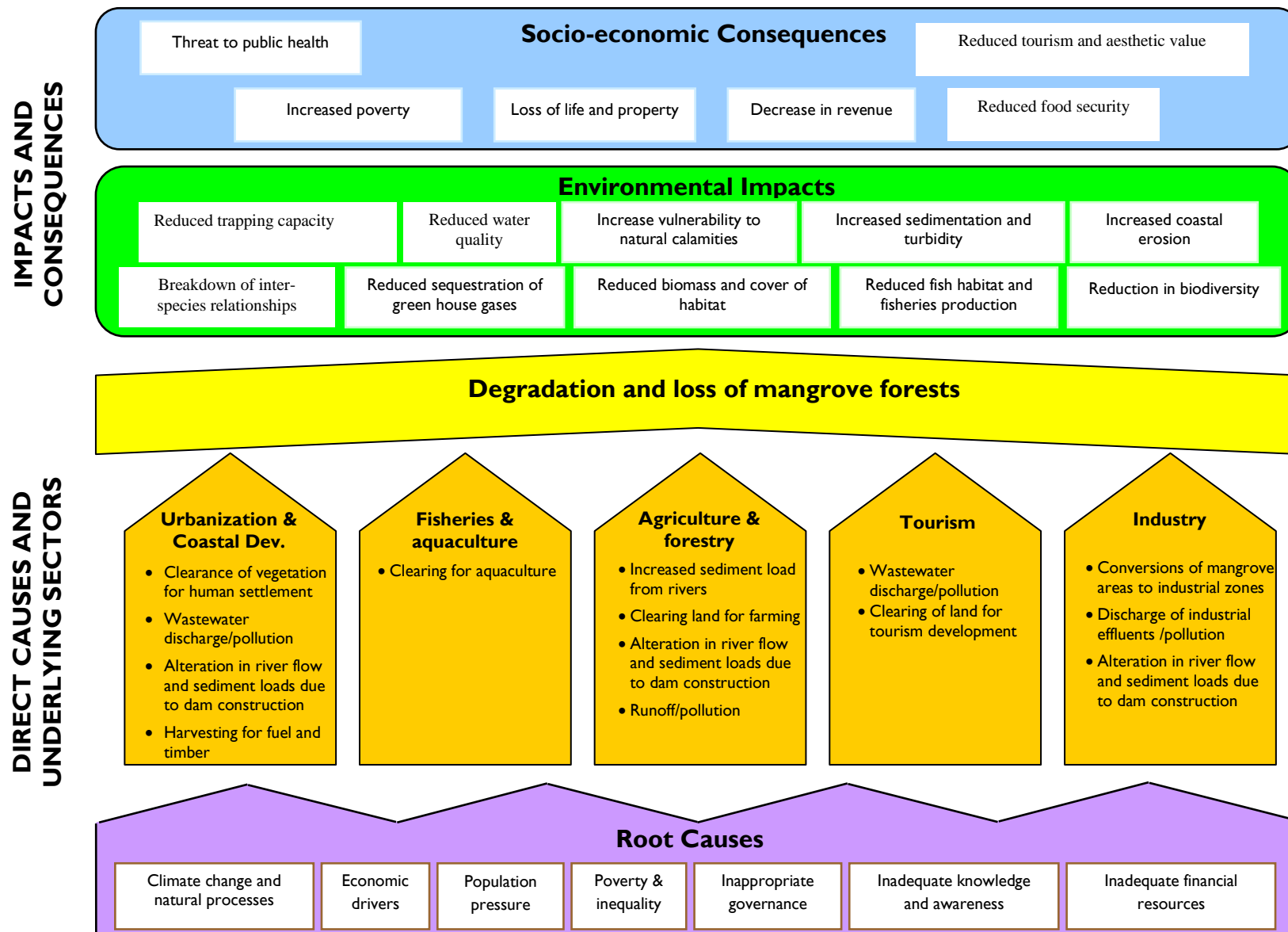


Figure 2-16 Causal chain analysis for the degradation and loss of mangrove forests.

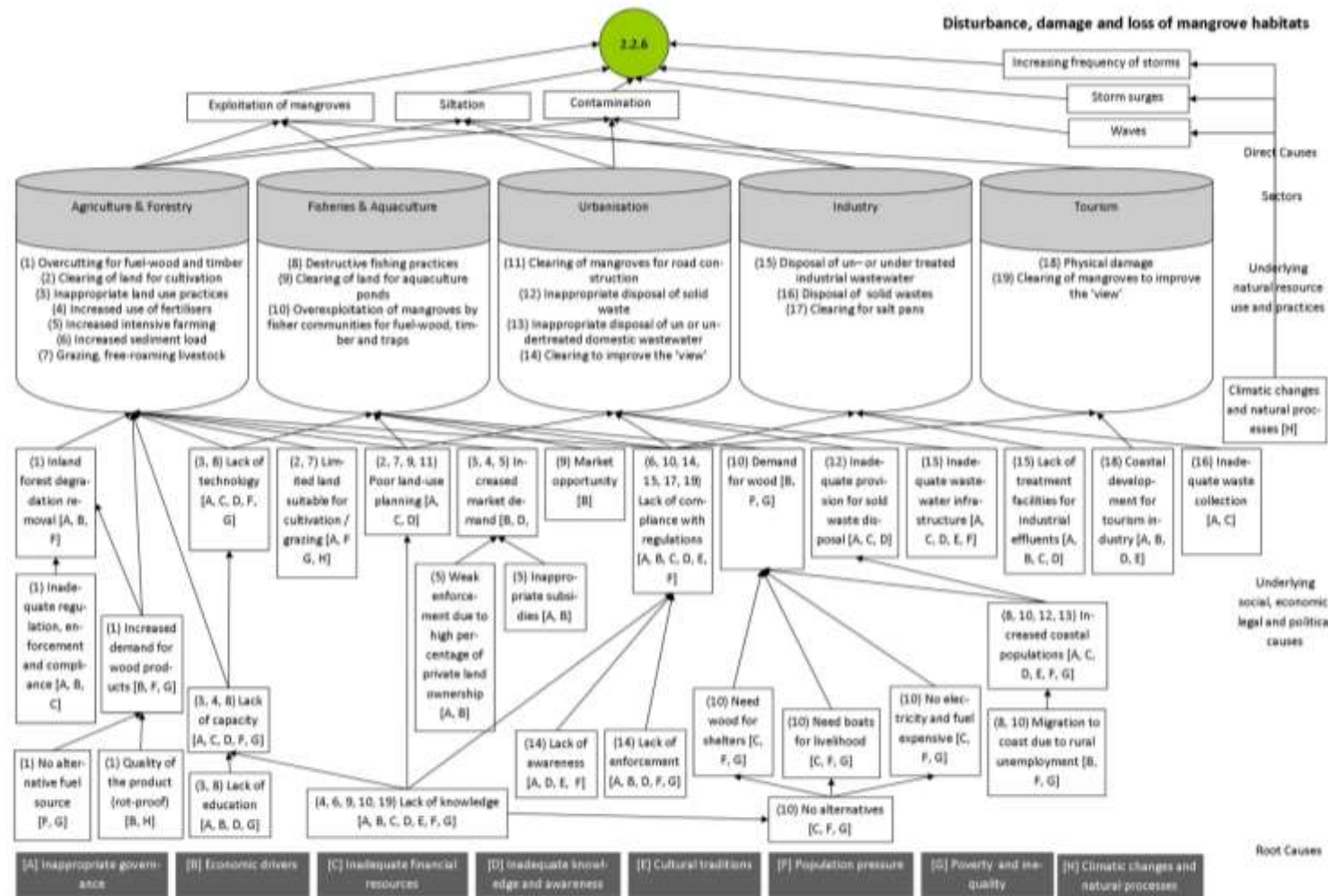


Figure 2.17: Causal Chain Analysis for the degradation and loss of mangrove forest habitats

1.5.3.5 Degradation and loss of coral reef habitat

(a) Impact Chain Analysis

The most severe environmental impacts caused by degradation and loss of coral reef habitats are: loss of biodiversity; increased risk of extinction of vulnerable species; reduced area of critical habitats (feeding, breeding, spawning); changes to trophic structure; loss of 'natural' shoreline protection and increased risk of coastal flooding; increased coastal erosion; changes to sediment composition (e.g. organic composition, particle size etc.); changes to sediment transport dynamics (accretion); changes in fisheries productivity; and phase shifts and changes in community composition. A further severe impact which is likely to seriously degrade parts of the ecosystem is: modification of coastal hydrodynamics. The ecosystem services likely to be affected by the environmental impacts resulting from disturbance, damage and loss of coral reef habitats include:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion); freshwater (e.g. for drinking, irrigation, cooling); and geological resources.

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. Natural drainage, irrigation and drought prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility (incl. soil formation); and pollination; and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; information for cognitive development knowledge systems and education; and social relations; and spiritual.

The most severe socio-economic impacts caused by disturbance, damage and loss of coral reef habitats are: increased risk of coastal flooding, increased risk to human life; loss of property; reduction in property/real estate value; loss of infrastructure; increased costs of sea defence; change in livelihood; increased operation costs (e.g. due to increased travel costs due to loss of landing sites for fishers, fishing grounds etc); reduction in recreational space available for tourists; loss of foreign revenues; reduction in GDP; reduction in income generating livelihoods (non-fisheries related e.g. tourism); reduction in income generating livelihoods (fisheries related); reduced resilience/increased vulnerability; reduced food availability/security; reduced food availability/security due to degradation of soil quality (salinisation); reduced availability of favoured food fishes/loss of traditions; increased malnutrition; loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; reduced well-being; increased stress; loss of social cohesion; increase in social conflicts; increased unemployment; increased vulnerability to climate variability and change; reduced revenue from fisheries; reduced availability of raw materials (building etc); reduction in quality of seafood; and increased poverty and inequality. These will all be major socio-economic problems within 10 years if the issues are allowed to continue.

(b) Causal Chain Analysis

The underlying root causes of coral reef degradation in the region can be grouped into three broad categories that include: a) global climate change and natural processes; b) socio-economic conditions, including lack of alternative livelihood options and c) inappropriate and ineffective governance. In

most cases more than one of these drivers is responsible for any observed degradation on coral reefs thus making the determination of root causes a complex issue (Payet *et al.*, 2005). The sections that follow describe the problem of coral reef degradation from this perspective, highlighting the three underlying root causes.

Underlying root cause 1: Global climate change and natural processes

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

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

Freshwater input, discharged as a result of surface runoff, is known to be one of the major influences controlling coral reef distribution in the WIO region. Heavy sediment discharge at Malindi Bay (from Athi-Sabaki River) is affecting the coral reef system at Malindi–Watamu Marine National Park and Reserve (Blorn *et al.*, 1985; McClanahan and Obura, 1995; Obura, 2002; Kitheka *et al.*, 2003a-b, 2005; Arturton *et al.*, 2006). As a result of heavy river discharge of sediments and freshwater, coral reefs are absent in the extensive swampy coast of central Mozambique (Bandeira *et al.*, 2002). In Madagascar, sediment-laden rivers such as Betsiboka are known to have been responsible for degradation of coral reef ecosystem. In addition to sedimentation associated with river discharge, coastal currents and winds have been known to be responsible for the increased sedimentation of coral reefs at Ponta Torres, Inhaca Island, Mozambique (Kalk, 1995). Change in rainfall pattern could increase the amount of freshwater and sediments discharged from river catchments areas/basins to coral reefs throughout the WIO region. This would cause further stress, phase shift and degradation on coral reefs. Outbreaks of plague organisms such as crown of thorns starfish (COTS), black-spined sea urchins (BSU) and coral-eating snail *Drupella* have been recorded on many coral reefs where they have grazed live corals causing death of the colony which has led to reduction in live coral cover and collapse of the reef matrix through increased bio-erosion (Schleyer, 1998; Carreiro-Silva and McClanahan, 2001; Spencer and Viles, 2002; Celliers and Schleyer, 2006). The population outbreak of black-spined sea urchin is of particular relevance to our region as recovery on many reef sites is being retarded by their grazing habits (Carreiro-Silva and McClanahan, 2001).

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

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

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

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

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

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

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

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

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

The most important direct causes of degradation and loss of coral reef ecosystem habitats are: natural climate variability and change and increased sea water temperature. Other direct causes include: unsustainable harvesting of living marine resources and suspended solids (turbidity). The sectors responsible for causing disturbance, damage and loss of coral reef habitats are: urbanisation, tourism, fisheries (all sectors), agriculture and forestry, industry, mining, transportation and shipping, energy and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

In summary, the main Underlying Causes of damage and loss of coral reef habitats include the following:

- Rural poverty, increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Increased internal market demands for (use of) natural resources/materials.
- Lack of alternative sustainable livelihoods.
- Low compliance with existing regulations.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Open access resource/tragedy of commons.
- Lack of education, training and awareness.
- Limited knowledge, lack of technology and understanding of best environmental practice.
- Gaps in regulations/and lack of legal expertise.
- Lack of adequate and reliable data to support management.
- Lack of management plans for MPAs.
- Lack of ICZM plan/failure to implement ICZM plan.
- Lack of MPA management plans.
- Unresolved legal issues related to land ownership.
- Inadequate investment in infrastructure.
- Lack of knowledge, technology and use of best practice.
- Lack of transparency (EIA procedures)/Wealth creation and corruption.
- Lack of awareness of the longer term implications in Government.
- Failure to mainstream climate change into planning and decision making.
- Weak national planning and regulatory frameworks.

The Root Causes of damage and loss of coral reef habitats are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions,[F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

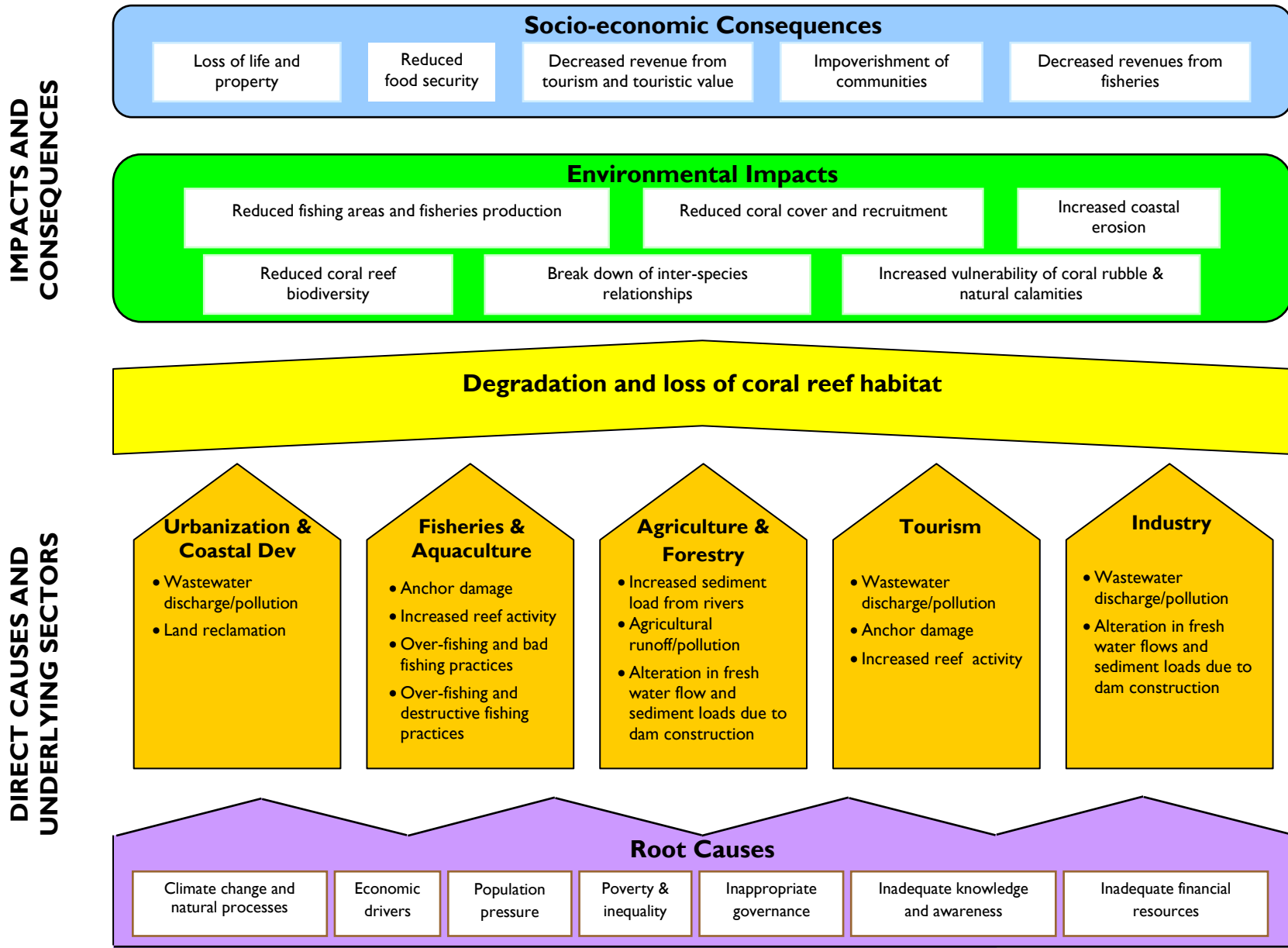


Figure 2-2 Causal chain analysis for the degradation and loss of coral reef habitats

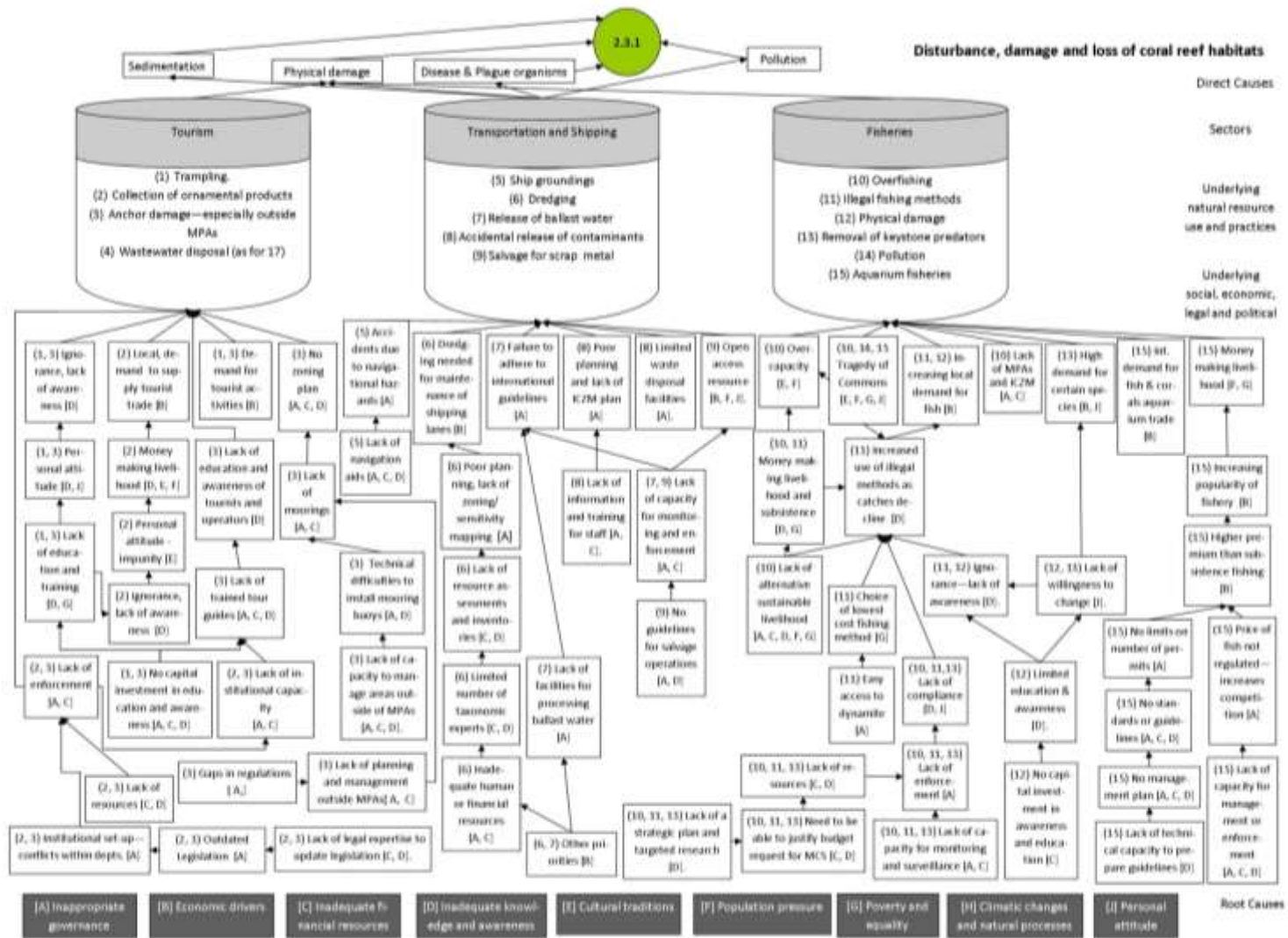


Figure 2-19: Causal Chain Analysis for the degradation and loss of coral reef habitats (part 1 of 2)

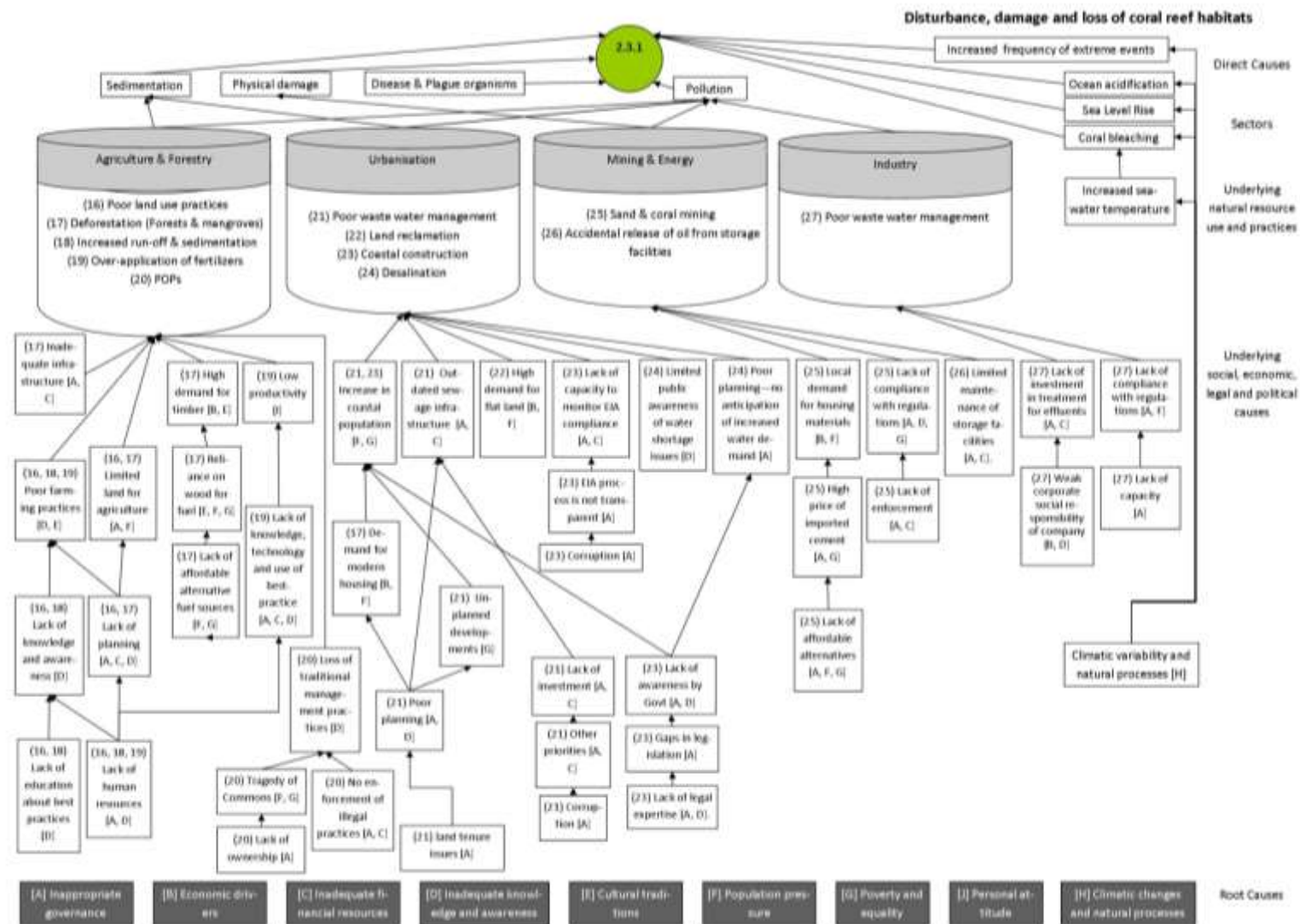


Figure 2-20: Causal Chain Analysis for the degradation and loss of coral reef habitats (part 2 of 2)

1.5.3.6 Degradation and loss of seagrass habitats

(a) Impact Chain Analysis

The most severe environmental impacts caused by degradation and loss of seagrass habitats are: increased coastal erosion; changes to sediment transport dynamics (accretion) and changes in fisheries productivity. Further severe impacts which are likely to seriously degrade parts of the ecosystem are: loss of biodiversity; increased risk of extinction of vulnerable species; loss of biomass 'carbon' sink; reduced area of critical habitats (feeding, breeding, spawning); changes to trophic structure; loss of 'natural' shoreline protection and increased risk of coastal flooding; changes to sediment composition (e.g. organic composition, particle size etc.); reduced water clarity and light available to photosynthetic organisms (turbidity); modification of coastal hydrodynamics; changes in primary productivity; and phase shifts and changes in community composition. The ecosystem services likely to be affected by the environmental impacts resulting from the disturbance, damage and loss of seagrass habitats include:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); and biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion); freshwater (e.g. for drinking, irrigation, cooling); and geological resources.

Regulating Services - climate regulation (e.g. Carbon sequestration, influence of vegetation on rainfall etc.); natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. Natural drainage, irrigation and drought prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility (incl. soil formation); and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; information for cognitive development knowledge systems and education; and social relations; and spiritual experience.

The most severe socio-economic impacts caused by disturbance, damage and loss of seagrass habitats are: reduction in income generating livelihoods (fisheries related); reduced resilience/increased vulnerability; reduced food availability/security; reduced food availability/security due to degradation of soil quality (salinisation); increased malnutrition; loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; increase in social conflicts; increased unemployment; increased vulnerability to climate variability and change; and reduced revenue from fisheries. Other important socio-economic impacts are: change in livelihood; and increased operation costs (e.g. due to increased travel costs due to loss of landing sites for fishers, fishing grounds etc).

(b) Causal Chain Analysis

The degradation of seagrass beds is due to multiple causes. At the root-cause level, poorly planned coastal development, legislation and policies together with inadequate monitoring and enforcement of existing regulations are probably the most important problems that affect not only seagrass meadows but also other habitats. Among the underlying sectors causing the problems, urbanization and coastal development rank highly. This, in turn, results in various other activities that affect the seagrass environment to some extent. Population growth, poverty and the growing need for natural resources to fulfil basic human needs are increasing the pressure on marine resources. The WIO region continues

to experience an increase in tourism with concomitant development of tourism infrastructure often not planned and constructed as part of a strategic spatial development framework. The high density of tourist hotels in some areas has led to an increase in the discharge of untreated domestic waste to the sea, as well as negative effects caused by associated tourist activities such as boating (damage caused by boat propellers, anchoring), and physical removal of seagrasses by tourist operators in order to make beaches more attractive to tourists (Daby, 2003). The removal of seagrasses leads to environmental changes such as increased water turbidity, loss of associated fauna, decreased biomass and increased vulnerability to extreme events. These impacts in turn affect the long-term sustainability of the tourism industry itself (Daby, 2003).

Pollution is one of the direct causes of seagrass habitat degradation. A study undertaken in Mauritius at Flic en Flac and Grand River North West, during the period 1996-1997, have shown that chromium and lead concentrations had exceeded the permissible limits; the main sources attributed to tourist hotels and industrial activities (Ramessur *et al.*, 1998). Also, destructive fishing practices such as drag-nets, dynamite, poisons, harpoons and nets with smaller mesh size, exacerbate the negative effects of over-fishing in seagrass bed areas (Mangi and Roberts, 2007). Collection by coastal communities of a diversity of invertebrates from seagrass beds is also causing degradation. At Inhaca Island sea cucumber and seahorse harvesting for commercial purpose has increased in the last few decades and this has led to a significant decline in the availability of invertebrates (Pereira, M., *pers. comm.*). Digging in *Zostera capensis* beds and surroundings seagrass areas for the collection of edible bivalves has also led to the destruction of the seagrass beds at Bairro dos Pescadores near Maputo (Balidy, 2003; Bandeira and Gell, 2003).

Among the underlying sectors causing the degradation of seagrass beds, urbanization and coastal development rank highly, accompanied by various other activities that to a lesser or greater extent also affect the seagrass environment. Population growth, the need for infrastructure development, higher levels of tourism that are not consistent with planned coastal development are all contributing factors. High concentration of tourist hotels generate more waste, increases damage caused by motor boat propellers, anchoring and often lead to physical removal of seagrasses by tourist operators in order to make beaches more attractive to tourists (Daby, 2003). The removal of seagrasses leads to environmental changes such as increased water turbidity, loss of fauna, decreased biomass and increased vulnerability to extreme events. In particular the loss of primary production may have serious consequences for the energy budget of a host of species that are dependent on the seagrass ecosystem. These impacts in turn affect the long-term sustainability of the tourism industry itself (Daby, 2003). Aquaculture in general and seaweed farming in particular, are two activities that potentially affect seagrass beds. Seaweed farming has been implicated in the reduction of seagrass cover, reduction of macrofauna biomass and changes in community structure. It potentially also results in changes in sediment composition, including texture and organic content (de la Torre-Castro and Rönnaback, 2004; Eklöf *et al.*, 2005).

Climate change is also a potential agent of seagrass bed degradation. The effects of climate change includes the alteration of growth rates and physiological functions, changes in distribution and reproduction patterns, changes in plant community structure and loss of some key species (Short and Neckles, 1999). In the WIO, the best examples of climate impacts on seagrasses are those from Mozambique, a country with cyclones and floods nearly every year. Heavy floods in Mozambique in 2000 caused smothering of 24 km² and 10 km² of seagrass beds in southern Mozambique and Inhassoro, respectively (Bandeira and Gell, 2003). Other areas where seagrass beds were lost included those off Pemba town, Moçambique Island, Inhambane Bay and Inhaca Island. It is estimated that close to 28 km² of seagrass beds was lost due to sediment smothering associated with flooding of the Incomati and Govuro rivers (Bandeira and Gell, 2003). Harbour development, sewage disposal and coastal development in areas of southern Mozambique have further diminished seagrass area (Bandeira and Gell, 2003).

Excessive harvesting of some fish species that feed on sea urchins can lead to uncontrolled and rapid growth of sea urchin populations which in turn can seriously affected the seagrass communities. This

has been reported from the Diane-Chale lagoon, the Malindi-Watamu Marine National Park and Reserve (Uku *et al.*, 2005) and other places along the Kenya coast. There has also been a significant loss of seagrasses along the Kenya coast as a result of anthropogenic activities. More than 50% of the Diane-Chale lagoon's seagrass bed cover was lost, and in most of the cases, the degraded sites were found to have a density of more than 37 sea urchin individuals per m², a very high number when compared to the 4 individuals/m² in healthy sites (Uku *et al.*, 2005).

In Mauritius, seagrass beds are threatened by eutrophication caused by the organic fertilizer run-off from sugar cane plantations (Ramessur and Jarvis, 1998). Furthermore, the dredging of channels for swimming and water skiing has also resulted in degradation (Daby, 2003). Other factors that have impacted on the seagrass beds of Mauritius include sedimentation, disposal of sewage and sand mining (Ramessur, 2002). In Seychelles, sedimentation, reduced salinity and decreased water quality associated with effluent discharge have adversely affected seagrass beds (Ingram and Dawson, 2001). Also in Seychelles, the East Coast reclamation project and the December 2005 Tsunami has had a serious effect on the degradation of seagrass beds found in shallow areas inside the reefs. Large areas of seagrass beds were destroyed by the reclamation (Bijoux *et al.*, 2003) and the Tsunami caused seagrass beds at Baie Ternay Marine Park on the north-west coast of Mahé to be covered with a thick layer of sand that has still not cleared (Obura and Abdulla, 2005). Also, sedimentation associated to effluent discharge has caused salinity and water quality to reduce, affecting adversely seagrass beds (Ingram and Dawson, 2001).

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

In summary, the most important direct cause of disturbance, damage and loss of seagrass habitats is: Physical habitat removal and disturbance. Other direct causes include: Infilling and reclamation; Over-extraction of non-living marine resources; Siltation and changes in the natural sediment transport patterns. The sectors responsible for causing disturbance, damage and loss of seagrass habitats are: urbanisation, tourism, fisheries (all sectors except for recreation, sport and mariculture), agriculture and forestry, industry, mining, transportation and shipping, energy and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

Agriculture and Forestry: (1) Poor land use practices take place due to limited land available for agriculture. There has also been loss of traditional practices due to the 'tragedy of the commons' (river banks are open access) and lack of knowledge, technology and use of best practices due to lack of awareness. There is also no enforcement of illegal practices due to lack of resources. (2) Deforestation takes place due to high demand for wood due to high reliance on wood for fuel and lack of affordable alternative fuel sources. (3) Over-application of fertilizers takes place due to an increased demand for food production and low productivity as a result of lack of knowledge, technology and use of best practice.

Urbanisation: (4) Poor wastewater management, sewerage and storm water draining and surface run-off arise due to an increase in coastal populations and an increased demand for modern housing. This results in unplanned developments, due to weak planning, which occurs because there is no communication between planning levels and a complicated planning system. The sewage infrastructure is outdated as a result of lack of investment due to other political priorities. (5) Coastal engineering works, and (6) Infilling and land reclamation activities, can result in the loss of seagrass beds. All the above resource use activities which impact on seagrass habitats are due to a lack of awareness by Government of the issues and potential impacts. There is often outdated legislation, which often arises from a lack of legal expertise. The EIA process is also weak due to a lack of

capacity to monitor EIA compliance and ensure mitigation measures are implemented. This is often caused by a lack of suitably trained environment and enforcement officers. In addition, a lack of transparency in the EIA process means that it can be overridden due to corruption in planning activities.

Tourism: (7) Damage from boat propellers and anchors arises due to a lack of moorings outside MPAs as a result of technical difficulties to install mooring buoys and a lack of planning and management. There is a lack of capacity to manage areas outside of MPAs. (8) Seagrass clearing by hotels takes place to improve the aesthetics for tourists in order to increase profits. Both activities also occur due to ignorance and lack of awareness as a result of a lack of education and training.

Industry: (9) Poor wastewater management occurs due to the lack industrial effluent treatment systems caused by inadequate planning and a lack of resources. There is also a lack of compliance with regulations due to a lack of enforcement.

Fisheries: (10) Destructive fishing practices take place due to an increasing local demand for fish and a decline in catches. The decline in catches occurs due to the 'tragedy of the commons' (it is a common pool resource). Fishing is a money making livelihood and there is a lack of alternative sustainable livelihoods. Destructive fishing methods are also used to a lack of awareness amongst the fishing community caused by a lack of education and training. There is also a lack of enforcement as a result of lack of resources. (11) Damage from boat propellers and anchors arises due to a lack of moorings outside MPAs as a result of technical difficulties to install mooring buoys and a lack of planning and management. There is a lack of capacity to manage areas outside of MPAs.

Natural environmental variability and change: Damage and loss of seagrass habitats can occur as a result of increased seawater temperatures, sea level rise, variations in rainfall and increasing frequency of extreme events.

The main Underlying Causes of damage and loss of seagrass habitats can be summarised as follows:

- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Low compliance with existing regulations.
- Limited knowledge, access to technology and understanding of best environmental practices.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Lack of alternative sustainable livelihood opportunities.
- Inadequate investment in infrastructure/poor maintenance.
- Gaps in regulations and lack of legal expertise.
- Lack of enforcement/extension officers.
- Lack of ICZM plan/ICZM plan not implemented.
- Failure to mainstream climate change into planning and decision making.
- Lack of transparency/Wealth creation and corruption.
- Weak national planning and regulatory frameworks.
- Weak economy (need for finances).

The Root Causes of damage and loss of seagrass habitats are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

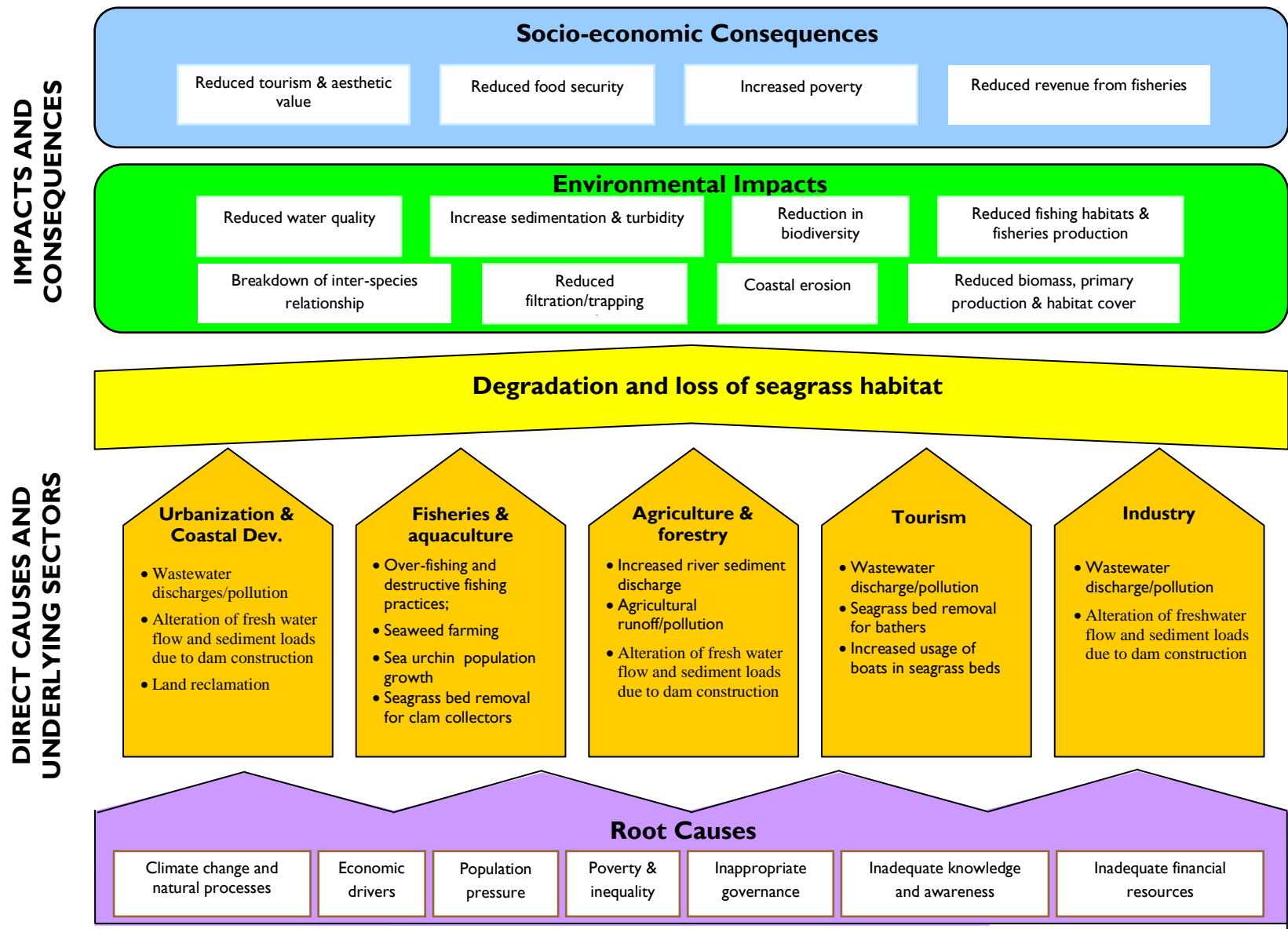


Figure 2-20 Causal chain analysis for the degradation and loss of seagrass habitat.

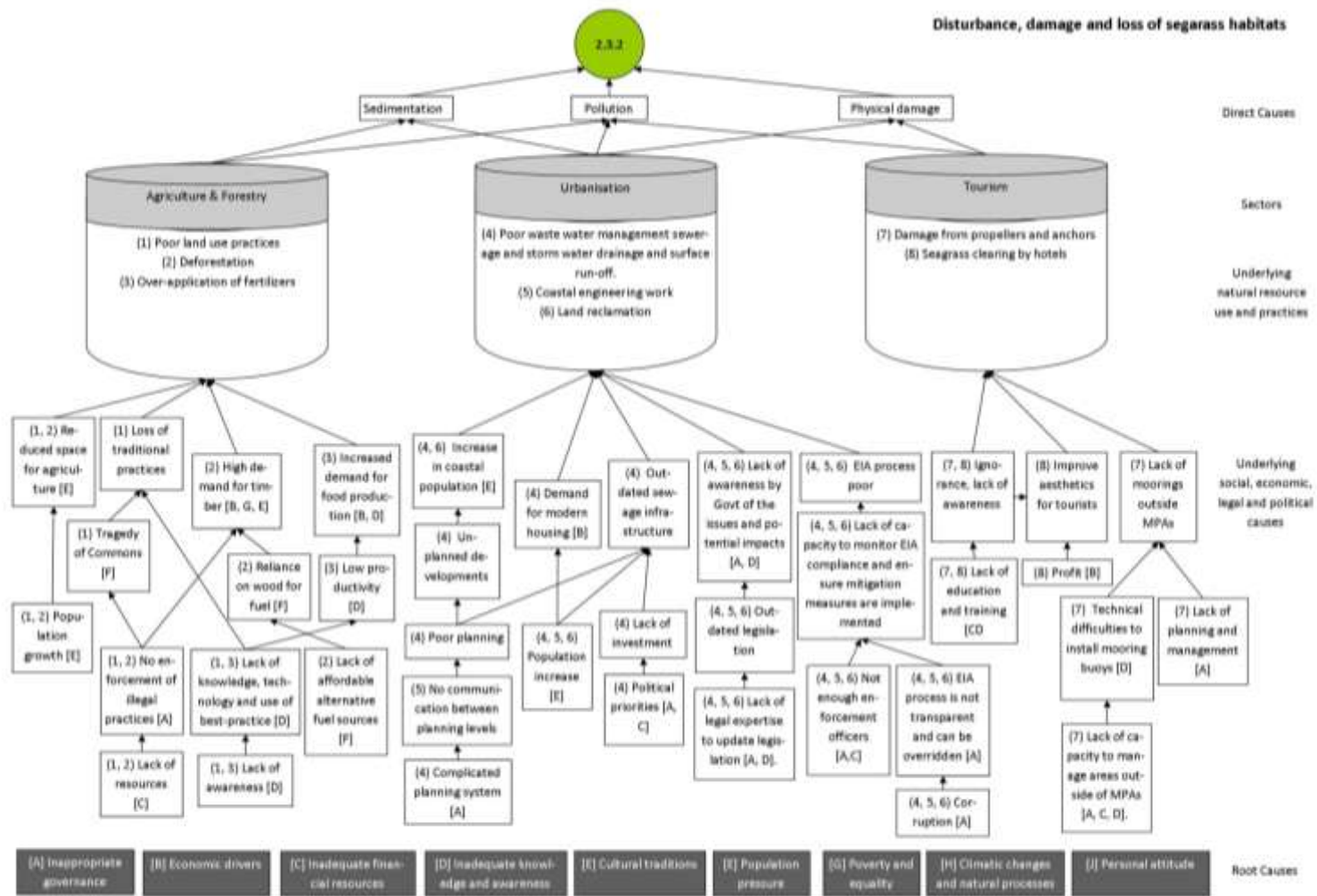


Figure 2.21: Causal Chain Analysis for the degradation and loss of seagrass habitats (part 1 of 2)

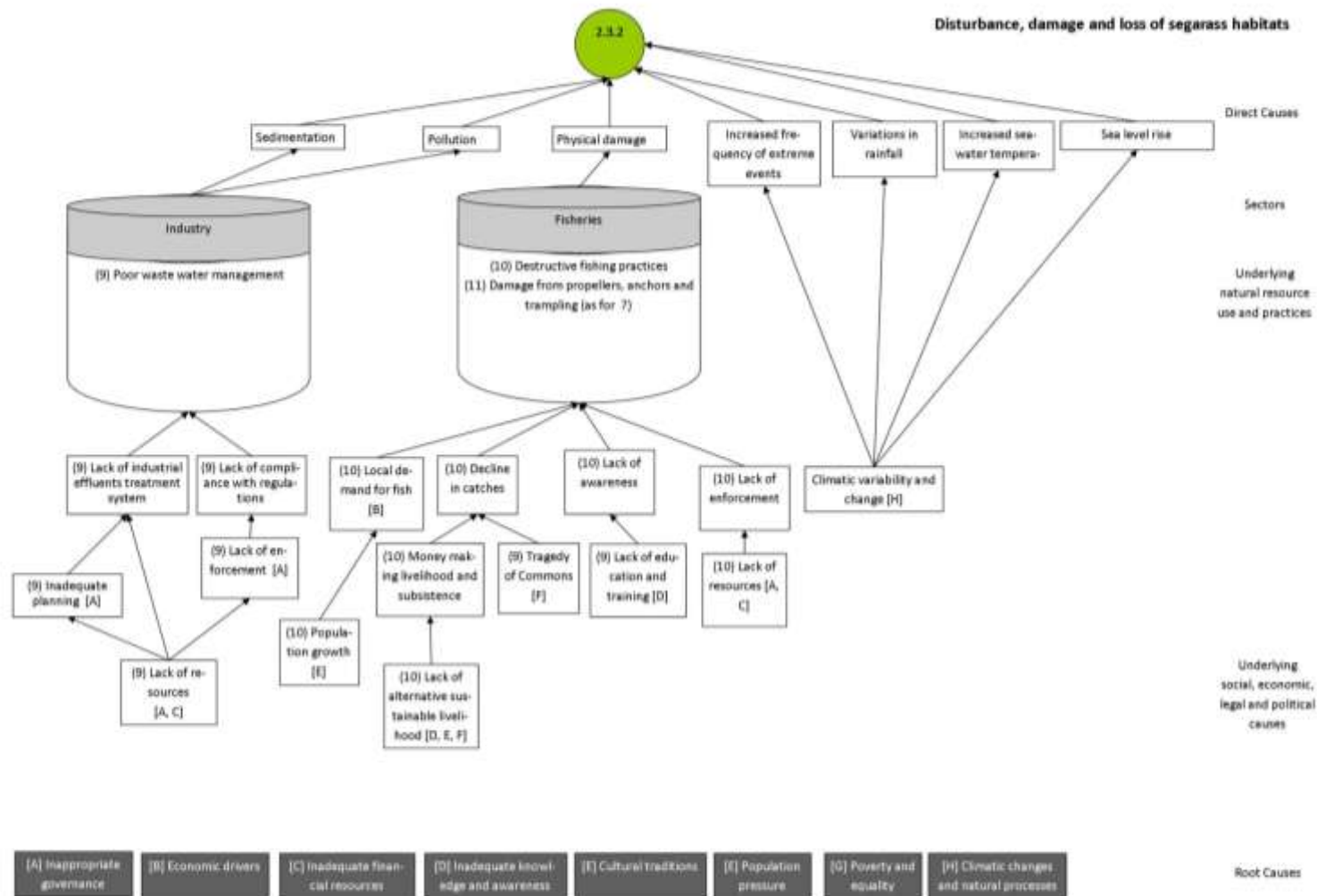


Figure 2.22 Causal Chain Analysis for the degradation and loss of seagrass habitats (part 2 of 2).

1.5.3.7 Degradation and loss of deep water habitats including sea mounts

(a) Impact Chain Analysis

The most severe environmental impacts caused by disturbance, damage and loss of deep water habitats including sea mounts are: loss of biodiversity (through physical habitat removal and damage); loss of unique habitats; increased sedimentation impacts on benthic fauna; changes in nutrient cycles; changes in fisheries productivity; increased risk of extinction of vulnerable species; reduced area of critical habitats (feeding, breeding, spawning); changes to trophic structure and; changes in primary productivity. The ecosystem services likely to be affected by the environmental impacts resulting from the disturbance, damage and loss of deep water habitats include:

Provision Services-food (e.g. fish, game fruit); genetic resources (e.g. for crop improvements and medicinal purposes); and biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) and geological resources.

Regulating Services - climate regulation (e.g. carbon sequestration, influence of vegetation on rainfall etc.) and; nutrient cycling and maintenance of fertility including soil formation.

Supporting/Habitat Services-photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); and secondary production.

Cultural and Amenity Services-bequest, intrinsic and existence; information for cognitive development knowledge systems and education; and social relations.

The most severe socio-economic impacts caused by disturbance, damage and loss of deep water habitats including sea mounts are: reduced resilience/increased vulnerability; reduction in food availability/security (local) due to destructive/non-selective gear used by foreign industrial vessels; reduction in future use value (bequest, intrinsic and existence value) of ecosystems; increase in social conflicts; increased vulnerability to climate variability and change; and reduction in income generating livelihoods (fisheries related) due to unsustainable harvesting and destructive practices and reduced revenue from fisheries.

(b) Causal Chain Analysis

The most important direct causes of the disturbance, damage and loss of deep water habitats (including sea mounts) are: over-extraction of non-living marine resources; over-exploitation of living marine resources; unsustainable fishing practices; physical habitat removal and disturbance; inappropriate waste disposal (solid and liquids) and climate variability and change. The sectors responsible for causing disturbance, damage and loss of deep water habitats (including seamounts) are: fisheries (commercial), mining, transportation and shipping, energy and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: Continued market demand for fish and the overexploitation and reduction in the catches of more easily accessible (demersal and pelagic) stocks has driven fishing fleets further offshore, in search of new resources. While there are some established deep water demersal fisheries within the WIO (e.g. South Africa, Seychelles and Mauritius), there is also Illegal, Unregulated and Unreported deep water resources within EEZ and in Areas Beyond National Jurisdiction. (1) Deep water trawling and (2) line fishing both cause habitat damage, and because longer lived deepwater species are vulnerable to overexploitation, the fisheries tend to be characterised by a boom and bust. Lack of adequate monitoring programmes means there is no way of assessing the damage caused by fishing gear, or assessing stocks and setting appropriate catch quotas or limits. There is also lack of management plans for the deep water fishery, which may be due to other political financial issues taking priority. (3) Illegal, unreported and unregulated fishing takes place due to overcapacity in other fisheries (see below), and lack

of capacity for monitoring, control and surveillance. (4) Fishing vessels may lose or jettison their fishing gear if it becomes entangled on seabed structures, some gear may continue to fish through 'ghost fishing'.

Energy: (5) Exploration and (6) exploitation activities for oil and gas in deep water habitats has already commenced in the WIO region. The expansion of these activities are driven by declining global supplies of oil and gas in tandem with ever expanding global market demand and also by the economic development potential this sector can provide.

Mining / Bio-prospecting: The (7) mining of polymetallic nodules from deepwater habitats is extremely expensive and only commercially viable once the availability (and hence price) of the remaining resources of these metals become too difficult or too expensive to extract from land. Similarly (8) bio-prospecting, exploratory surveys are expensive, and usually only viable with private sector support. In the future, damage to deepwater habitats could occur as a result of lack of monitoring, control and surveillance capacities and weak regulatory frameworks to control the impact of such activities.

Transportation and shipping: (8) the practice of dumping ballast water from ships can introduce non-native species, which can spread and become invasive. (9) The practice of dumping other waste materials from ships (e.g. rubbish, animal carcasses, plastics, pharmaceuticals etc.) has increased as a result of increased international trade and shipping of goods globally, due to lack of monitoring, control and surveillance, and enforcement capacities, disregard for international regulations and personal attitude (negligence).

Natural environmental variability and change: Damage and loss of deepwater habitats can occur as a result of increased seawater temperatures (which have been recorded in deep waters as well as shallow coastal waters) and ocean acidification, as well as changes in the natural variability, currents and other processes, which may variably influence deep water habitats. Ocean warming particularly of surface layers can result in stratification of the water column leading to nutrient depletion in the surface waters, while dissolved oxygen levels in the lower layers become depleted. The potential to dispose of greenhouse gases underneath the seabed or on the surface is also driven by climate change and the need to find new ways of disposing of the carbon dioxide gas.

The main Underlying Causes of disturbance, damage and loss of deep water habitats including seamounts can be summarised as follows:

- Increased external market demands for (use of) natural resources/materials.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Low compliance with existing regulations (international).
- Lack of adequate and reliable data to support management.
- Lack of awareness of the longer term implications in Government.
- Weak national planning and regulatory frameworks.
- Lack of transparency / Wealth creation and corruption.

The Root Causes of damage and loss of seagrass habitats are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics, [H] Climate change and natural processes and [J] Personal attitude.

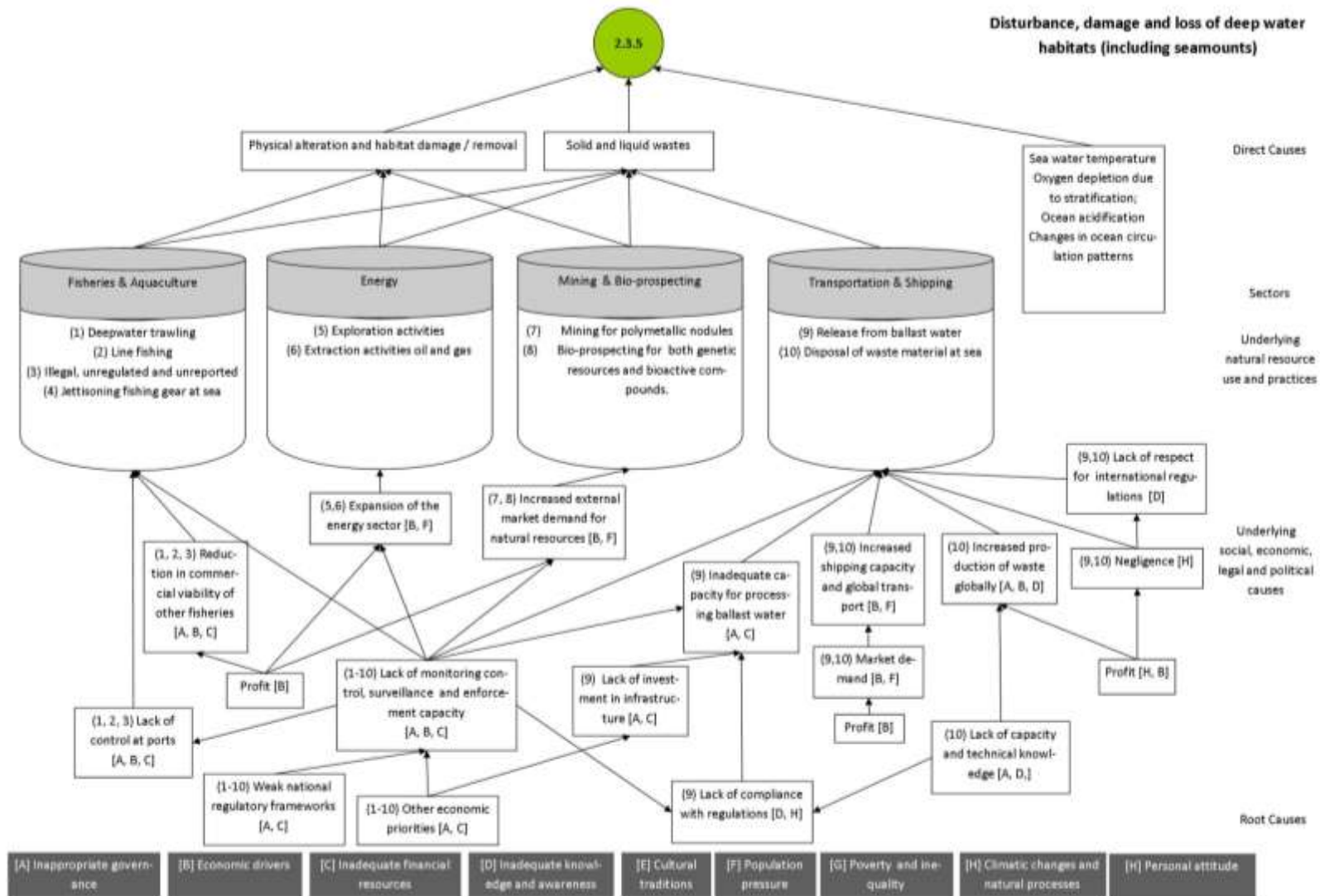


Figure 2-23: Causal Chain Analysis for the disturbance, damage and loss of deep water habitats including sea mounts.

1.5.3.8 Introduction of exotic non-native, invasive and nuisance species

(a) Impact Chain Analysis

Introduction of exotic non-native invasive and nuisance species is a growing problem in the WIO region. In Tanzania, several invasive species reported by the IUCN Species Survival Commission include *Musculista senhousia* (mollusc), *Salmo trutta* (fish), *Tilapia zillii* (fish), *Vibrio cholera* (micro-organism), *Acanthophora spicifera* (algae), *Gracilaria salicornia* (algae), *Tubastraea coccinea* (coral) and *Lutjanus kasmira* (fish) (ASCLME 2012c). In Kenya and South Africa, 36 and 85 exotic species have been reported, respectively (ASCLME 2012b). The threat from new alien species in the region remains high due to the high volume of shipping processed at key ports in the region (ASCLME 2012e). In Seychelles, introduction of *Rattus* spp., *Felis catus*, *Tyto alba* and *Acridotheres tristis*, have caused severe reductions in breeding bird populations through the predation of eggs, chicks and adult birds (ASCLME 2012g). The Indian crow is also known to be feeding ferociously on eggs of other bird species thus threatening indigenous populations and their continued existence (ASCLME 2012c). There have also been introductions of species for mariculture purposes, including exotic seaweeds that are being farmed in Northern Mozambique (Cabo Delgado and Nampula Provinces), the outcome of which remains unknown (Mozambique MEDA 2012).

The corallivorous crown-of-thorns (COTs) starfish (*Acanthaster planci*) have been found on coral reefs throughout the region, and outbreaks have affected the reefs in Kenya, Tanzania, Mozambique, South Africa (ASCLME 2012b-e) and Mauritius (Fagoonee and West 1983). Between 1995-1996 there was an outbreak of COTs in Mozambique, which caused extensive reef damage at Bazaruto (80 %) and Inhambane (95-98 %) (ASCLME 2012d). The reefs of Mauritius have also been subject to several COTs outbreaks, the first of which occurred in the 1970s (Fagoonee and West 1983, Fagoonee *et al.*, 1985, Fagoonee 1990). Between 1971 and 1980, COT densities increased from 30 per 10,000 m² in 1971 to 416 per 10,000 m² in 1980 at Trou aux Biches in Mauritius (Fagoonee 1990). Contributory factors for the outbreaks were declines in the predator numbers, in particular the gastropod mollusc (*Charonia tritonis*) and contamination due to land-based sources of pollution such as fertilisers, pesticides, industrial chemicals and sedimentation (Fagoonee 1990).

The most severe environmental impacts caused by the introduction of exotic non-native species, invasives and nuisance species in coastal-marine waters are: reduced area of critical habitats (feeding, breeding, spawning) and phase shifts and changes in community composition. These can seriously degrade part of the coastal-marine ecosystems. Other medium impacts which are likely to moderately degrade part of the coastal ecosystem are: loss of biodiversity; changes to trophic structure; changes in fisheries productivity. Minor impacts which are likely to only slightly impair part of the ecosystem are: changes in epifauna and infauna; loss of 'natural' shoreline protection and increased risk of coastal flooding; and changes in primary productivity. The ecosystem services likely to be affected by the environmental impacts resulting from the introduction of exotic non-native species, invasives and nuisance species include:

Provision Services - food (e.g. fish, game fruit); raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer); genetic resources (e.g. for crop improvements and medicinal purposes); and biochemical medicines and pharmaceuticals (e.g. biochemical products, and test organisms) for which there are very strong links; and ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) for which there is a strong link;

Regulating Services – pollination; biological control (e.g. seed dispersal, pest and disease control); and nutrient cycling and maintenance of fertility (incl. soil formation) for which there are very strong links; and natural hazard regulation (e.g. storm protection and flood prevention) for which there is a medium link.

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles (including nursery, spawning, breeding, feeding) and secondary production for which there are very strong links.

Cultural and Amenity Services - opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; sense of place; and social relations for which there are very strong links; aesthetics information; spiritual experience; and information for cognitive development knowledge systems and education for which there are strong links.

The most severe socio-economic impacts caused by the introduction of exotic non-native species, invasives and nuisance species are: reduction in GDP; reduction in income generating livelihoods (fisheries related); loss of landscape and seascape aesthetics; loss of cultural heritage and traditions; threats to public health; and reduction in bathing water quality. These will all be major socio-economic problems if the issues are allowed to continue.

(b) Causal Chain Analysis

The most important direct cause of the introduction of exotic non-native species, invasives and nuisance species is accidental introductions. Other direct causes include direct introductions and natural climate variability and change. The sectors responsible for causing the introduction of exotic non-native species, invasives and nuisance species are: transportation and shipping; fisheries (mariculture); energy and natural environmental variability. The resource use practices and underlying (social, legal and political) causes are as follows:

Transportation and Shipping: An increase in the (1) release of ballast water and fouling on ships occur due to an increase in shipping capacity and global transport as a result of market demand. There is inadequate capacity for processing ballast water due to lack of control at entry points caused by inadequate financial resources and lack of compliance with regulations. There are also often inadequate facilities for ship cleaning and waste disposal.

Tourism: (3) The accidental introduction of species occurs due to an expansion of the tourism sector and more visitors. There is a lack of control at entry points due to lack of compliance with customs regulations and a lack of knowledge.

Fisheries and Aquaculture: (4) Deliberate and (5) accidental introduction of species takes place due to lack of knowledge, lack of technical capacity and inadequate inspection of mariculture facilities.

Natural environmental variability and change - also cause the introduction of exotic non-native species, invasives and nuisance species due to natural invasions and range extensions associated with ocean warming and current changes.

The main Underlying Causes of the introduction of exotic non-native species, invasives and nuisance species can be summarised as follows:

- Increased external market demands for (use of) natural resources (shipping).
- Inadequate investment in infrastructure.
- Low compliance with existing regulations.
- Lack of extension officers/environment officers.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Limited knowledge, access to technology and understanding of best environmental practices.
- Lack of transparency/wealth creation and corruption.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Weak national planning and regulatory frameworks.

The Root Causes of the introduction of exotic non-native species, invasives and nuisance species are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [F] Population pressure and demographics and [H] Climate change and natural processes.

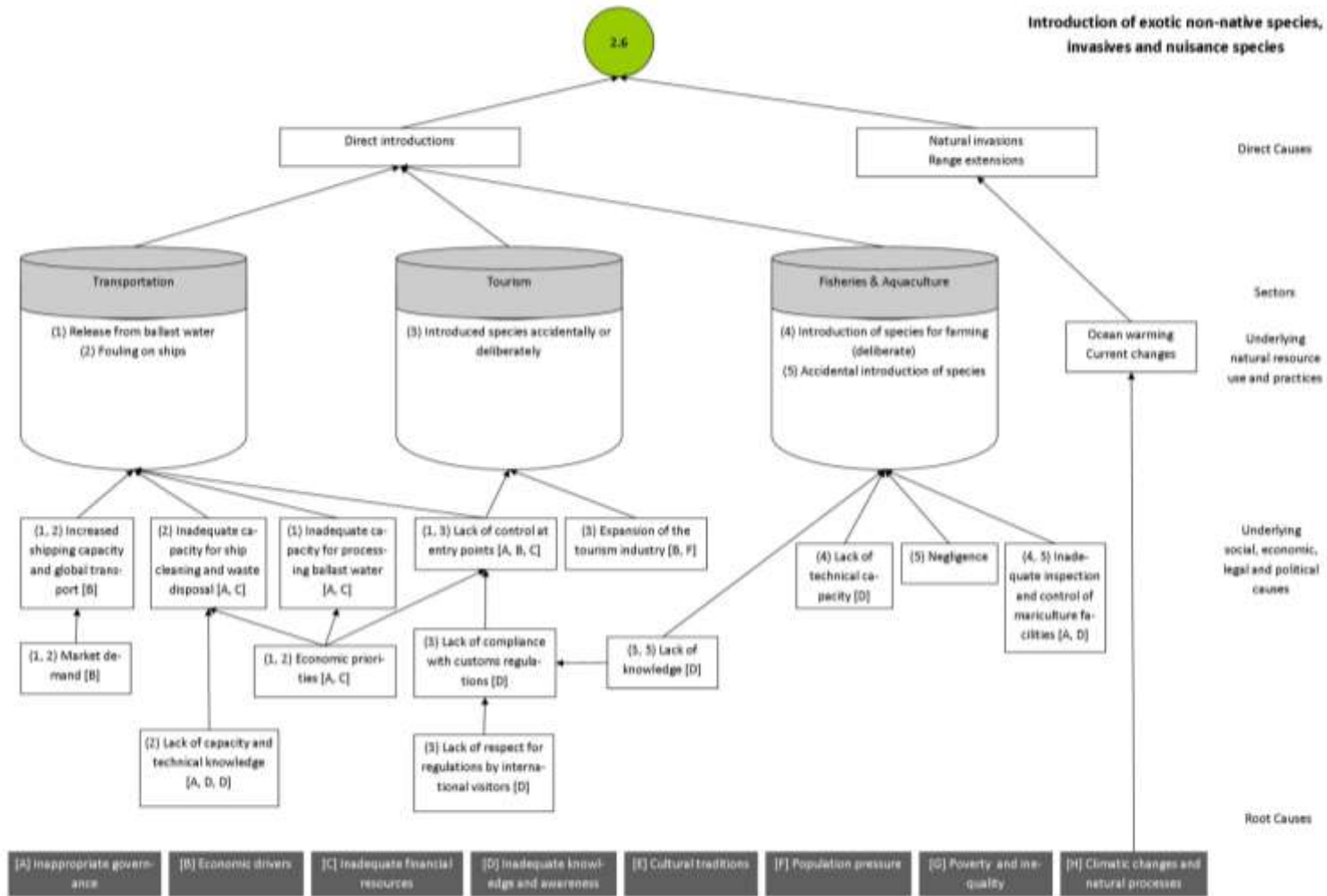


Figure 2-24: Causal Chain Analysis for introduction of exotic non-native species, invasives and nuisance species.

1.5.4 Problem Area 3: Alteration in river freshwater flows and sediment loads

1.5.4.1 Alteration of river sediment loads

(a) Impact Chain Analysis

The environmental impacts that occur as a result of alteration of natural river flow and sediment loads include reduction in freshwater discharge, alteration of coastal dynamics, shoreline change due to erosion and or accretion, reduction in clarity of coastal waters (reduced light available for photosynthetic activities), degradation of floodplains, degradation of deltas, degradation of saltmarshes, degradation of estuaries, degradation of mangrove forests, degradation of seagrass beds, degradation of coral reefs, alteration of the extent of mud flats, decreased natural productivity, changes in nutrient input and loss of biodiversity. The ecosystem services likely to be affected by the environmental impacts resulting from the alteration of natural river flow and sediment load include the following:

The changes in river flow and sediment load impact many estuaries of the region and which represent enormously important habitats for sustaining mangroves, seagrass beds and nurseries or refugia for a wide range of important fish and crustacean resources. In other words, the actual effects relate back to the two main categories of transboundary problems that were analyzed in sections 4.2 and 4.3. For this reason, the secondary environmental impacts and related socio-economic consequences related to river-coast interactions are not dealt with in this section, but for further analyses on these aspects, the reader is referred to the respective sections of this TDA.

The ecosystem goods and services that are impacted by changes in river discharges and sediment load include the following:

Provision Services - food (e.g. fish, game fruit); freshwater (e.g. for drinking, irrigation, cooling); biochemical medicines and pharmaceuticals (e.g. biochemical products and test organisms); ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) and energy.

Regulating Services - natural hazard regulation (e.g. storm protection and flood prevention); regulation of water flows (e.g. natural drainage, irrigation and drought prevention); wastewater treatment (especially water purification); erosion prevention; nutrient cycling and maintenance of fertility (including soil formation) and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - photosynthesis and primary production; maintenance of genetic diversity (gene pool protection); maintenance of life cycles including nursery, spawning, breeding, feeding grounds and secondary production.

Cultural and Amenity Services - aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values) and bequest, intrinsic and existence values.

Table 2-15 Overview of common environmental impacts and socio-economic consequences associated with alteration of river flows, quality and sediment loads.

TRANSBOUNDARY PROBLEM				COASTAL IMPACTS
Alteration of river flow	Water quality degeneration	Increased sediment loads	Decreased sediment loads	
				Impacts on coastal habitats and shorelines
X				Increased salinisation of agricultural land (flood plain agriculture) due to lack of flooding
X	X	X	X	Modification of ecosystem (riverine and estuarine) community structure and dynamics
X				Loss of wetlands due to lack of flooding and erosion
X	X	X	X	Decreased natural productivity due to changes in habitats, nurseries and spawning areas (e.g. vertebrate and crustacean fisheries)
X				Changes in habitats of terrestrial fauna including birds
X	X	X	X	Reduction of available natural living resources (fauna and flora)
X				Loss of natural estuarine/river mouth riparian habitat resulting in human encroachment onto floodplain and subsequent loss of buffering benefits to flooding from upstream and sea storms
X	X	X	X	Loss of biodiversity
		X	X	Shoreline changes (erosion/accretion)
		X		Coral reef degradation
X			X	Mangrove forest degradation
				Impacts on water quality
X	X			Water quality degeneration due to decreased absorption capacity
	X			Water quality degeneration due to increased pollutant loads from rivers or decreased dilution factor through reduced flows
X				Increased salt water intrusion into downstream end of rivers
		X		Increased turbidity, siltation and at times eutrophication of estuarine and coastal waters

Table 2-16 Overview of common causes and sectors associated with alteration of river flows, quality and sediment loads.

TRANSBOUNDARY PROBLEM				IMMEDIATE CAUSES	UNDERLYING SECTORS
Alteration of river flow	Water quality degeneration	Increased sediment loads	Decreased sediment loads		
X	X		X	Damming of rivers, construction of off-channel impoundments, weirs	Energy, Agriculture and Forestry, Urbanisation
X	X			Direct water abstraction for urban water supply, irrigated agriculture and wet process mineral mining	Agriculture, Urbanisation, Mining
X			X	Inter-basin water transfer	Energy, Urbanisation
X				Hydrological variability	N/A
	X	X		Poor land-use	Agriculture
	X			Agricultural runoff of nutrients and pesticides	Agriculture
	X			Wastewater discharges	Urbanisation, Industry, Mining, Energy
	X			Stormwater runoff	Urbanisation
X		X	X	Changes in vegetation types and patterns (including afforestation) ¹⁰	Agriculture and Forestry
X		X	X	Alteration of climatic conditions	N/A
		X		Unsustainable agricultural techniques (e.g. slash and burn)	Agriculture
		X		Deforestation	Agriculture and Forestry
		X		Encroachment on river banks ¹¹	Urbanisation
		X		Mining of sand and aggregates ¹¹	Mining
		X		Road development	Urbanisation
			X	Canalization and impoundment of river reaches for navigation purposes ¹¹	Transportation

¹⁰ Includes also direct abstraction by large-scale non-indigenous plantations.

¹¹ Note: to some extent, such causes may even lead to alteration in river flow. However, generally such consequences are relatively limited and localized and therefore not highlighted in this analysis.

The socio-economic impacts that occur as a result of alteration of natural river flow and sediment loads included all of those identified during the workshops (excluding reduced quality of seafood products; human health risk through contact recreation; human health risk through ingestion of contaminated seafood; reduced productivity of workforce due to sickness and ill health; and increased costs of living).

(b) Causal Chain Analysis

The alteration of river flows and sediment loads is caused by several factors (Tables 2.15-2.16). The most important direct causes of alteration of natural river flow and sediment load are rainfall variability; natural topography; water abstraction, obstruction of natural river channels; changes in land use and vegetation cover; deforestation. The sectors responsible for causing alteration of natural river flow and sediment load are industry, agriculture and forestry, mining, energy, tourism, urbanisation, transportation and shipping, and natural environmental variability. At the root-cause level, seven common factors contribute to environmental problems related to river-coast interaction in the WIO region:

Climate change and natural processes – Climate change and natural events to an important extent influence river flows, turbidity and sediment transport. For example, Mozambique has in recent years had several severe floods impacting on the floodplain and the delta in the lower reaches of the Zambezi and Limpopo rivers. Most of the region is characterized by large spatial as well as temporal variations in rainfall. Year-on-year variation around the long-term norm for various parts of the region is as high as 30–35% (Earle and Malzbender, 2007). This natural climatic variability is exacerbated by human induced climate change. Temperature increases of between two and six degrees by the end of the 21st Century have been predicted by the IPCC (2005) for much of the region, though the exact impact is more difficult to predict, with some areas experiencing an increase and others a decrease in rainfall. What seems likely though is that there will be an increase in what is termed “extreme events”—floods and droughts following on from each other (UNEP, 2005). This is likely to increase stress on the river systems in the region by increasing soil erosion and sedimentation and, in places, increasing pollution concentrations where average water volumes decline. It is also likely that there will be decreased freshwater flows to the coast in times of drought.

Economic growth - Increased demands for limited water resources due to economic growth in the region results in growing competition over the resource between different sectors and the construction of more dams on rivers. Several countries in the WIO region have, over the past half century, experienced high levels of economic development, with a commensurate increase in water use in river basins for industry, mining, urban development, agriculture and energy production (TPTC, 2001; Arthurton *et al.*, 2002; van der Zaag and Carmo Vaz, 2003; Hogueane *et al.*, 2009). This trend is likely to continue with several countries in the region already experiencing electricity shortages due to the increase in demand from industrial users. The response in South Africa has been to plan the construction of new power stations, such as the dry cooled Medupi plant in the Limpopo River basin. With electricity production currently the largest user of water in that country, and forecast to grow, this will likely lead to increased demands for water on the resources of the Limpopo and Incomati rivers.

Population pressure – The increased demand for water resources by growing populations can change river systems irreversibly. For example, in the Pangani River basin (Tanzania) where increased water use of the Luengera and Mkomazi rivers, which were historically perennial, has now led to only seasonal flow (PBWO/IUCN, 2007). All of the countries in the region are experiencing medium to high rates of overall population growth, which in the context of a finite supply of water resources, equates to ever greater demands on existing supplies (Hirji *et al.*, 2002).

Poverty and inequality – Due to limited resources, people engage in unsustainable land-use practices, such as over-stocking of cattle leading to over-grazing and therefore increased run-off of nutrients and soil erosion. Other harmful practices are the inefficient application of fertilizers and use of (often cheap) harmful pesticides leading to compromised river water quality. Poverty and inequality are also at the base of large-scale deforestation for fuelwood and building materials in many areas at the coast, which is at the root of increased soil erosion and sediment load to rivers.

Inappropriate governance - The lack of inter-sectoral coordination, notably little or no involvement of different water-use sectors, with different sets of priorities in the management of the resource, leads to the misuse of the resource. This is widespread in the region, often with no, or inadequate, intervention and governing regulatory instruments. The inclusion of stakeholder views, knowledge and interests is also limited. The lack of information and data in some areas of the nature, causes and impacts of environmental problems, and weakly enforced legislation, compounded by the lack of harmonised legal and institutional frameworks for the management of transboundary rivers has allowed the deterioration of river and adjacent coastal areas. Fortunately, these issues are increasingly being addressed, with a more detailed analysis of governance related issues presented in the later sections of the TDA.

Inadequate knowledge and awareness – This concerns two important factors: Shortcomings in information and data (in some areas) of the nature, causes and impacts of environmental problems. For example, in the Pangani River the melting of glaciers on Mount Kilimanjaro has increased streamflow at certain periods in some of the tributaries, making it difficult to determine whether increased water abstraction has had an impact on overall streamflow or not (PBWO/IUCN, 2007).

Lack of awareness of stakeholders of the impact of their activities on other stakeholders and the ecosystem as a whole. For instance, in the Incomati River water is abstracted for cooling power stations and for use in irrigated agriculture, with the result that there is an increase in salt water intrusion from the marine environment into previously freshwater reaches of river systems (TPTC, 2001).

Inadequate financial resources and human capital – There is limited financial and human resource capacity for effective implementation and monitoring of agreements and comprehensive water management regimes.

The resource use practices and underlying (social, legal and political) causes are as follows:

Industry: Increased (1) water abstraction and usage occurs as a result of the expansion of the industrial sector driven by economic development pressures and market demand. The problem is exacerbated by inadequate or lack of planning and use of inappropriate incentives/subsidies. There is also lack of technology, inadequate investment in infrastructure, and low enforcement and compliance due to limited capacity for monitoring, control and surveillance.

Agriculture and Forestry: (2) Irrigation projects requiring diversion of river courses, damming of rivers and high water abstraction are as a result of the expansion of the agriculture and commercial agricultural sector, occurs due to the increased demand for food and other agricultural produce. Lack of technology and the use of inappropriate irrigation and farming methods persist due to incorrect incentives for water use and cultural/traditional practices. There is inadequate planning, lack of land use plans and appropriate environmental policies due to weak national planning and regulatory frameworks.

Degradation of catchments and poor land use practices occur as a result of (3) land clearing for commercial agriculture or logging, driven by external market demand for timber or agricultural products due to a poor economy and need for finances. There is also lack of land use plans and environmental policy due to slow policy development and weak national planning and regulatory frameworks. There is low compliance with regulations and monitoring and control capacity is lacking.

Degradation due to (4) traditional land use practices (e.g. slash and burn) occur due to an increased demand for farmland caused by an external market demand for food products and population growth. There is also lack of education, outreach and awareness and appropriate technology is also lacking. The (5) introduction of alien species occurs due to wealth creation and corruption and low enforcement and compliance due to weak regulatory frameworks and slow policy development. Degradation due to the (6) unsustainable harvesting of timber for fuel wood takes place due to the internal market demand for fuel wood, which arises due to a lack of alternative fuel sources. It is also an income generating livelihood activity and there is a lack of technology.

Degradation due to (7) seasonally inappropriate farming activities occurs due to lack of education and awareness and lack of outreach (extension officers). There is also low compliance with regulations due to

weak regulatory frameworks and lack of appropriate information on seasonal rainfall. Degradation due to (8) commercial harvesting for timber occurs due to external market demand for timber, weak economies and the need for finances.

Mining: (9) High water usage/abstraction for processing in commercial mining (open cast mining and alluvial mining) takes place due to the expansion of the commercial mining sector as a result of the external market demand for natural resources and the weak economies and need for finances. It is also an employment opportunity and an income generating livelihood. External companies may have weak environmental management policies, but continue to operate due to lack of monitoring and control capacity at the national level. There is also poor planning due to slow policy development. (10) Water abstraction for artisanal mining (e.g. for sapphire or gold) also takes place due to the expansion of this mining sector as a result of the external market demand for natural resources. It is also an income generating livelihood activity. Lack of planning and regulation of artisanal mining at the national level occurs due to slow policy development and limited capacity for planning, monitoring and control.

Energy: The (11) damming of rivers for hydroelectric power generation and (12) high consumption of water for use in cooling occur due to an increased electricity demand caused by economic development pressure. There is a growing demand for cheap power for industries and households and lack of investment in alternative energy technologies (e.g. solar), mainly due to weak energy legislation.

Tourism: (13) High water consumption by the tourism sector arises due to the increased number of tourists, lack of regulation to encourage water saving measures and low uptake of alternative technologies (e.g. rain water harvesting or grey water recycling) due to a lack of incentives. (14) Clearing of land for tourism occurs as there is limited suitable land available for tourism development and there is also an increased demand due to the expansion of the tourism sector and economic development pressures. There is lack of regulation and incentives to encourage sustainable tourism development. (15) Large scale changes in topography and inappropriate drainage as a result of tourism developments occurs due to bad construction processes and gaps in regulations. All the above are due to poor planning, lack of land use plans and suitable environmental policies, as well as low enforcement of regulations, due to lack of capacity for monitoring and control.

Urbanisation: The expansion of urban areas results in an increased demand for domestic piped water supplies and this leads to increased (16) domestic water usage, (17) increased domestic wastewater disposal and (18) increased damming for water supply to meet the high demand for piped water supply. There is a lack of investment in alternative technologies such as rain water harvesting and inadequate investment in municipal wastewater disposal infrastructure. (19) Construction activities for modern homes, which occur as a result of increased development, are either poorly regulated or there is a lack of compliance with regulations due to lack of monitoring and enforcement capacities. The expansion of urban areas can result in (20) increased surface run-off as a result of an increase in area of hard structures due to a lack of poor planning and policy development and lack of investment in upgrading urban drainage.

Transportation and Shipping: (21) Land clearing for road construction and (22) inappropriate drainage and canalisation of roadways occur due to the expansion of the road network and use of inappropriate road construction practices. There is poor planning and poor compliance due to lack of or inadequate regulations.

Climate change and extreme events: Alteration of natural river flow and sediment load are being exacerbated due to high rainfall variability, increased evaporation, flooding and fires which may be linked to global climate change. There has been an increase in the occurrence of extreme events that causes extreme flooding and drought conditions that significantly affects river flows.

The main Underlying Causes of the alteration of natural river flow and sediment load can be summarised as follows:

- Rural poverty, increased coastal migration and urbanization.
- Inadequate investment in infrastructure/poor maintenance.

- Increased external market demands for natural resources/materials.
- Increased internal market demands for natural resources/materials.
- Limited knowledge and lack of appropriate technology and best practices.
- Low compliance with existing regulations.
- Lack of alternative sustainable livelihood opportunities.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Wealth creation and corruption.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Weak national planning and regulatory frameworks.

The Root Causes of alteration of natural river flow and changes in sediment load are: [A] Inappropriate governance; [B] Economic drivers; [C] Inadequate financial resources; [D] Inadequate knowledge and awareness; [E] Cultural traditions; [F] Population pressure and demographics; [G] Poverty and inequality and [H] Climate change and natural processes.

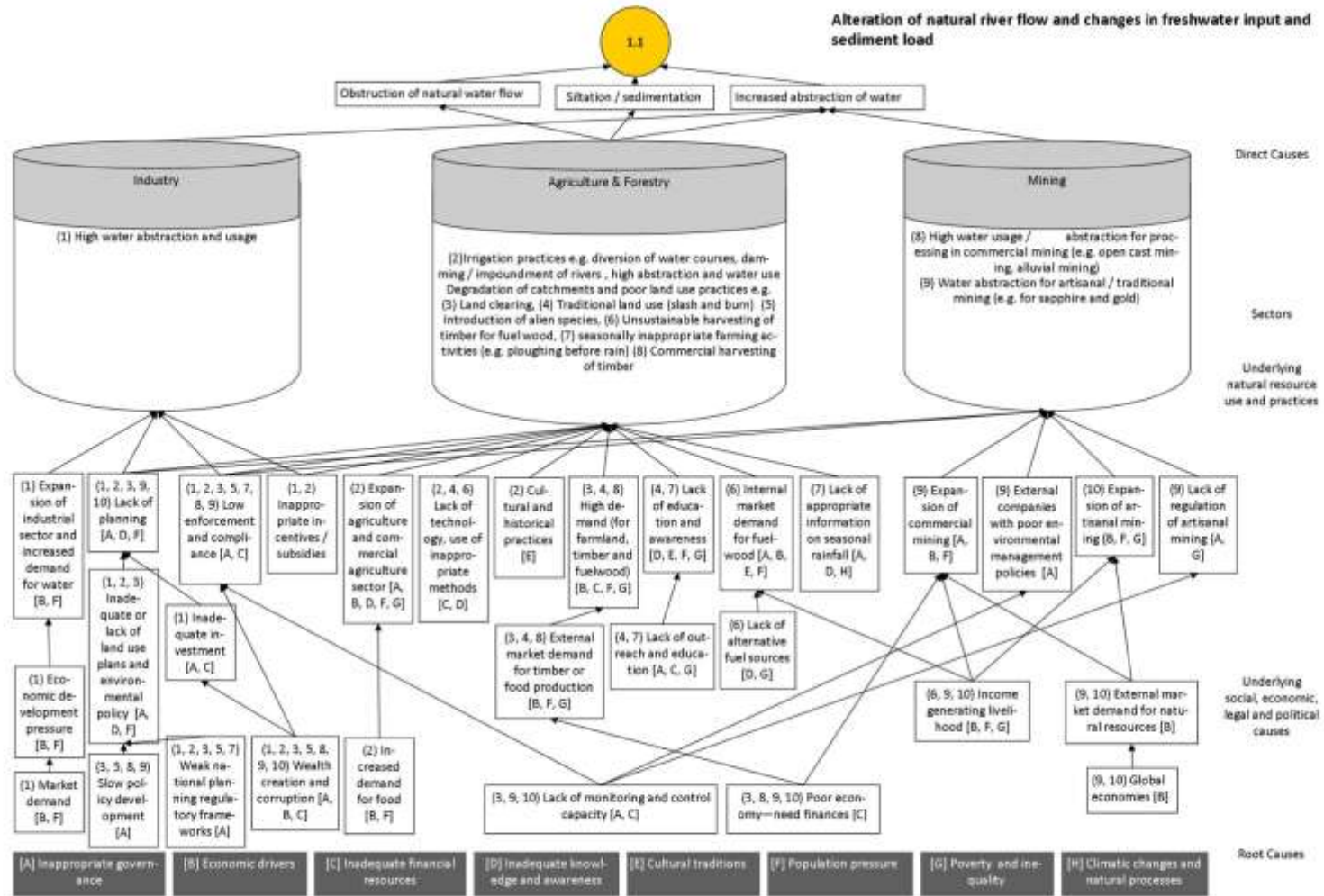


Figure 2.25a: Causal Chain Analysis for the Alteration of river sediment loads (part 1 of 2).

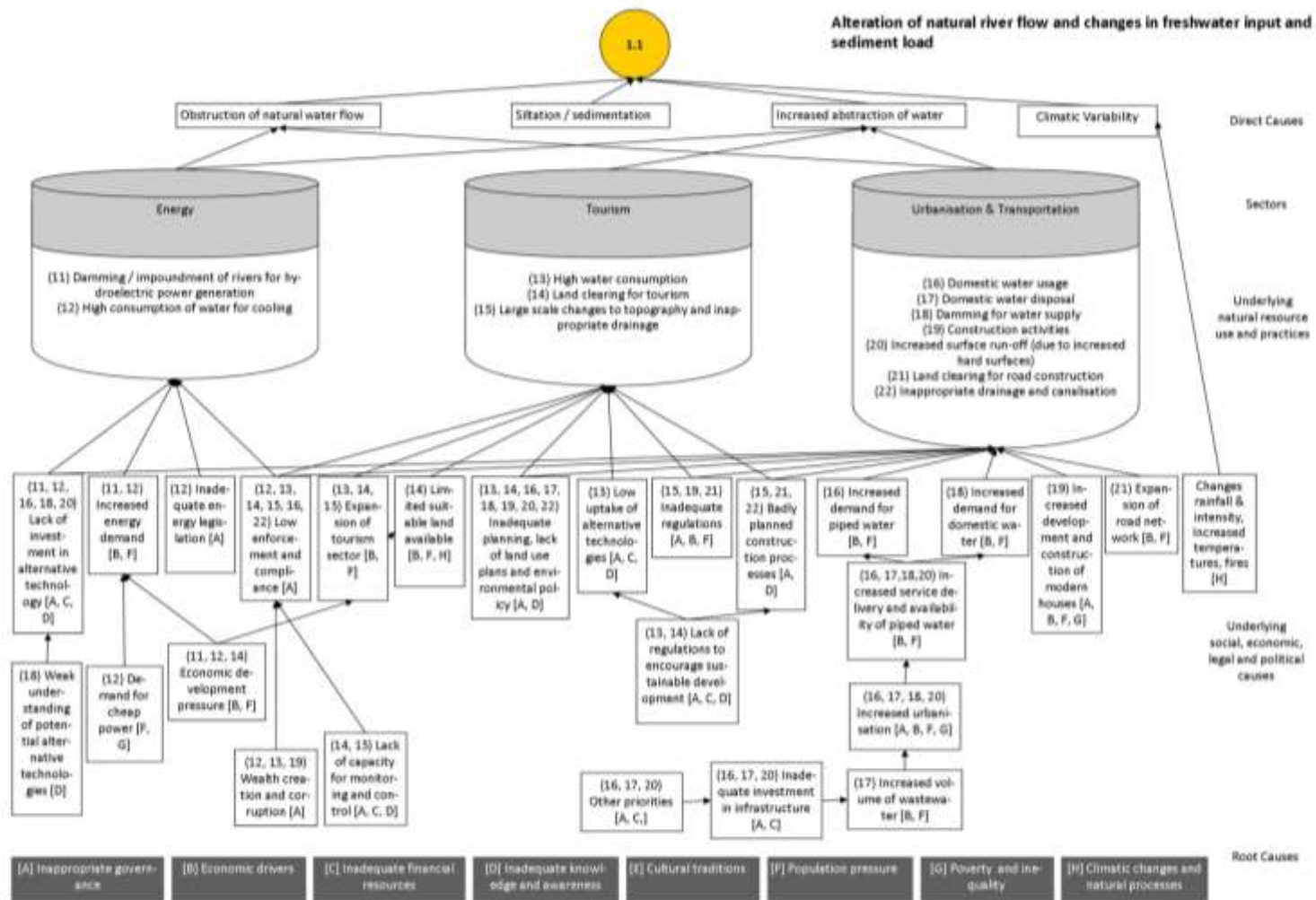


Figure 2.25b: Causal Chain Analysis for the alteration of natural river sediment load (part 2 of 2).

1.5.4.2 Alteration of river flows and river water quality

(a) Impact Cain Analysis

For most of the rivers in the WIO region, pollution of the marine environment from freshwater flows is not significant. However, studies undertaken in the Pangani, Limpopo, Incomati and the Maputo rivers show that there has been some reduction in water quality and that the spatial-temporal distribution of such reduction is usually significant. In a few hotspot areas however, where there are changes to the estuarine environment due to increased pollution levels, reduced flows and changed sediment deposition patterns have severely affected fish and shrimp catches for example, at the Zambezi Delta. The reduction in flow, and especially the flood events has led to the physical alteration and destruction of habitats (PADH) of the lower delta, mainly through salt-water intrusion, impacting on important spawning grounds for fish and shrimp (ZRA, 1998). The other PADH impact on the Zambezi Delta area is the reduction in mangrove forests coverage. Similar trends, leading to reduced fish catches linked with alteration of flow and drop in water quality, have been observed for the coast off the Incomati River mouth (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and off the Pangani River mouth (PBWO/IUCN, 2007). The Maputo River has experienced high levels of chemical and biological pollution emanating from industries and from effluent from neighbouring towns, threatening seagrass beds (Fernandes, 1995). The combination of increased pollutants from the city of Maputo and a reduction in freshwater flows from the Incomati River which leads to salt-water intrusion, threatens mangrove forests and seagrass beds in the vicinity of Maputo Bay (Hoguane *et al.*, 2002). Increased demands for water in the region, coupled with possible drops in rainfall due to climate change, could lead to further problems.

In Mozambique, alteration of river flow from impoundments and water abstraction e.g. the Incomati River has led to the delta suffering from an increase in the salt-water intrusion, extending upstream for about 40 km. This is accompanied by an increased erosion of the delta due to reduced sediment load and consequent reduction in mangrove forest areas (Hoguane *et al.*, 2004).

The growing demand for water and unsustainable land use practices are often coupled with limited awareness at grassroots levels of the cause-impact relationships as well as weak legal and institutional frameworks and capacity to address the problems. Poor enforcement of water use licenses, such as in the Pangani basin (PBWO/IUCN, 2007), limited knowledge of environmental water requirements, such as in the Incomati basin (Van der Zaag and Carmo Vaz, 2003; Hoguane *et al.*, 2009) and lack of financial and human resources to effectively mitigate and adequately manage causes and impacts are common problems throughout the WIO region.

Governance is specifically related to flow alterations from the damming of rivers through dam operating rules. Hydro-power and water supply dams aim to provide maximum hydraulic pressure at times when power is needed most and store wet season runoff for use in the dry season respectively. The net impact is a reduction in the natural flow variability of the river, leading to loss of biodiversity and habitat destruction. For instance, the construction of the Cahora-Bassa Dam and its operation and its impact on the downstream fisheries has been mentioned above. The same is true for the Pangani River where hydro-power reservoirs upstream have impacted the flow regime at the estuary (PBWO/IUCN, 2007).

The ecosystem services likely to be affected by degradation of river water quality include the following:

Provisioning Services - food (e.g. fish, game fruit); freshwater (e.g. for drinking, irrigation, cooling); and ornamental resources (e.g. artisan work, decorative plants etc.).

Regulating Services—wastewater treatment especially water purification; nutrient cycling and maintenance of fertility including soil formation; and biological control (e.g. seed dispersal, pest and disease control).

Supporting/Habitat Services - maintenance of life cycles (including nursery, spawning, breeding, feeding); photosynthesis and primary production; and secondary production.

Cultural and Amenity Services - aesthetics information and opportunities for recreation, tourism and lifestyle.

(a) Causal Chain Analysis

The main sectors linked to the immediate causes of river flow alteration and degradation of water quality are: Agriculture, in particular extensive farming and forestry, Urbanisation, Mining, Energy Production, and Industry. Each of these sectors is associated with the abstraction of water from rivers, with or without damming. The consequent drop in river flows can lead to a wide range of impacts on the marine environment, both in terms of destruction of coastal habitats and shoreline changes as well as on water quality modifications. These issues are presented in the problem trees for river flow alteration in the WIO region (**Error! Reference source not found.**) and degeneration of water quality (see **Error! Reference source not found.**). An overview of direct causes, impacts and affected stakeholders for the major river basins in the WIO region, based on currently available data, is shown in Table 2-18.

Table 2-18 Overview of the key problems, impacts and direct causes related to alteration of freshwater flows and degradation of water quality in the main river basins of WIO region.

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSE
	Alteration of freshwater flow	Degradation of water quality		
Tana	X	X	Decrease in the extent and frequency of flooding (IUCN, 2003). Increased turbidity of coastal waters in Ungwana Bay. Increased seawater intrusion and erosion of the delta leading to loss of mangroves and other important habitats such as riverine forests.	Damming of river for hydro-power generation Direct abstraction for urban water supply and irrigated agriculture Hydrological variability Poor land use
Athi-Sabaki	X	X	High flow variability (Kitheka <i>et al.</i> , 2004; Fleitmann <i>et al.</i> , 2007) Increased flash of flood events due to reduced percolation of rainfall (Snoussi <i>et al.</i> , 2004). Increased turbidity of water in Malindi Bay (Kitheka <i>et al.</i> , 2004) Impacts on coastal habitats particularly coral reef ecosystem	Poor land use Wastewater and stormwater runoff from urban settlements Hydrological variability
Pangani	X	X	Smoothing-out of the annual-flow hydrograph leading to reduced flooding downstream (Lugeiyamu, 2002; PBWO/IUCN, 2007) Low oxygen levels in water entering estuary associated with a heavy pollution load (Lugeiyamu, 2002; PBWO/IUCN, 2007) Increased salt water intrusion at estuary	Damming of river for hydro-power generation Direct abstraction for irrigated agriculture and urban water supply Agricultural runoff Wastewater and stormwater runoff from urban settlements Hydrological variability

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSE
	Alteration of freshwater flow	Degradation of water quality		
Rufiji		X	Limited and localised water quality degradation (Shaghude, 2004; Arthurton <i>et al.</i> , 2002)	Agricultural runoff and pesticides
Ruvuma	---	---	Very little development in the basin, resulting in insignificant impacts	
Zambezi	X		Reduction in inter-seasonal flow variability resulting in the decrease in mangrove forest cover, decrease in fish and shrimp catches. Reduced colonisation of sandbanks in delta by riverine plants (Turpie, 2006; Brown and King, 2002; Beilfuss, 1999; Chenje, 2000; ZRA, 1998)	Damming of river (to supply water for hydropower generation and irrigated agriculture) Land use change
Pungwe	X		Increased water abstraction upstream of the estuary has led to a reduction in streamflow and increase in coastal erosion (Van der Zaag, 2000; Hogueane <i>et al.</i> , 2002)	Water transfer out of the basin Direct abstraction for agriculture and urban water supply Exotic forest plantations consuming more water
Limpopo	X		Increased salinisation of the estuary associated with sea water intrusion leading to loss of biodiversity in estuary. Reduced absorptive capacity of the river has led to a reduction in water quality.	Direct abstraction for agriculture and urban water supply
Incomati	X		Reduced streamflow leading to reduced sediment load and sediment deposition; increased sea water intrusion; reduction in fish and shrimp catches (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003; Hogueane <i>et al.</i> , 2009)	Damming of River to supply water for irrigation and cooling of power generation stations, (TPTC, 2001) Direct abstraction for irrigated agriculture, inter-basin water transfers (TPTC, 2001; Van der Zaag and Carmo Vaz, 2003)
Maputo		X	Reduction in water quality associated with increased anthropogenic activities; Reduction in the water and sediment quality in Maputo Bay; Reduced aesthetic/recreational values of Maputo Bay	Increased direct discharge of industrial effluents. Increased water abstraction for urban water supply
Thukela	X		Increased frequency of river mouth closure due to increased sediment deposition and erosion dynamics (DWAF, 2004a&b) Compromised water quality due to presence of industrial waste	Damming of river for irrigated agriculture and consumptive use Inter-basin water transfers (DWAF, 2004a) Discharge of industrial effluents and poorly treated sewage

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSE
	Alteration of freshwater flow	Degradation of water quality		
Betsiboka	X		Slow shift of the Bay of Mahajanga to lagoon system (Autrand, 1997) Inter-seasonal high variability of salinity	Harsh climate Bush fire and slash and burn practice Steeply and long slope Irregular and intense rainfall
Tsiribihina	X		Increased salinisation and regression of mangroves area at the delta	Harsh climate and expansion of drought Bush fire for grazing purpose Steeply and long slope Irregular and short-lived intense rainfall
Mangoky	X		Increased salinisation and regression of mangroves area at the delta	Harsh climate and expansion of drought Bush fire for grazing purpose Steeply and long slope Irregular and short-lived intense rainfall
Fiherenana	X		Severe flooding affecting the riverine plain and the city of Toliara (Chaperon <i>et al.</i> , 1993)	Harsh climate and expansion of drought Bush fire for grazing purpose Steeply and long slope Irregular and short-lived intense rainfall

Key: Highly impacted basins are highlighted

Addressing the underlying root causes requires cooperation between countries as solutions often cannot be developed on a national basis. The transboundary nature of the resource renders national or local responses, often in isolation, ineffective at addressing the described environmental problems. These can only be solved if they are addressed throughout entire basins, some requiring harmonisation of legal instruments on a regional level beyond the basin scale. Increased cooperation between sectors is also needed to overcome management interventions that are mainly sectoral in nature with little coordination between sectors. Further analysis of the governance-related problems related to river flows and quality is presented in Chapter 5.

The **Underlying Causes** can be summarised as:

- Inadequate investment in infrastructure/poor maintenance.
- Rural poverty, increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Limited knowledge and lack of technology and best practices.
- Lack of alternative sustainable livelihood opportunities.
- Low compliance with existing regulations.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Weak national planning and regulatory frameworks.

The **Root causes** include: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [H] Climate change and natural processes.

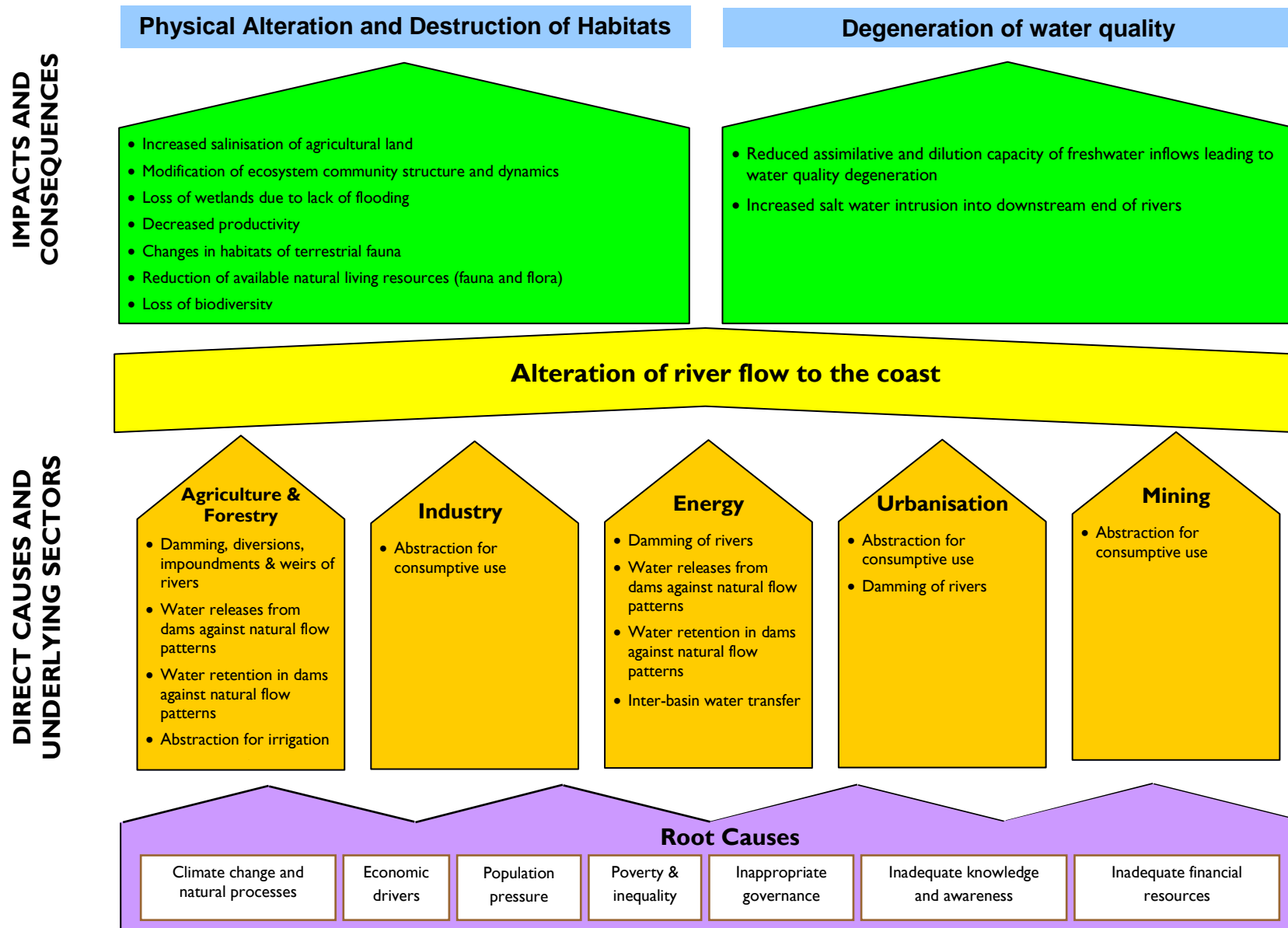


Figure 2-26 Causal chain analysis for the alteration of flow at river outflow

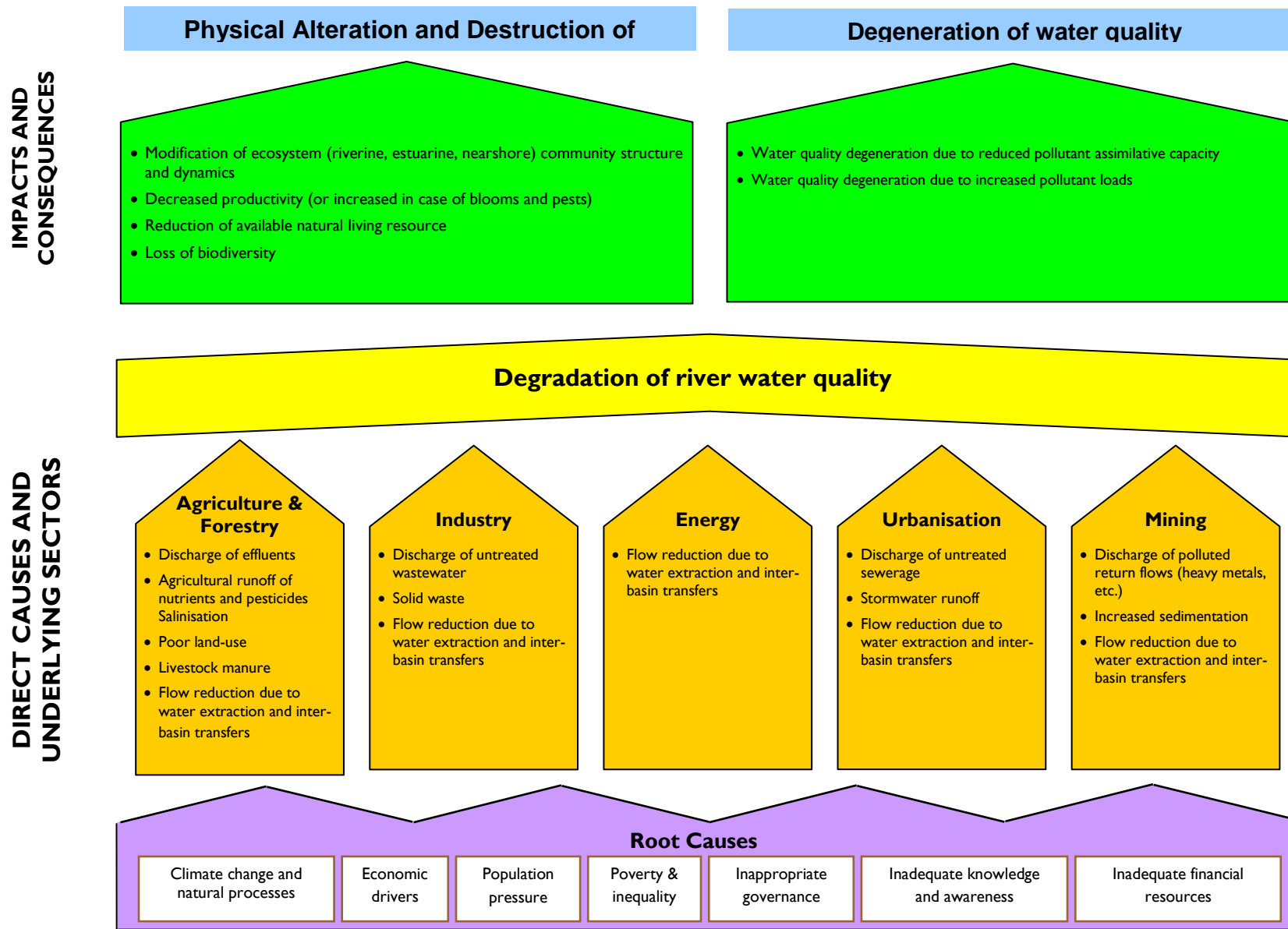


Figure 2.27 Causal chain analysis for the degradation of river water quality

1.4.1.1 Alteration of river sediment loads

(a) Impact Chain Analysis

Alteration of river sediment load is growing problem in most countries in the WIO region. However, the magnitude of the problem is yet to be fully determined due to lack of sufficient studies covering most of the rivers in the region. However, few studies that have been undertaken in the region shows that a number of factors, such as changing climatic conditions, land use practices and dam construction are leading to changes in the sediment load transported by the rivers in the WIO region. Broadly, the alteration of river sediment loads manifests itself in three ways in the region:

Increased river sediment loads in some river systems such as the Athi-Sabaki river in Kenya and the Pangani river in Tanzania that are showing evidence of increased sediment loads (e.g. van Katwijk *et al.*, 1993; Fleitmann *et al.*, 2007; PBWO/IUCN, 2007). The increase in the sediment load of these rivers has negative impact on the coastal and marine environment through the degradation of the mangrove, seagrass and coral reef ecosystems (van Katwijk *et al.*, 1993; Kitheka *et al.*, 2004).

Decreased river sediment loads as in the case of the Tana, Zambezi, Limpopo and Incomati rivers where there is evidence of decreasing sediment loads due to damming of the rivers upstream (e.g. Kitheka *et al.*, 2003; Turpie, 2006; Hogueane *et al.*, 2009). The decreased sediment load is having negative impacts on the coastal and marine environment in the Kenya's Tana Delta, Mozambique's Zambezi and Incomati deltas. The size of the Zambezi Delta has decreased from 18,000 km² in 1977 to around 15,000 km² in 1998 as a result of trapping of sediments in the Cahora-Bassa Dam (Chenje, 2000). In the Incomati Delta, reduction in sediment load has increased erosion of the delta leading to deepening and increased salt-water intrusion up to 40 km upstream. This has led to a reduction in mangrove forest area (Hogueane *et al.*, 2004). In the Tana Delta, the reduction of sediment load has led to intensification of the coastal erosion at the delta, leading to channel deepening and increased sea water intrusion up to 20 km inland. The intrusion of seawater inland contaminates freshwater supplies and soils making agriculture impossible in the deltas (Kitheka *et al.*, 2003; Hogueane *et al.*, 2004).

Variable river sediment loads in different parts of the basin in which some rivers exhibit both increased sediment loads, from erosion in upstream areas and reduced sediment transport downstream of dams, following the trapping of the sediments in dams. The latter situation could affect more rivers in the WIO region, as construction of more dams is taking place in most countries. Even where rivers are dammed, the sediment load reduction immediately downstream of the dam can at times be off-set by sediment load increases caused by bad land use practices on the river stretch between the dam and the river mouth. It is difficult to judge what the impacts of such an altered situation will be on the marine ecology, with no studies found covering the issue.

(b) Causal Chain Analysis

Several sectors contribute to changes in sediment load in the basins in the region. For the basins with documented evidence for sediment load changes (e.g. Athi-Sabaki, Zambezi, Incomati, and Betsiboka) the main underlying sectors causing these changes include: (i) Agriculture and Forestry, (ii) Urbanisation, (iii) Transport, (iv) Energy Production and (v) Industry. The combination of direct anthropogenic causes such as erosion with changing climatic conditions (e.g. changing rainfall patterns) makes it difficult at times to determine the exact contribution of a specific factor to the problem of sediment load alterations.

The **Underlying Causes** can be summarised as:

- Inadequate investment in infrastructure/poor maintenance.
- Rural poverty, increased coastal migration and urbanization.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.
- Increased external market demands for (use of) natural resources/materials.

- Increased internal market demands for (use of) natural resources/materials.
- Inadequate or lack of land use plans and appropriate environmental policy.
- Limited knowledge and lack of technology and best practices.
- Lack of alternative sustainable livelihood opportunities.
- Low compliance with existing regulations.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Weak national planning and regulatory frameworks.
- Wealth creation and corruption.

The **Root causes** of degradation of ground and surface water quality include: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [H] Climate change and natural processes.

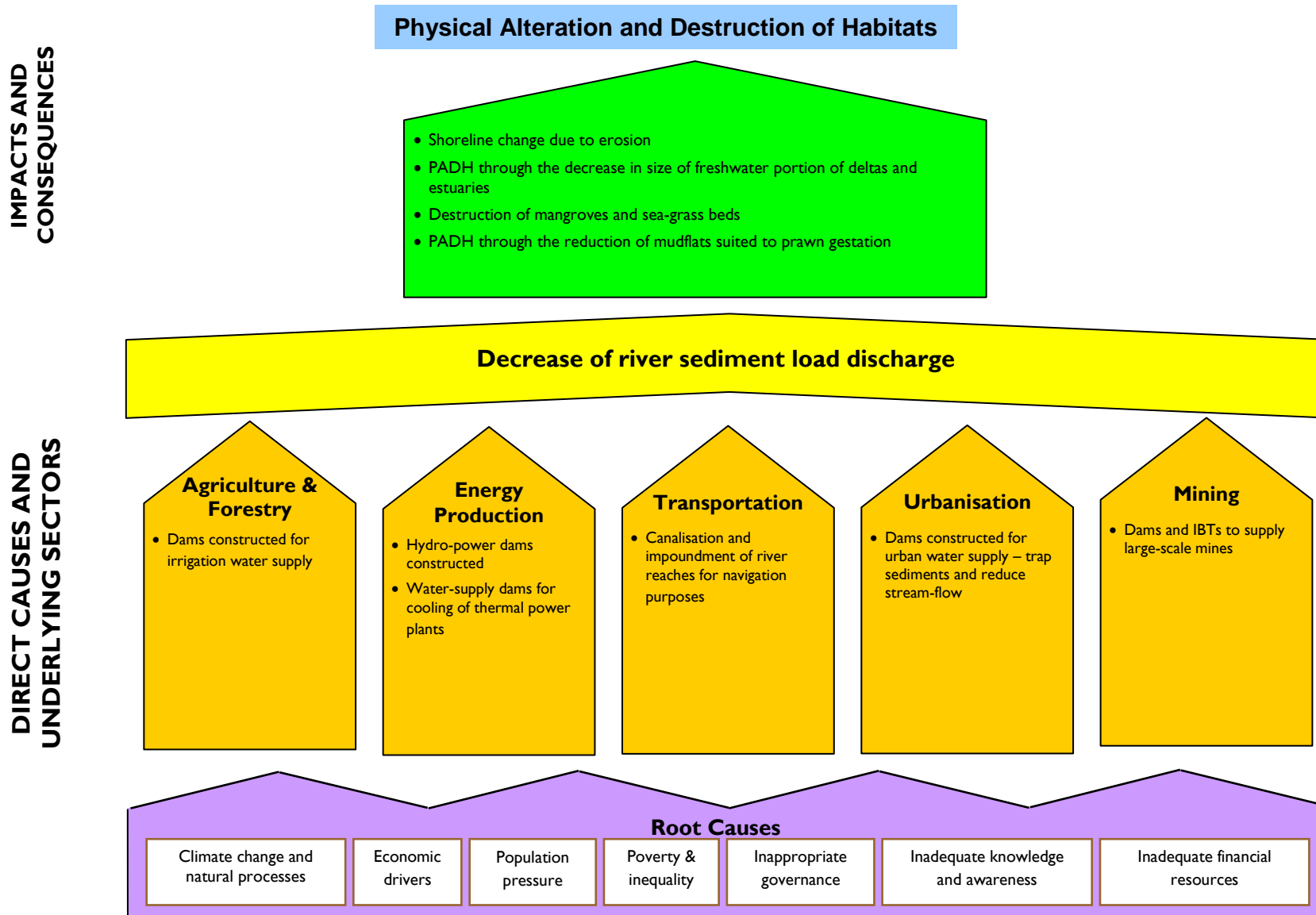


Figure 2.27 Causal chain analysis for the decrease of river sediment loads in the WIO, 253

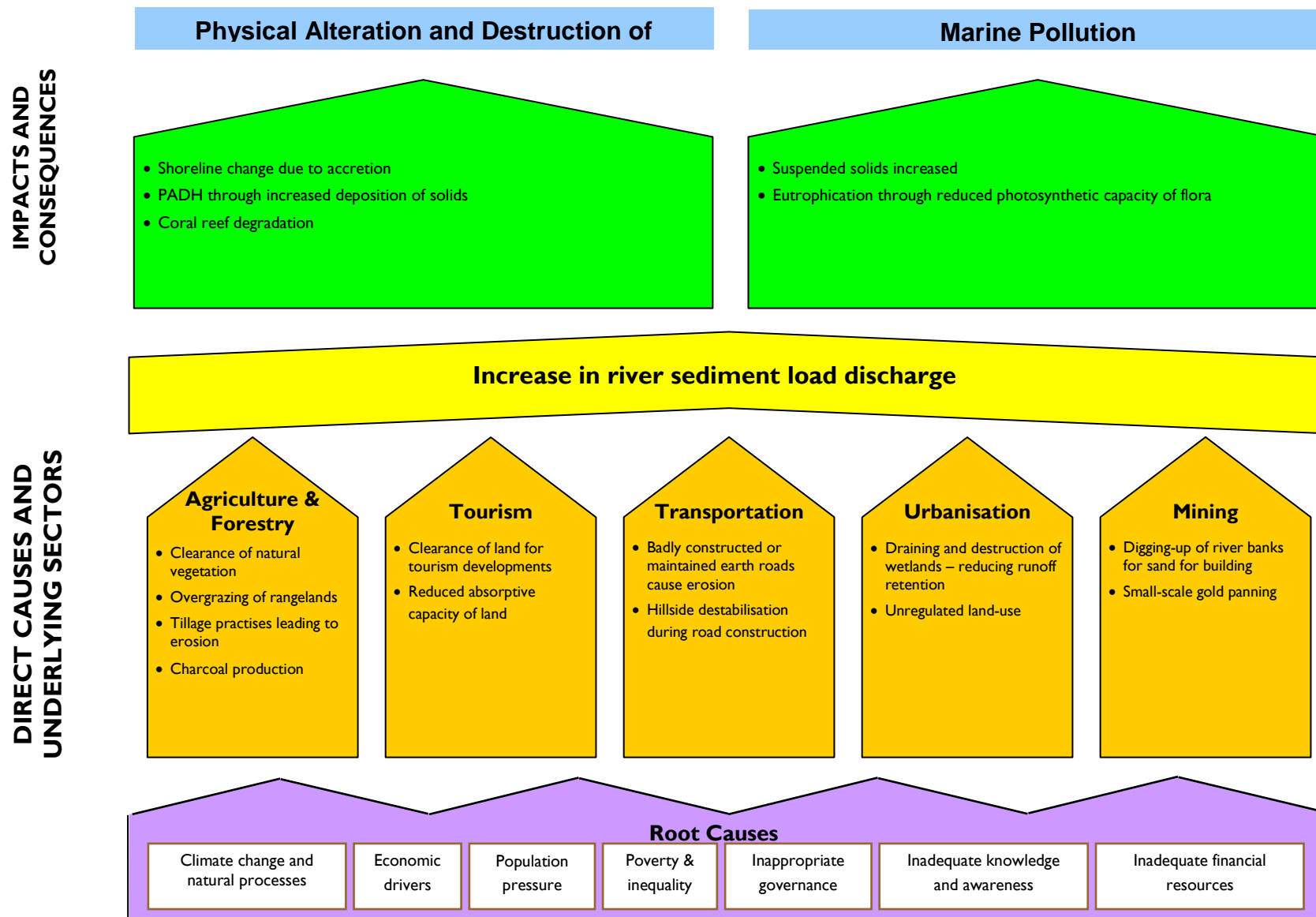


Figure 2-28 Causal chain analysis for the increase in river sediment loads in the WIO region

Table 2-18 Overview of the key problems, impacts and direct causes related to alteration of sediment loads in the main river basins of WIO region.

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSES
	Increase sediments	Decrease sediment		
Tana		X	Erosion of the Tana delta and the Ungwana Bay coastline leading to loss of biodiversity (NB. the sediment load has dropped from 12×10^6 tons.yr ⁻¹ to about 6.8×10^6 tons.yr ⁻¹ (Ongwenyi, 1979; 1983; Otieno and Maingi, 1983; Dunne, 1974; Dunne and Ongwenyi, 1976; Kitheka <i>et al.</i> , 2005). Reduced spatial extent of mangrove forests and associated impacts on coastal fisheries and biodiversity. Changes in the morphology of the Tana Delta and associated estuaries. Increased turbidity of water impacting on the productivity and fisheries of Ungwana Bay.	Damming of river for hydropower generation Direct abstraction (weirs) for irrigated agriculture
Athi-Sabaki	X		Siltation of Malindi Bay limiting the use of port facilities such as jetties. Deposition of sedimentary matter (and debris) on beaches thus reducing the aesthetic and recreational values of Malindi Bay beaches. Increased turbidity of water impacting on the productivity and fisheries of Malindi Bay. Degradation of the coral reefs sea-grass beds off the shoreline and in particular at Malindi Marine National Park (van Katwijk <i>et al.</i> , 1993; Fleitmann <i>et al.</i> , 2007; Snoussi <i>et al.</i> , 2004; Kitheka <i>et al.</i> , 2002b, 2003a & 2004). Accretion creating new grounds for colonisation by mangroves and other coastal vegetation.	Poor land use - increased cultivation and livestock grazing. Deforestation Rural roads and other constructions Urban development Hydrological variability
Pangani	X		Increased water turbidity that impacts on the productivity of the coastal waters.-excess phytoplankton concentrations (Akitanda and PBWO/IUCN, 2007). Changes in the morphology of the Pangani Estuary due to increased scouring of the channel.	Poor land use – increased cultivation Encroachment on river banks Deforestation Rural roads and other constructions Sand mining
Rufiji	---	---	No major changes in sediment loads at the mouth mentioned in the literature consulted	No major changes in sediment loads at the mouth mentioned in the literature consulted
Rovuma	---	---	No major changes in sediment loads at the mouth mentioned in the literature consulted	No major changes in sediment loads at the mouth mentioned in the literature consulted
Zambezi		X	Reduction of nutrients supply to Sofala Banks leading to reduced productivity and reduced fisheries.	Damming of river (to supply water for hydropower generation and irrigated

River Basin	KEY PROBLEM		COASTAL IMPACTS	DIRECT CAUSES
	Increase sediments	Decrease sediment		
			Erosion of the delta and the coastline leading to loss of valuable land and biodiversity. Loss of mangrove forests at the Zambezi delta	agriculture)
Pungwe		X	Increased coastal erosion leading to loss of land and valuable biodiversity.	Water transfer out of the basin Direct abstraction for agriculture and urban water supply Exotic forest plantations consuming more water
Limpopo	---	---	No sediment studies in the estuary have been carried out – increased erosion in the headwaters is countered by dams (Louw and Gichuki, 2003)	No sediment studies in the estuary have been carried out – increased erosion in the headwaters is countered by dams (Louw and Gichuki, 2003)
Incomati		X	Reduced fish and shrimp catch (Hoguane <i>et al.</i> , 2009; Van der Zaag and Carmo Vaz, 2003) See the summary prepared by Hoguane	Damming of river (TPTC, 2001) Landuse change – increased agriculture and other rural activities such as charcoal production Climate change
Maputo	---	---	No major changes mentioned in the literature consulted	No major changes in sediment loads at the mouth mentioned in the literature consulted
Thukela		X	The decrease in flood peaks from natural to present day conditions is estimated at 8% and the impact of the reduced sediment on the estuary is minimal (DWAF, 2004).	Damming of river; inter-basin transfers (DWAF, 2004a)
Betsiboka	X		Siltation of Mahajanga Bay hindering the shipment activities Confinement of the Bay leading it to shift into lagoon system (Autrand, 1997) Weak development of coral reef around (Maharavo, 2003) Red-coloured water up to few miles of the coast	Poor land use leading to the degradation of the basin Irregular intense rainfall
Tsiribihina	X		Siltation at the delta	Poor land use leading to the degradation of basin Irregular intense rainfall
Mangoky	X		Siltation of rice growing field Siltation of the delta	Poor land use leading to the degradation of basin and agriculture Irregular intense rainfall
Fiherenana	X		Subsurface flow due to accumulation of sand and silt in the river bed (Vasseur, 1997) Siltation affecting the Great reef barrier in the Toliara Bay	Poor land use, agriculture and rush mining

Key: Highly impacted basins are highlighted

1.5.5 Problem Area 4: Declines in living marine resources

The following section presents the impact and causal chain analysis for the top priority transboundary issues related to the declines in living marine resources. The top priority issues identified by the countries within MAC03 were as follows: Decline in populations of sharks and rays; decline in populations of large pelagic; decline in populations of small pelagic; decline in populations of reef and demersal fish; decline in populations of sea cucumbers; decline in populations of prawns and shrimp; decline in populations of lobster and excessive bycatch and discards. A summary of the impact chain analysis (environmental impacts, the ecosystem services affected by these impacts, and socio-economic impacts) and the causal chain analysis (direct causes, sectors and resource use practices, underlying social, legal and political causes, and root causes) is presented for each of these issues.

1.5.5.1 Decline in populations of sharks and rays

(a) Impact Chain Analysis

The most severe environmental impacts caused by the decline in populations of sharks and rays are: loss of marine biomass (and productivity) and trophic cascades (food-web impacts) associated with the removal of apex predators. Further severe impacts which are likely to seriously degrade parts of the ecosystem are: loss of biodiversity; enhanced risk of extinction of vulnerable or endangered species; reduction in genetic diversity of wild populations (meta-populations) and implications for their long term survival; reduction in genetic diversity of wild commercial stocks (e.g. reduction in proportion of fast growing and late spawning individuals); and trophic cascades associated with other keystone predators (e.g. *Lethrinids* and sea urchins). The ecosystem services likely to be affected by the environmental impacts resulting from the decline in populations of sharks and rays include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes)

Regulating Services: nutrient cycling and maintenance of fertility including soil formation.

Supporting/Habitat Services: biological control (e.g. seed dispersal, pest and disease control); maintenance of life cycles (including nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); spiritual experience; bequest, intrinsic and existence; information for cognitive development Knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of sharks and rays are: reduction in future use value (bequest, intrinsic and existence value) of ecosystems; and reduction in local biodiversity derivable benefits due to foreign commercial vessels. Other impacts which are likely to be serious socio-economic problems include: reduction in food availability/security (local) due to destructive/non-selective gear used by foreign industrial vessels; reduction in opportunities for recreation, tourism and leisure due to loss of biodiversity; reduction in income generating livelihoods (non-fisheries related e.g. tourism) due to foreign commercial vessels; and reduction in income generating livelihoods (fisheries related) due to unsustainable harvesting and destructive practices.

(b) Causal Chain Analysis

The most important direct causes of the decline in populations of sharks and rays are: Accidental capture / bycatch; Overexploitation/overfishing; Unsustainable harvesting (bad practices). Other direct causes include: Poaching/illegal fishing; Illegal, unregulated and unreported fishing; Recruitment overfishing and, Damage to nursery habitats. The main sector responsible for causing the decline in populations of sharks and rays is: fisheries (all sectors including mariculture). Other sectors that contribute towards damage to nursery habitats include urbanisation, tourism, agriculture and forestry; industry; mining; energy and environmental. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: (1) Overfishing occurs due to external market demand as a result of the cultural/ traditional consumption of shark fin soup. (2) Accidental capture occurs because there is no means of monitoring, control or surveillance as a result of inadequate enforcement of regulations and inappropriate regulations (don't know life cycle). (3) Shark finning takes place due to irresponsible fishing practices. This is underpinned by the political/financial need to allow foreign fleets to fish as a result of a conflicting decision-making framework. (4) Finning and dumping occurs due to the international market demand for fins and not bodies. As the price of fins is much higher and fishing vessels only have limited storage, dumping the bodies and only retaining the fins allows the vessels to increase their landings. There are limits and regulations in place in one country, but these are poorly defined and not well informed by research. Enforcement of these limits is also often inadequate as a result of corruption and insufficient funding for patrols. Lack of research is due to shortage of trained scientists, which is due to the difficulty in attracting students into science as a result of inadequate funding (low salaries) and failure in the basic education system (maths and science).

The lack of funding for enforcement and research occurs because there is lack of political understanding of the need for monitoring, research and development, but also because of the funding model used to pay for the research. The Treasury is not willing or able to commit more funds than the funding model allows. The funding model is based on licence fees and levies but these are set too low to leverage sufficient funds to cover the costs of research. There are no spare funds available as there are already insufficient tax revenues to cover social relief and other priorities. The Treasury is unwilling to increase fisheries licence fees (levies) as it fears that it will increase unemployment and place further demand on social welfare system.

The main Underlying Causes for the decline in populations of sharks and rays fish:

- Increased external market demands for (use of) natural resources/materials.
- Lack of alternative livelihoods for fishers.
- Lack of management plans.
- Lack of adequate and reliable data and research to support management.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Lack of education, training and awareness.
- Lack of awareness of longer term implications in Government.
- Weak national planning and regulatory frameworks.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.

The Root Causes of the decline in populations of sharks and rays are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, and [J] Personal attitude.

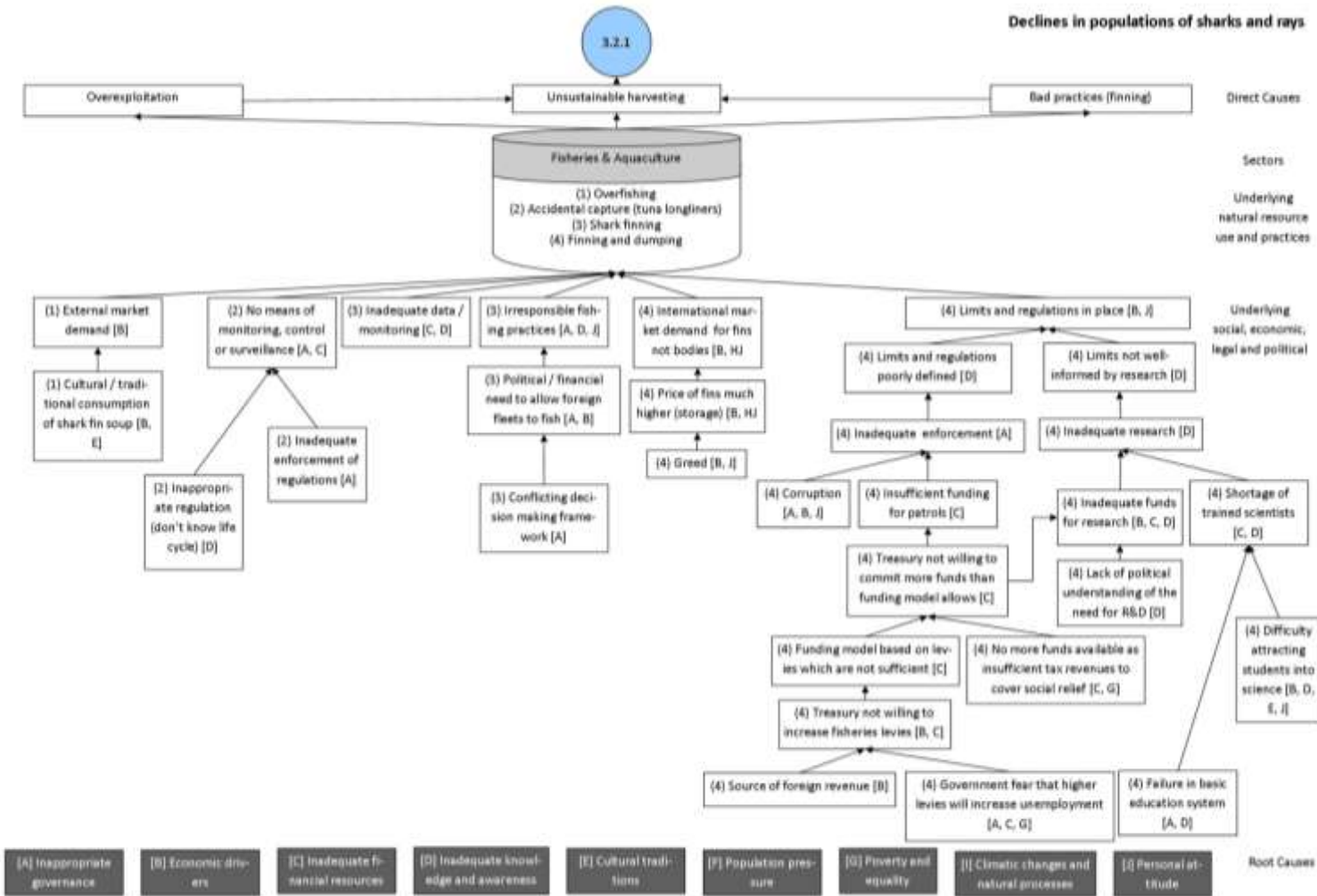


Figure 2-29: Causal Chain Analysis for the decline in populations of sharks and rays.

1.5.5.2 Decline in populations of large pelagics

(a) Impact Chain Analysis

The most severe environmental impact caused by the decline in populations of large pelagics is: loss of marine biomass (and productivity). Further severe impacts which are likely to seriously degrade parts of the ecosystem are: loss of biodiversity; trophic cascades (food-web impacts); trophic cascades (food-web impacts) associated with the removal of apex predators; trophic cascades associated with other keystone predators (e.g. *Lethrinids* and sea urchins). The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of large pelagics include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes)

Regulating Services: nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. seed dispersal, pest and disease control); maintenance of life cycles (including nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; opportunities for recreation, tourism and lifestyle; inspiration for culture, art and design (cultural heritage values); spiritual experience; bequest, intrinsic and existence; information for cognitive development Knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of large pelagics are: reduction in food availability/security (local) due to local overexploitation; reduction in opportunities for recreation, tourism and leisure due to loss of biodiversity; increased dependence on tourism due to a reduction in income generating fishery; increased unemployment; and conflicts between sectors (artisanal and industrial). These will all be serious socio-economic problems within 10 years if the issues are allowed to continue.

(b) Causal Chain Analysis

The most important direct cause of the decline in populations of large pelagics is recruitment overfishing. Other important direct causes are: Unsustainable harvesting; Poaching/illegal fishing; Illegal, unregulated and unreported fishing; Overexploitation/overfishing; and Changes in ocean circulation and seawater temperature. The sectors responsible for causing the decline in populations of large pelagics are: fisheries and aquaculture. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: Overfishing of large pelagics is driven by primarily by external market demand for fish. Fishing licenses are an important source of revenue for Governments within the WIO. For several countries in the region this may be their only means of generating revenues. (1) The use of non-selective gears and (2) drifting FADS, (4) fishing techniques and (6) recruitment overfishing take place due to the use of irresponsible fishing practices and lack of monitoring or surveillance capacity. Lack of monitoring programmes means there is no way of assessing stocks and setting catch quotas or limits, and lack of management of the fishery, which may be due to other political financial issues taking priority. Where there are monitoring programmes, scientific recommendations are not always considered, due to a conflicting decision-making framework. (3) Illegal, unreported and unregulated fishing takes place due to overcapacity in the fishery (see below), and the lack of capacity for monitoring, control and surveillance. (5) Overcapacity within the fishery results from lack of monitoring programmes to allow for stock assessments and regulation and management of catches. The above causes are also affected by high unemployment and lack of alternative sustainable livelihoods, due to lack of education and training.

Tourism: The expansion of tourist industry has increased the demand for (7) tourist sports fishing. The expansion of the recreational sports fishing has attracted foreign nationals to the region to set up new

businesses. There is also an increase in the number of fishers becoming skippers for sport fishing companies due to a decline in fisheries catches which has resulted in increased unemployment. There is also no means of monitoring or managing the fishery and lack of regulation of the catches is a major constraint.

Natural environmental variability and change: Changes in primary productivity which is linked to changes in ocean circulation and sea temperatures can also contribute towards a decline in populations of large pelagics due to reduced primary productivity.

The main Underlying Causes for the decline in populations of large pelagics:

- Increased external market demands for (use of) natural resources/materials.
- Lack of alternative livelihoods for fishers.
- Lack of management plans.
- Lack of adequate and reliable data to support management.
- Inadequate monitoring, control, surveillance and enforcement.
- Lack of education, training and awareness.
- Economic growth potential and employment opportunities.
- Failure to cost the environment.

Lack of transparency/wealth creation and corruption.

The Root Causes of the decline in populations of large pelagics are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

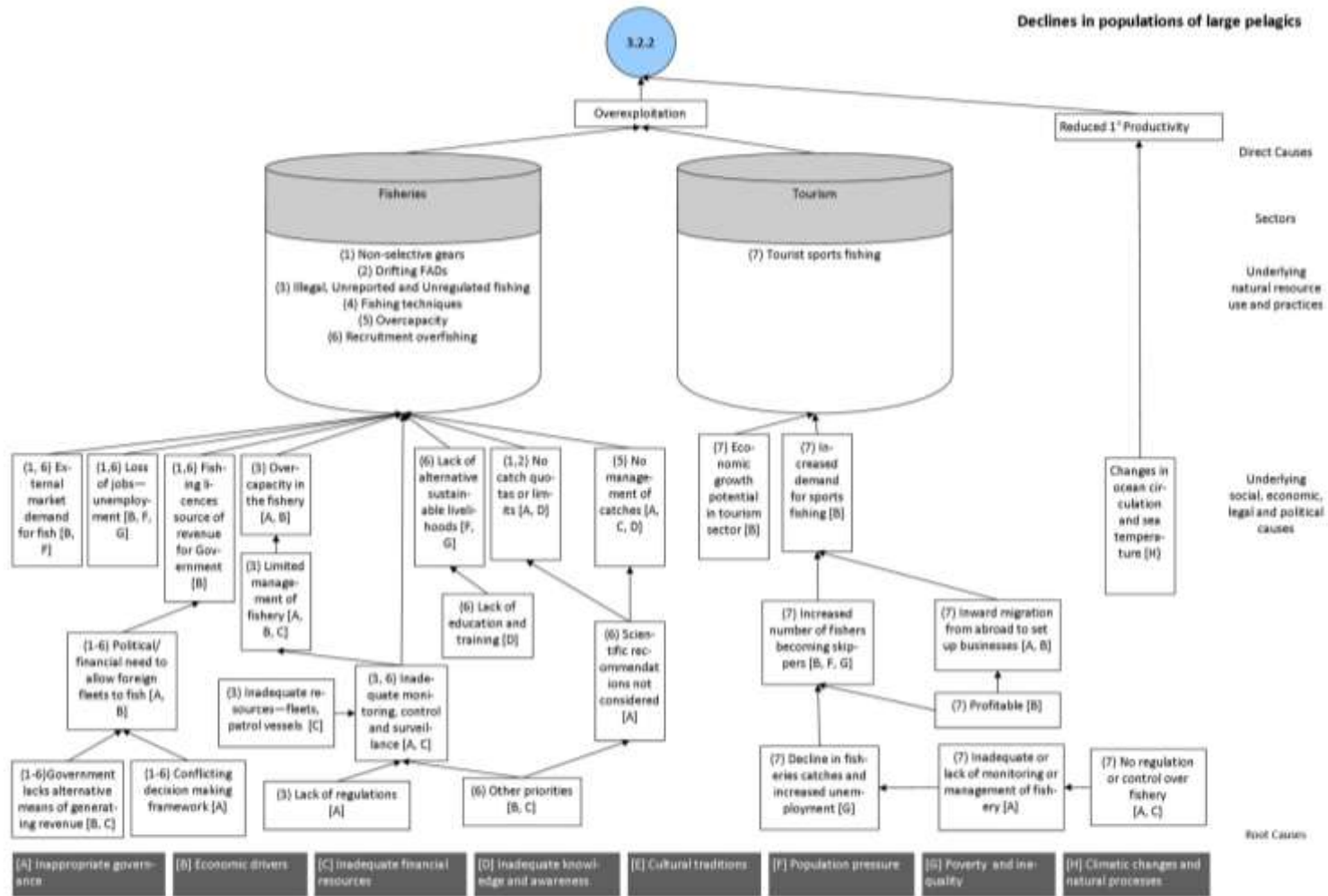


Figure 2-30: Causal Chain Analysis for the decline in populations of large pelagics.

1.5.5.3 Decline in populations of small pelagics

(a) Impact Chain Analysis

The most severe environmental impacts caused by the decline in populations of small pelagics are: loss of marine biomass (and productivity); reduction in food available to other species (food-web cascade) as a result of fishery; and reduction in food available to other species (food-web cascade) as a result of feed production. The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of small pelagics include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes).

Regulating Services: nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; inspiration for culture, art and design (cultural heritage values); spiritual experience; bequest, intrinsic and existence; information for cognitive development Knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of small pelagics are: increased malnutrition; increased food prices for local community; and increased migration leading to social issues. Other impacts which are likely to be serious socio-economic problems include: reduction in food availability / security due to trophic cascades; reduction in food availability/security due to local overexploitation; increased operational costs for fishers; increased cost of living for local community; decrease in value of catches as a result of “fishing down the food chain”; increased dependence on tourism due to a reduction in income generating fishery; unpredictable household incomes; increased unemployment; increased poverty; and social conflicts.

(b) Causal Chain Analysis

The most important direct cause of the decline in populations of small pelagics is changes in ocean circulation and seawater temperature. Other important direct causes are: Accidental capture/bycatch; Unsustainable harvesting; Overexploitation/overfishing; Recruitment overfishing; Destructive fishing methods; and Unemployment. The sectors responsible for causing the decline in populations of small pelagics are: fisheries (all sectors including mariculture), energy and environmental. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: There has been (1) an expansion of the small pelagic fisheries because of local market demand for inexpensive food fishes. The removal of large pelagics and the shift in the distribution patterns of other species; has also meant there is no choice but to shift the species targeted in order to meet local demand. Small pelagics are also highly accessible species which require comparatively little investment. It is a money-making livelihood and there is a lack of monitoring, control and surveillance and a lack of regulations resulting from a lack of knowledge.

Energy: The (2) damming of waterways to generate hydroelectric power alters the volume and timing of when freshwater enters the sea. This has influenced the nursery habitats and recruitment success of the small pelagic fisheries.

Natural environmental variability and change: The decline in populations of small pelagics has been affected by shifts in primary and secondary production, changes in freshwater input, seawater temperature and nutrients as a result of climate variability and change.

The main Underlying Causes for the decline in populations of small pelagics:

Increased internal market demands for (use of) natural resources/materials.

- Lack of alternative livelihoods for fishers.
- Lack of management plans.
- Lack of adequate and reliable data to support management.
- Inadequate monitoring, control, surveillance and enforcement.
- Open access resource/tragedy of commons (fishing down the food chain).
- Lack of education, training and awareness.
- Rural poverty, increased coastal migration and urbanization.

The Root Causes of the decline in populations of small pelagics are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

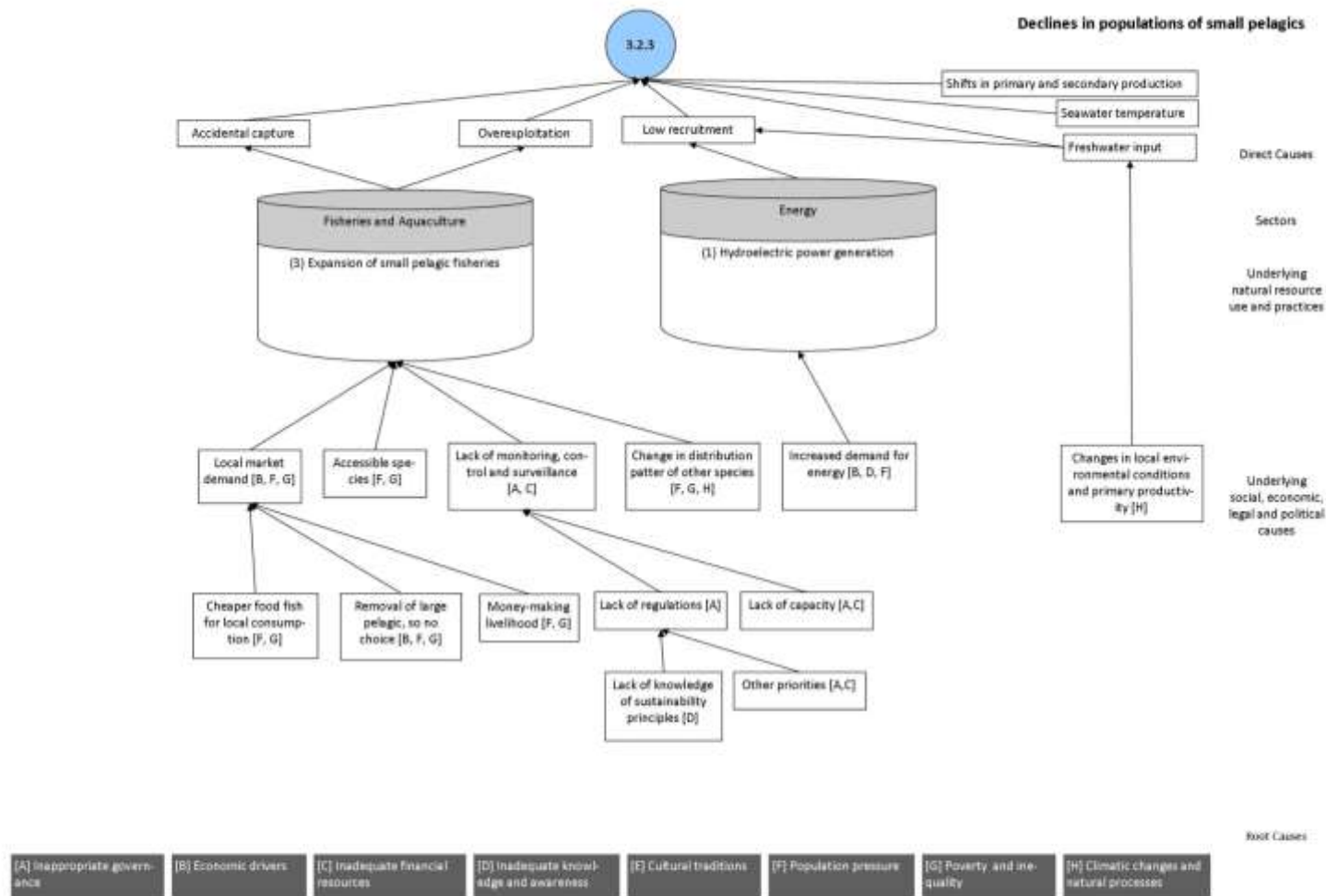


Figure 2.31: Causal Chain Analysis for the decline in populations of small pelagics.

1.5.5.4 Decline in populations of reef and demersal fish

(a) Impact Chain Analysis

The most severe environmental impacts caused by the decline in populations of reef and demersal fish are: loss of biodiversity; loss of marine biomass (and productivity); enhanced risk of extinction of vulnerable or endangered species; reduction in genetic diversity of wild populations (meta-populations) and implications for their long term survival; reduction in genetic diversity of wild commercial stocks (e.g. reduction in proportion of fast growing and late spawning individuals); trophic cascades (food-web impacts); trophic cascades (food-web impacts) associated with the removal of apex predators; trophic cascades associated with other keystone predators (e.g. *Lethrinids* and sea urchins); decline in ornamental species; change in community composition (increase / decrease in herbivores); increased illegal fishing and more intense pressure in protected areas; shifts in benthic cover / composition as the result of the loss of the species / group; reduction in food available to other species (food-web cascade) as a result of fishery; physical impacts on the seabed from trawls and other mobile gear (e.g. dredges); increased use of poisons, and associated impacts on nursery habitats and coral reefs, seagrass beds and other shallow habitats; increased use of dynamite fishing impacts on coral reefs; trampling impacts; and reduction in food available to other species (food-web cascade) as a result of feed production. The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of reef and demersal fish include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);

Regulating Services: natural hazard regulation (e.g. storm protection and flood prevention); erosion regulation / prevention; nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. Seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; inspiration for culture, art and design (cultural heritage values); spiritual experience; bequest, intrinsic and existence; information for cognitive development Knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of reef and demersal fish are: increased malnutrition; reduction in food availability/security due to trophic cascades; reduction in food availability/security (local) due to local overexploitation; reduction in food availability/food security (local) due to destructive / non-selective gear by local vessels; increased food prices for local community; and reduction in income generating livelihoods (fisheries related) due to unsustainable harvesting and destructive practices. Other impacts which will be a serious socio-economic problem include: increased operational costs for fishers; increased cost of living for local community; increased migration (people) leading to social issues; increased non-compliance (illegal fishing); change in gear and increased use of destructive fishing practices; reduction in opportunities for recreation, tourism and leisure due to loss of biodiversity; reduction in aesthetics 'landscape/seascape' value of the natural environment; reduction in future use value (bequest, intrinsic and existence value) of ecosystems; reduction in foreign earnings due to loss of biodiversity; decrease in value of catches as a result of "fishing down the food chain"; increased vulnerability decreased resilience; impacts upon traditional resource use patterns; livelihood impacts due to theft and vandalism; increased dependence on tourism due to a reduction in income generating fishery; unpredictable household incomes; loss of cultural heritage; increased unemployment; increased poverty; social conflicts; conflicts between sectors (artisanal and industrial); loss of traditional management practices; and pride - saltwater in the veins.

(b) Causal Chain Analysis

The most important direct causes of the decline in populations of reef and demersal fish are: unsustainable harvesting; overexploitation/overfishing; recruitment overfishing; destructive fishing

methods; physical habitat damage, degradation and loss; damage to nursery habitats; coral bleaching; sedimentation; alteration of river flows, changes in salinity and freshwater inflows; and unemployment. Other important direct causes are accidental capture/bycatch and poor water quality. The sectors responsible for causing the decline in populations of reef and demersal fish include: fisheries (all sectors including mariculture). Physical habitat damage, degradation and loss and damage to nursery grounds are caused by urbanisation, tourism, agriculture and forestry, mining, fisheries (all sectors except for recreational and sport), energy and environmental. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: (1) Overexploitation of ornamental species occurs as a result of the international market demand. There is a lack of regulation of the fishery, and limited control on the export of species. The use of (2) destructive fishing methods, (3) non-selective gear, (4) illegal fishing by spears (5) overcapacity and (6) over fishing occurs due to the preference for reef fish and an increase in local demand for seafood, as a result of migration to the coast. Overcapacity occurs because it is an open access fishery which can provide a money making livelihood. There has been a decline in stocks due to the increased use of destructive/ illegal fishing methods, which also cause habitat damage further contributing to the loss of certain species. There is lack of compliance with regulations as a result of inadequate knowledge and awareness and conflicts between resources users. There is lack of monitoring, control and surveillance due to a lack of fisheries management capacity and lack of data on species/stocks. There is also weak enforcement due to rent-seeking behaviour (bribery).

(7) Recruitment fishing occurs due to overcapacity and overfishing, in both artisanal and commercial fishing sectors. Within the commercial sector, there is continued fishing of heavily depleted stocks as fishers use political pressure to maintain/continue access. There is a culture of entitlement and blame shifting resulting from greed. Furthermore, small-scale fishers use recreational permits to allow them to fish without paying taxes, and then sell the fish (which is illegal) as it is a money making livelihood. (8) Bycatch from inshore trawl fisheries results from the lack of technology (to avoid bycatch) and due to the fact that the trawl fishery grounds overlap with those of line fish (reef fish). (9) Opportunistic targeting by trawlers occurs if trawl catches are low, then fishers will target line fish as these opportunistic catches are profitable, and due to the fact that the trawl fishery grounds overlap. There is also often a lack of awareness and knowledge, no monitoring, control and surveillance, no management plans and no enforcement and poor compliance.

Urbanisation: (10) Unplanned settlements and inappropriate developments (e.g. in estuaries and near river mouths) cause habitat damage in nursery and spawning habitats. (11) The disposal of un- or under treated wastewater (soakaways, septic tanks) occurs as a result of outdated or lack of wastewater infrastructure. The increase in unplanned developments also occurs as a result of migration to the coast caused by rural poverty and illegal immigration due to regional instability. There is weak strategic planning and a lack of implementation of ICZM plans, due mainly to failure to cost the environment.

Tourism: (12) Construction of holiday homes and poorly planned tourism developments (e.g. in estuaries and near river mouths) cause habitat damage in nursery and spawning habitats. (13) Impacts from recreational activities (trampling, water sports, and boat anchors) occur as a result of the expansion of the tourism sector. (14) Illegal fishing by recreational divers takes place due to market demand as well as lack of enforcement. (15) Poor disposal of wastewater occurs due to poor municipal management/ infrastructure as a result of the lack of investment and maintenance caused by a failure to cost the environment. There is a general lack of awareness and knowledge about the potential impacts of tourism development on reef fisheries and the ICZM plan has not been implemented.

Mining: (16) Coral mining for lime occurs as a result of an increased demand for building materials due to migration to the coast and lack of affordable alternatives. (17) Mining in estuaries occurs due to high market demand for sand and minerals and lack of control and enforcement.

Agriculture and Forestry: There are various resources use practices within this sector that contribute towards a decline in reef and demersal fish associated with a reduction in water quality. (18) Dam building occurs due to the increased demand for water to supply the expanding agricultural sector. (19)

The use of agricultural chemicals takes place due meet the increasing demand for food, and due to inadequate or lack of regulations, as well as a lack of awareness and knowledge.

(20) Poor land-use practices, which increase soil erosion and sediment loads in rivers, occur as a result of failure to protect the watersheds, inadequate land use planning and the fact that ICZM plans are not implemented.(21) Low productivity soils and poorly adapted crops result from poor knowledge of farming, which is exacerbated by lack of extension officers. (22) The introduction of non-native trees and plants results in a reduction in water quality and quantity.

Industry: (23) Discharge of untreated industrial effluent occurs due to poor processing of industrial effluents as a result of the lack of investment in wastewater treatment and disposal infrastructure.

Natural environmental variability and change: The decline in populations of reef and demersal fish is affected by ocean acidification, coral bleaching and sea level rise.

The main Underlying Causes of the decline in populations of reef and demersal fish:

- Open access resource / Tragedy of Commons.
- Increased internal market demands for (use of) natural resources/materials.
- Increased external market demands for (use of) natural resources/materials.
- Lack of alternative sustainable livelihoods for fishers.
- Inadequate monitoring, control, surveillance and enforcement.
- Low compliance with existing regulations.
- Lack of management plans.
- Lack of adequate and reliable data to support management.
- Rural poverty, increased coastal migration and urbanization.
- Lack of education, training and awareness.
- Inadequate investment in infrastructure.
- Lack of ICZM plan / ICZM plan not implemented
- Political pressure for continued access to despite declining catches.
- Limited knowledge, lack of technology (to avoid/manage bycatch) and use of best practices
- Wealth creation and corruption.

The Root Causes of the decline in populations of reef and demersal fish are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions,[F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

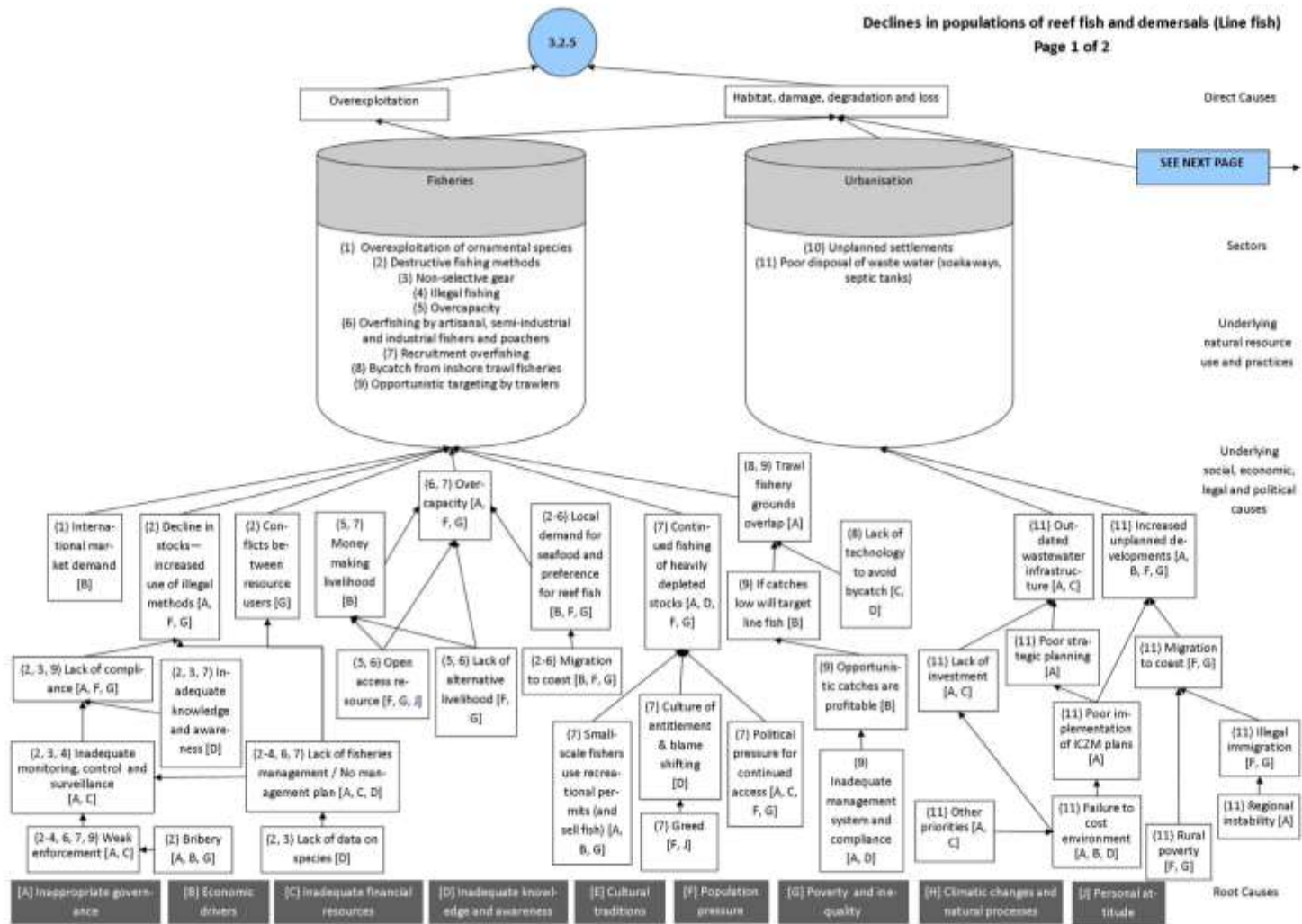


Figure 2-31a: Causal Chain Analysis for the decline in populations of reef and demersal fish (part 1 of 2)

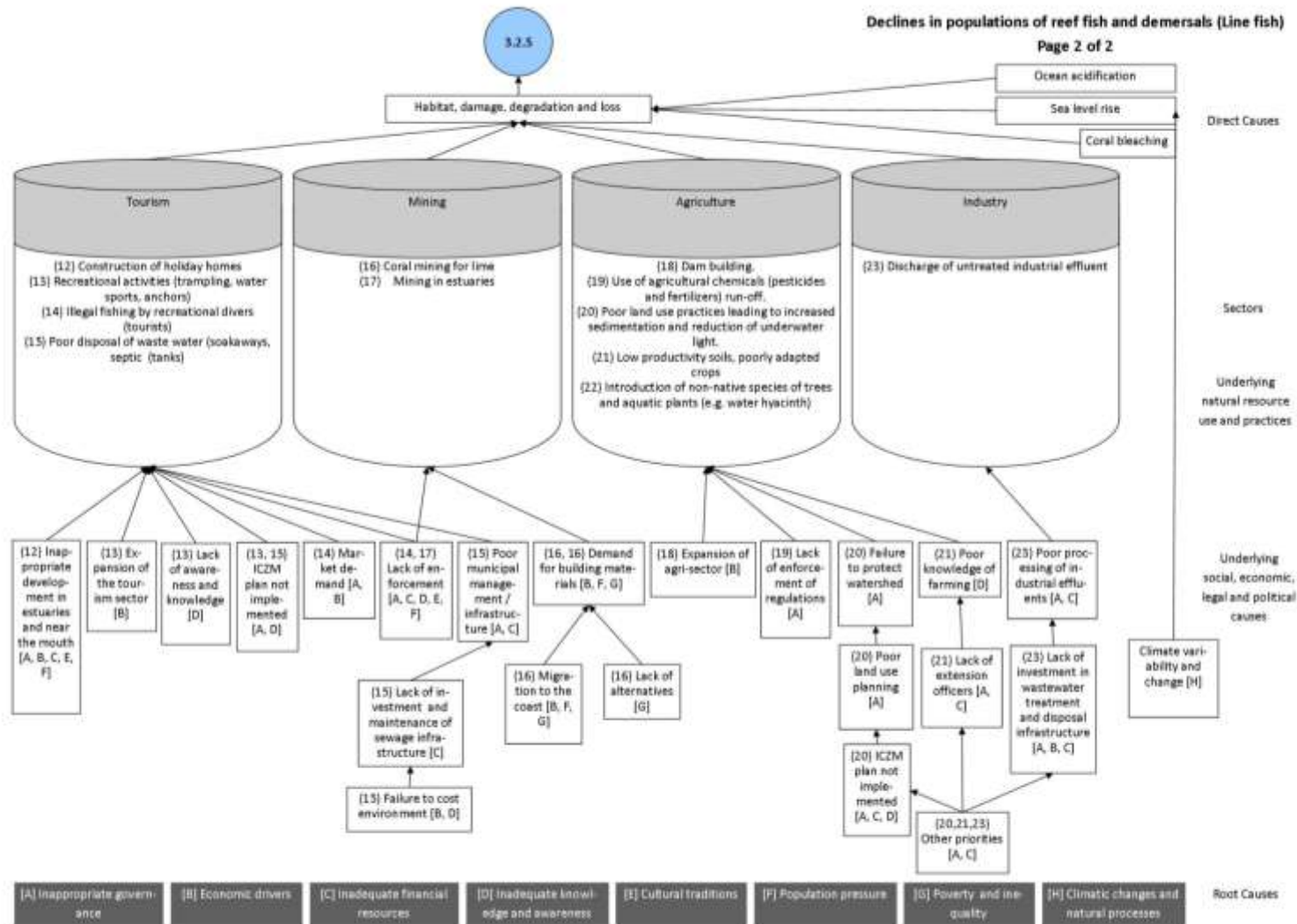


Figure 2-31b: Causal Chain Analysis for the decline in populations of reef and demersal fish (part 2 of 2).

1.5.5.5 Decline in populations of sea cucumbers

(a) Impact Chain Analysis

The most severe environmental impact caused by the decline in populations of sea cucumbers is: increased illegal fishing and more intense pressure in protected areas. Further severe impacts which are likely to seriously degrade parts of the ecosystem are: reduction in genetic diversity of wild populations (meta-populations) and implications for their long term survival; reduction in genetic diversity of wild commercial stocks (e.g. reduction in proportion of fast growing and late spawning individuals); and impacts upon sedimentary processes (accretion and bioerosion). The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of sea cucumbers include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);

Regulating Services: natural hazard regulation (e.g. storm protection and flood prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection); photosynthesis and primary production; secondary production.

Cultural and Amenity Services: aesthetics information; bequest, intrinsic and existence; information for cognitive development; knowledge systems and education values and; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of sea cucumbers are: increased operational costs for fishers; increased cost of living for the local community; and increased migration (people) leading to social issues. Other impacts which will be moderate socio-economic problems include: abuse of office by government officers; increased non-compliance (illegal fishing); increased rent-seeking behaviour (bribery) by government officers; reduction in income generating livelihoods (fisheries related) due to unsustainable harvesting and destructive practices; reduction in future use value (bequest, intrinsic and existence value) of ecosystems; reduction in foreign earnings due to loss of biodiversity; increased vulnerability decreased resilience; impacts upon traditional resource use patterns; unpredictable household incomes; increase unemployment; increased poverty; and social conflicts.

(c) Causal Chain Analysis

The important direct causes of decline in populations of sea cucumbers are overexploitation/overfishing, unsustainable harvesting, poaching/illegal fishing, illegal, unregulated and unreported fishing and other important direct causes are recruitment overfishing and habitat damage, degradation and loss. The sector responsible for causing the decline in populations of sea cucumbers is: fisheries (all sectors including mariculture). Physical habitat damage, degradation and loss is caused by urbanisation, tourism, agriculture and forestry, mining, fisheries (all sectors except for recreational and sport), energy and environmental. The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: Expansion of the sea cucumber (bêche-de-mer) industry and (1) overexploitation has occurred due to the international market demand and the internal restaurant trade (Chinese). This is often an open access fishery with high money-making potential. High levels of unemployment and poverty in the fisheries sector due to a reduction in catches of other target stocks, and a lack of alternative income-generating livelihoods for fishers, makes the bêche-de-mer fishery an attractive option. There is also lack of or inadequate regulation, and monitoring, control and surveillance. There is also a self-funding drug-dependent culture, whereby money made from sea cucumber fishing is used to purchase drugs and drugs are used to improve catches. (2) Illegal fishing takes place due to the external and internal market demand and unemployment and poverty in the fisheries sector. (3) Dangerous diving takes place because it has money-making potential and due to lack of control.

The main Underlying Causes of the decline in catches of sea cucumbers:

- Open access resource/Tragedy of Commons.
- Increased external market demands for (use of) natural resources/materials.
- Lack of alternative livelihoods for fishers.
- Lack of management plans.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Low compliance with existing regulations.
- Lack of adequate and reliable data to support management.
- Wealth creation and corruption.
- Weak national planning and regulatory frameworks.

Root causes of the decline in populations of sea cucumbers are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

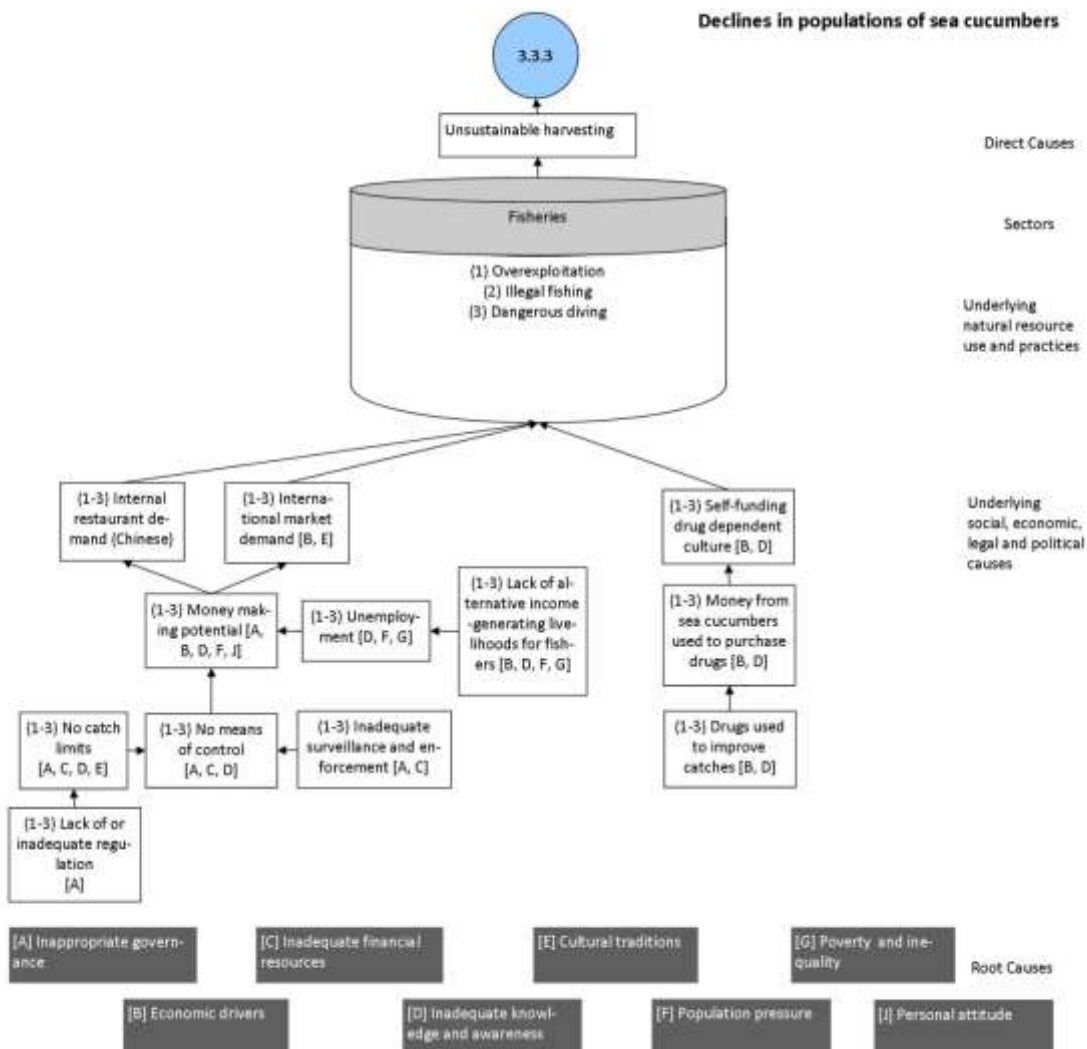


Figure 2-32: Causal Chain Analysis for the decline in populations of sea cucumber.

1.5.5.6 Decline in populations of prawns and shrimp

(a) Impact Chain Analysis

The most severe environmental impact caused by the decline in populations of prawns and shrimp is: physical impacts on the seabed from trawls and other mobile gear (e.g. dredges). Other medium impacts which are likely to moderately degrade part of the ecosystem include: loss of marine biomass (and productivity); and reduction in food available to other species (food-web cascade) as a result of fishery. The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of prawns and shrimp include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);

Regulating Services: natural hazard regulation (e.g. storm protection and flood prevention); erosion regulation/prevention; nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. Seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; information for cognitive development; knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by the decline in populations of prawns and shrimp are: increased malnutrition; reduction in food availability/food security (local) due to destructive/non-selective gear by local vessels; change in gear and increased use of destructive fishing practices; and change in land-use and loss of critical habitats (e.g. mangrove). Other impacts which will be a serious socio-economic problem include: reduction in food availability/security (local) due to local overexploitation; reduction in food availability / security (local) due to destructive / non-selective gear used by foreign industrial vessels; increased food prices for local community; increased operational costs for fishers; increased cost of living for local community; increased migration (people) leading to social issues; conflicts between sectors (artisanal and industrial); and increased (dependence on) mariculture.

(b) Causal Chain Analysis

The most important direct causes of the decline in populations of prawns and shrimp are: unsustainable harvesting; overexploitation/overfishing; alteration of river flows, changes in salinity and freshwater inflows. A further important direct cause is physical habitat damage, degradation and loss. The sectors responsible for causing the decline in populations of prawns and shrimp are: fisheries (all sectors including mariculture), urbanisation, tourism, agriculture and forestry, mining and environmental. Physical habitat damage, degradation and loss is caused by urbanisation, tourism, agriculture and forestry, mining, fisheries (all sectors except for recreational and sport), energy and environmental.

Fisheries and Aquaculture: (1) Overfishing and (2) overexploitation of juveniles takes place as a result of a high market demand. There is overcapacity in the fishery due to increasing unemployment and lack of alternatives forms of employment for fishers. There is an increase in the traditional fishing, as there are no licence fees or taxes to pay and because it requires minimum investment. All fisheries results in post harvest losses due to lack of access to adequate facilities. There has also been overcapitalisation of the commercial fishery and high investment in gear/boats. There is also little gear choice due to lack of knowledge. (3) Physical damage from bad fishing practices (trawling) occurs due to the market demand and profit drive. The overcapitalisation in the fishery and competition with aquaculture, results in the continued use of unsustainable practices. This situation is further aggravated by inefficient boats and increased fuel prices. All of the above are because the fishery is not regulated or managed; there is lack of monitoring, control and surveillance and no management plan. There is no enforcement and illegal

fishing increases with the decline in catches. Better technology has increased effort and there is no respect for good environmental practices.

Agriculture and Forestry: (4) Abstraction of water for irrigation and other purposes occurs due to the expansion of the commercial agricultural sector linked to other economic priorities. There is poor planning and a lack of access to technology due to lack of technical and financial capacity. (5) Clearing of mangroves for timber and fuelwood occurs due to high demand for wood products for building and fuel as a result of lack of alternative fuel sources and construction materials.

Mining: (6) Coral mining for lime production takes place due to the demand for building materials and lack of affordable alternatives.

Industry: (7) Clearing of mangroves for salt production occurs due to the high demand for salt and commercial profits and lack of alternative livelihoods. There is also poor planning.

Urbanisation: (8) Clearing of mangroves/deforestation takes place due to the high demand for timber for construction and fuel.

Energy: (9) The obstruction or diversion of natural river flows for hydroelectric power generation, and shifts in the salinity patterns within the nearshore environment and estuaries can alter the juvenile/nursery grounds for young prawn and shrimp.

Natural environmental variability and change: The decline in populations of prawns and shrimp can occur due to lowered recruitment linked to changes in rainfall patterns as a result of climate variability and change.

The main Underlying Causes of the decline in populations of prawn and shrimp:

- Increased external market demands for (use of) natural resources/materials.
- Lack of alternative livelihoods for fishers.
- Lack of monitoring, control, surveillance and enforcement capacity.
- Lack of management plans.
- Lack of adequate and reliable data to support management.
- Lack of capacity for Environmental and Social Impact Assessment (ESIA).
- Limited knowledge, lack of technology and understanding of best environmental practice.
- Lack of education, training and awareness.

The Root Causes of the decline in populations of prawns and shrimp are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality, [H] Climate change and natural processes and [J] Personal attitude.

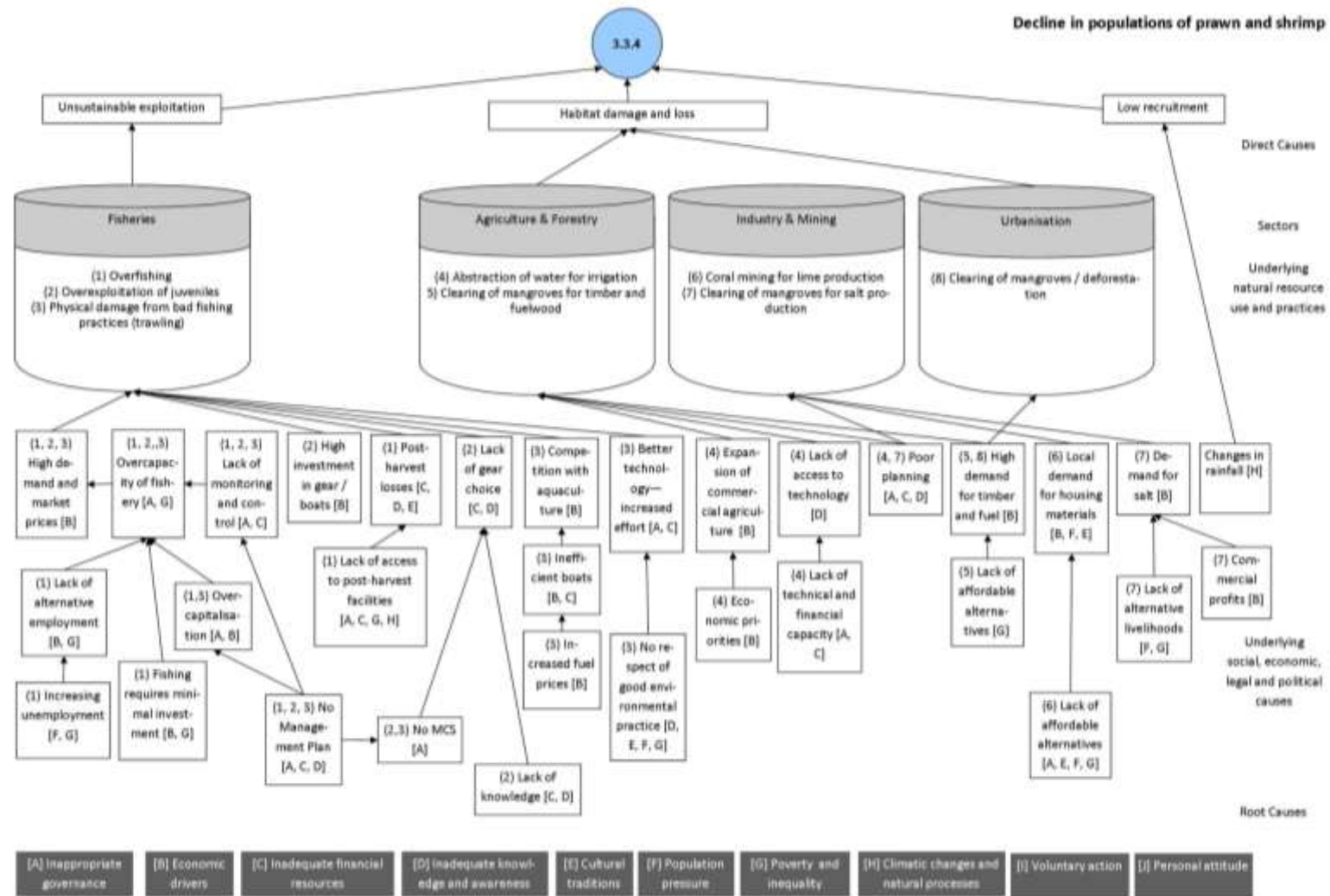


Figure 2-32: Causal Chain Analysis for the decline in populations of prawn and shrimp.

1.5.5.7 Decline in populations of lobster

(a) Impact Chain Analysis

The most severe environmental impacts caused by the decline in populations of lobster are: increased illegal fishing and more intense pressure in protected areas; and shifts in benthic cover/composition as the result of the loss of the species / group. A further medium impact which is likely to moderately degrade part of the ecosystem is: loss of marine biomass (and productivity). The ecosystem services likely to be affected by the environmental impacts resulting from a decline in populations of lobster include:

Provision Services: food (fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);

Regulating Services: nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) and; secondary production;

Cultural and Amenity Services: aesthetics information; inspiration for culture, art and design (cultural heritage values); bequest, intrinsic and existence; information for cognitive development; knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impact caused by the decline in populations of lobster is: change in land-use and loss of critical habitats (e.g. mangrove). Other impacts which will be a serious socio-economic problem include: increased operational costs for fishers; increased cost of living for local community; increased migration (people) leading to social issues; increased non-compliance (illegal fishing); and increased rent-seeking behaviour (bribery) by government officers.

(b) Causal Chain Analysis

The most important direct causes of the decline in populations of lobster are: Accidental capture/ bycatch and overexploitation/overfishing. Other important direct causes are: unsustainable harvesting and illegal unregulated and unreported fishing. The sector responsible for causing the decline in populations of lobster is: fisheries (all sectors including mariculture). The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: Declines in the (1) artisanal fishery as a result of: (i) non-selective gear (tangle nets traps); (ii) diving (SCUBA and snorkelling); (iii) collection of egg-bearing females; and (iv) collection of undersized individuals occur due to it being an open access fishery (no licences and no regulations) as a result of the 'Tragedy of the Commons' and greed. There is also lack of education and awareness (although the fishers are aware that the practices they use will cause a further decline in the fishery). While catches have declined and the number of export companies is now less, the fishery is still profitable due to high market prices. There is no law enforcement due to lack of management (collapse of government) there is also lack of capacity for management (financial or human) and lack of technical training for the new generation which occur as a result of other priorities.

Declines in the (2) industrial fishery as a result of: (i) trawl nets (big and small mesh sizes); (ii) collection of egg-bearing females; and (iii) collection of undersized individuals occur due to it being an open access fishery. Fishing licences are not paid for as there is no administrative authority to collect the fees due to lack of management. In addition, irresponsible fishing companies get away with fishing illegally as the EEZ is not declared and there are no legal boundaries.

The Underlying Causes of the decline in populations of lobster:

- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Lack of alternative livelihoods for fishers.

- Lack of capacity for monitoring, control, surveillance and enforcement.
- Lack of management plans.
- Lack of adequate and reliable data to support management.
- Lack of knowledge, technology and use of best practice.
- Lack of capacity for management.
- Lack of education, training and awareness.
- Weak national planning and regulatory frameworks.

The Root Causes of the decline in populations of lobster are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources and [D] Inadequate knowledge and awareness.

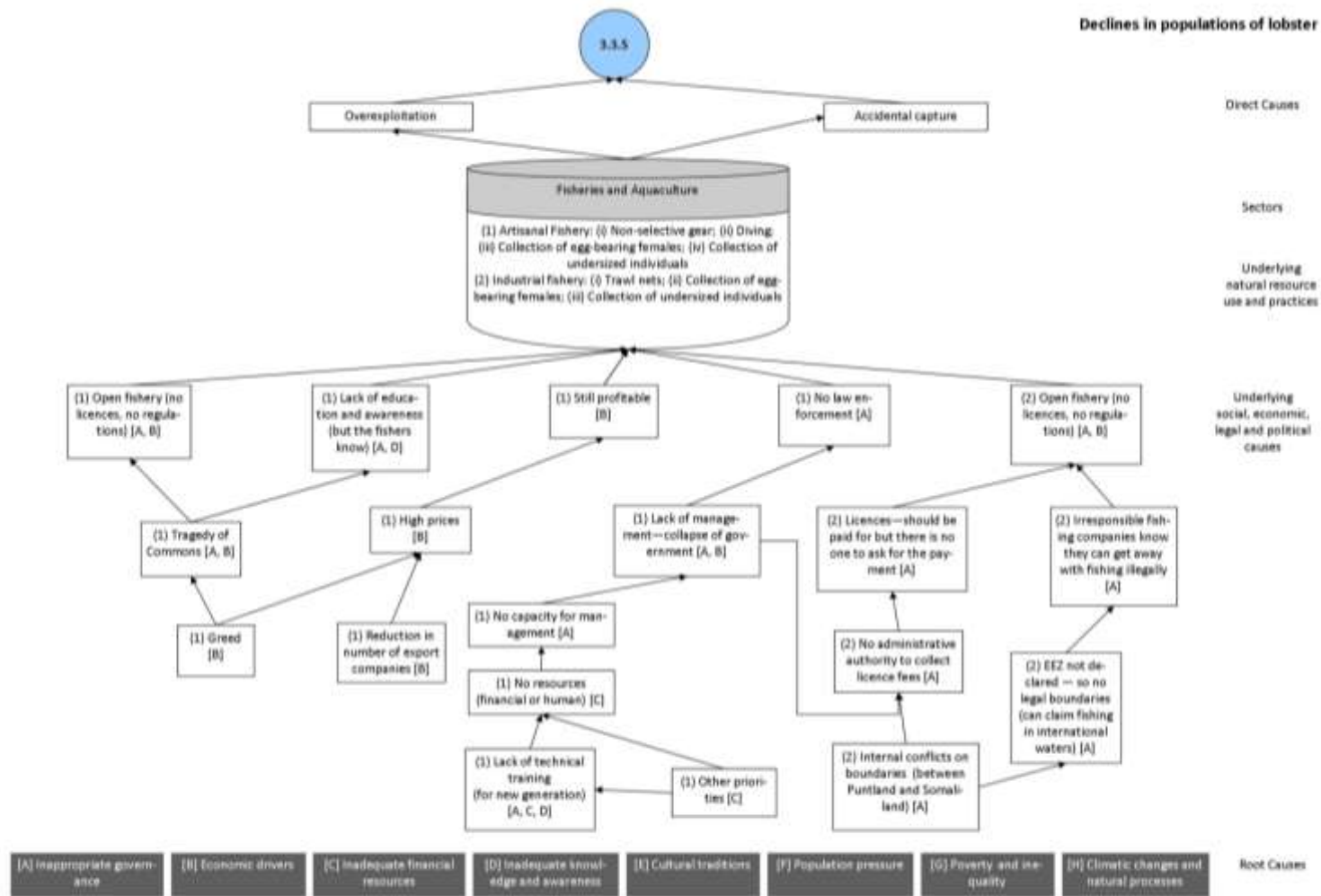


Figure 2.33: Causal Chain Analysis for the decline in populations of lobster.

1.5.5.8 Excessive bycatch and discards

(a) Impact Analysis

The most severe environmental impact caused by excessive bycatch and discards is: loss of biodiversity. This is likely to destroy or eliminate part of the ecosystem within 10 years if the issue is allowed to continue. Other severe impacts which are likely to seriously degrade part of the ecosystem are: loss of marine biomass (and productivity); enhanced risk of extinction of vulnerable or endangered species; reduction in genetic diversity of wild populations (meta-populations) and implications for their long term survival; reduction in genetic diversity of wild commercial stocks (e.g. reduction in proportion of fast growing and late spawning individuals); trophic cascades (food-web impacts); trophic cascades (food-web impacts) associated with the removal of apex predators; trophic cascades associated with other keystone predators (e.g. *Lethrinids* and sea urchins); changes in nutrient cycling pathways; reduction in the control of nuisance species (e.g. Turtles - Jellyfish); reduction in food available to other species (food-web cascade) as a result of fishery; physical impacts on the seabed from trawls and other mobile gear (e.g. dredges); and increased use of dynamite fishing impacts on coral reefs. The ecosystem services likely to be affected by the environmental impacts resulting from excessive bycatch and discards include:

Provision Services: food (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);

Regulating Services: nutrient cycling and maintenance of fertility.

Supporting/Habitat Services: biological control (e.g. Seed dispersal, pest and disease control); maintenance of life cycles (incl. nursery, spawning, breeding, feeding); maintenance of genetic diversity (gene pool protection) ; photosynthesis and primary production; secondary production;

Cultural and Amenity Services: aesthetics information; inspiration for culture, art and design (cultural heritage values); spiritual experience; bequest, intrinsic and existence; information for cognitive development Knowledge systems and education values; social relations and; sense of place.

The most severe socio-economic impacts caused by excessive bycatch and discards are: increased malnutrition; reduction in food availability/security (local) due to local overexploitation; reduction in food availability/food security (local) due to destructive/non-selective gear by local vessels; reduction in food availability/security (local) due to destructive/non-selective gear used by foreign industrial vessels; and increased non-compliance (illegal fishing). Other impacts which will be a serious socio-economic problem include: reduction in food availability/security due to trophic cascades; increased food prices for local community; increased operational costs for fishers; increased cost of living for local community; increased migration (people) leading to social issues; increased rent-seeking behaviour (bribery) by government officers; change in gear and increased use of destructive fishing practices; reduction in future use value (bequest, intrinsic and existence value) of ecosystems; decrease in value of catches as a result of "fishing down the food chain"; and conflicts between sectors (artisanal and industrial).

(b) Causal Chain Analysis

The cause of excessive bycatch and discards is mainly accidental capture. The sector responsible for causing excessive bycatch and discards is: fisheries (all sectors except for recreational and sports). The resource use practices and underlying (social, legal and political) causes are as follows:

Fisheries and Aquaculture: Increased bycatch occurs due to (i) increased fishing pressure; (ii) use of non-selective gears; (iii) illegal gears; (iv) low efficiency of BRDs; (v) limited use of exclusion devices; (vi) inappropriate gear (FADs); (vii) Illegal, Unregulated and Unreported fishing; and (viii) increased use of technology occurs due to the international and local market demand for some species and lack of market/low price for other species as a result of selection pressure and consumer demand. There is lack of gear regulations (for selective gear) and a lack of monitoring, control and surveillance. There is lack of compliance due to weak enforcement as a result of poor legislation and framework and a lack of fisheries management plans for some species. There is overcapitalisation of the fisheries leading to increased

competition as a result of conflicting policies (employment focus v sustainability) and political drivers due to the foreign exchange. There is also a cultural attitude towards openness to exploit the sea.

Main Underlying Causes of excessive bycatch and discards:

- Increased external market demands for (use of) natural resources/materials.
- Increased internal market demands for (use of) natural resources/materials.
- Lack of management plans.
- Lack of capacity for monitoring, control, surveillance and enforcement.
- Lack of knowledge, technology and use of best practice.
- Weak national planning and regulatory frameworks.

The Root Causes of excessive bycatch and discards are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality and [J] Personal attitude.

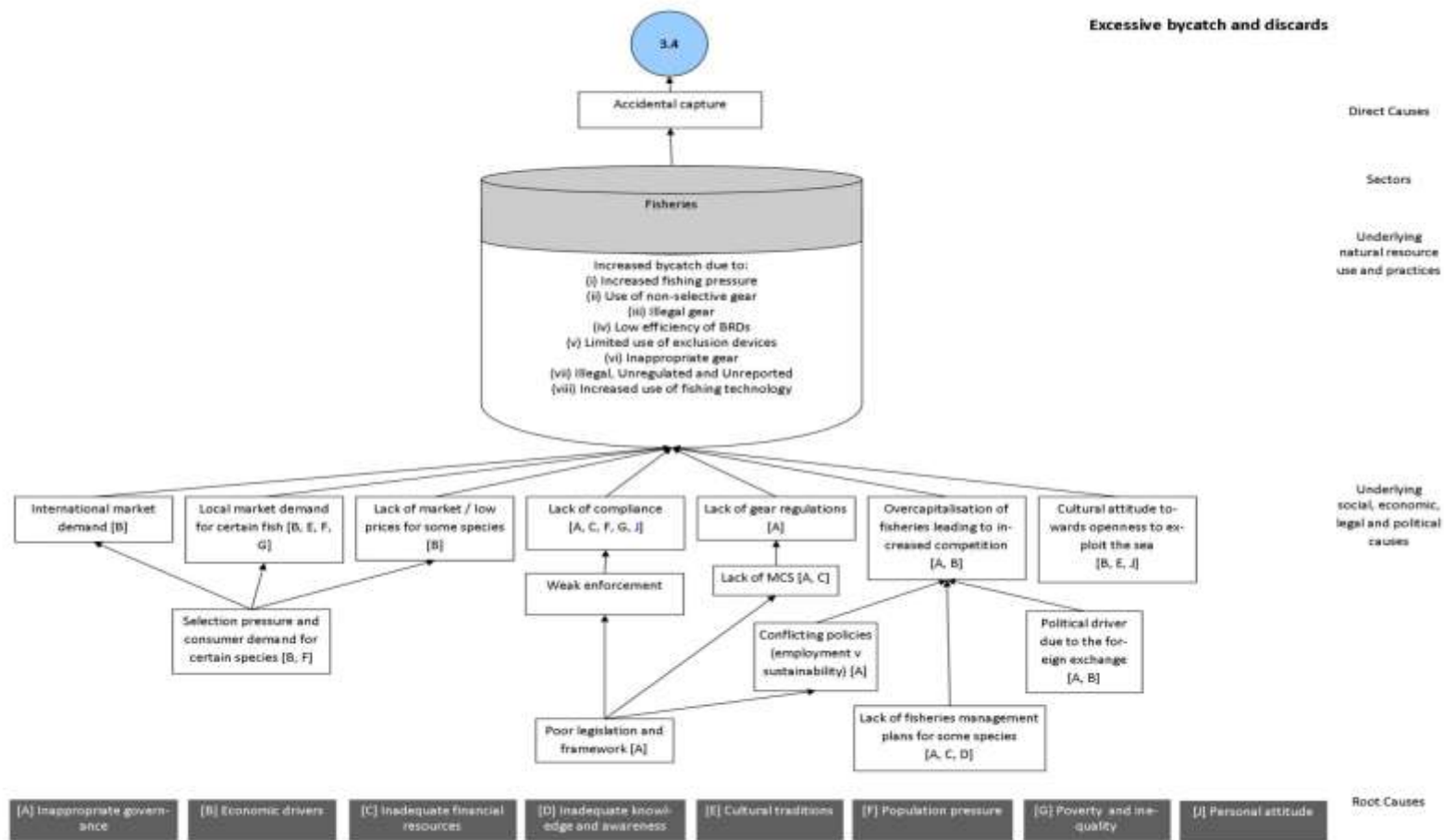


Figure 2-34: Causal Chain Analysis for excessive bycatch and discards.

1.6 Regional summary of underlying and root causes

The Causal Chain Analyses (CCA) described in the preceding sections identified the root causes and the underlying causes of the transboundary problems and main issues of concern in the WIO Region in as far as coastal and marine environment is concerned. The underlying causes included a range of social, political and economic causes. The first section below provides a general overview of some of the common root causes, the second section outlines and describes the underlying causes for the transboundary problems and issues that are considered to be of high priority in the region. Recommendations are also provided inclusion in the common SAP for the WIO region.

1.6.1 Common Root Causes

The ten (10) common root causes identified through the combined national to regional TDA process undertaken through the WIO-LaB and ASCLME-SWIOFP processes are: [A] Inappropriate governance, [B] Economic drivers, [C] Inadequate financial resources, [D] Inadequate knowledge and awareness, [E] Cultural traditions, [F] Population pressure and demographics, [G] Poverty and inequality, [H] Climate change and natural processes, [I] Voluntary action fills the governance void and [J] Personal attitude. The root causes and some of the underlying (social, legal and political) causes that are common to these priority issues are described below:

(i) **Inappropriate governance:** There are various common deficiencies in governance that are contributing towards the perpetuation of unsustainable practices in the WIO region. There is a general lack of harmonisation of legal and institutional frameworks for the management of marine and coastal resources. There is also a lack of inter-sectoral coordination, whereby Ministries have overlapping or conflicting mandates. Some of the underlying (social, legal and political) causes associated with this root cause include Lack of robust legal; Lack of monitoring, control, surveillance and enforcement; Lack of compliance; Weak national planning and regulatory frameworks; Lack of management capacity; Inadequate investment in infrastructure; Failure to cost the environment; Lack of transparency, wealth creation and corruption and; poor stakeholder/community participation in governance.

(ii) **Economic drivers:** While there is a huge diversity in terms of the state of the economies of the countries within the WIO region, the need for continued sustained economic growth and development is common to all countries. Although the global economic climate has cooled, the market demand for natural resources continues to expand, driven internally by population growth, but also externally by the global population and rapid economic growth of some of the South East Asian economies, which has opened up some new and tempting revenue sources. Many countries in the region are characterised by high levels of poverty, and insufficient national earnings and tax revenues to be able to sustain development or grow their economies without foreign income and investment. In some countries, lack of financial resources is so severe that they may be almost entirely dependent upon one or two revenue generating schemes, such as tourism, fisheries, mining or forestry. This high level of dependency on one or two income streams leaves the countries vulnerable to exploitation by foreign investors, especially if the investors themselves have poor internal environmental management policies and lack of good corporate social responsibility standards.

(iii) **Unfavourable international trade practices:** Most of the bilateral and multi-lateral international trade agreements do not favour developing countries of the WIO. For instance, globalization and market liberalization has tended to confine developing countries to activities focused on the exploitation of natural resources and export of raw materials. These activities do not bring sufficient income or revenues

to enable developing countries to develop required capacity for environmental management and conservation.

(iv) **Increased external market demands:** This is driving the use of inappropriate fishing practices leading to overfishing or over harvesting of large groupers, snappers, lobsters, octopus, and sea cucumber.

(v) **Inadequate financial and human resources:** Lack of or limited access to financial resources is a common root cause, often associated with inappropriate governance, Economic Drivers, and Inadequate knowledge and awareness. Most countries in the region have low GDPs, limited mechanisms for leveraging additional finances, and insufficient financial resources either in absolute terms or through inadequate priority setting, to be able to effectively manage problems in the coastal and marine environment. A country which simultaneously lacks human and financial resources for monitoring, control and surveillance operations, for example will be unable to enforce existing regulations and the risk of environment damage and exploitation is increased. Countries that lack the capacity for Environmental and Social Impact Assessments are also particularly at risk. Lack of research funding, data collection, monitoring, control and surveillance, enforcement of existing regulations, maintenance, education and training, employment of environment or extension officers is usually due to a inadequate financial and human resources.

(vi) **Inadequate knowledge and awareness:** Human capacity constraints identified include limitations due to inadequate training, colonial political past, institutional downsizing, re-trenching of environmental inspectors extension officers, or and low standards of environmental education and awareness, lack of awareness of best practices training in EIA procedures, lack of data and knowledge base and, inadequate awareness of the value of ecosystem goods and services provided by a healthy coastal and marine environment. An example of a historical beneficial practice was the employment of agricultural extension officers to encourage good farming practices, which has since ceased in many countries. Some of the other underlying (social, legal and political) causes associated with this root cause include: Low compliance with existing regulations; Lack of education, training and awareness; Lack of adequate and reliable data and research to support management; Inadequate ability to predict climatic events; Lack of capacity for handling oil spill / chemical clean-up operation; Inadequate or lack of land use plans and environmental policy; Limited knowledge, access to new technology; Limited understanding of alternative technologies.

(vii) **Weak scientific capability and lack of capacity to translate research findings into policy intervention:** This has been occasioned by lack of interaction between scientists who conduct research, and policy makers who make policies for environmental management, conservation and development. Most scientists are not well versed with the art of translating research findings into practical and implementable policies and strategies. On the other hand, most of the policy makers find it difficult to comprehend basic research findings delivered by scientists. Also, most of public institutions charged with research mandate are poorly funded, lack modern research equipment and laboratories and have inadequate number of experienced research scientists who can link science to policy.

(viii) **Lack of understanding among policy makers of the complex human-environment interaction:**-This leads to inadequacies in the formulation of policies with cases of inappropriate policies being formulated and implemented leading to adverse impacts on the coastal and marine environment.

(ix) **Corruption, bribery and ineptitude among government officials:-** This makes enforcement of legislation and or regulations related to the planning, conservation and management of coastal and marine environment ineffective or difficult. For instance, government departments responsible for physical planning may against all odds still grant a permit for construction of a hotel on a receding beach or in a wetland.

(x) **Cultural traditions:** A common root cause, cultural traditions often is associated with inadequate knowledge and awareness, Population Pressure and Demographics and Poverty. Some WIO countries have traditional or at least historical practices which have proven beneficial to the environment. While others have a legacy of decades of poor environmental management, including the traditional exploitation of vulnerable or threatened species (e.g. turtle, dugong, sharks), poor land-use management practices (e.g. slash and burn, free-roaming livestock). Traditional management of coastal and marine resources is no longer effective in most countries. This has been due to erosion of traditional good practices as coastal population densities have increased, as a result of inward or coastal migration, or as economies have developed. The increasing wealth of the average citizen in certain countries has influenced traditional food consumption patterns and resulted in the overexploitation of preferred food-fishes, for example. Some of the underlying (social, legal and political) causes associated with this root cause are: 'Lack of education, training and awareness'; 'Lack of knowledge, access to technology, and understanding of best practice'; 'Loss of traditional management practices', 'Rural poverty, coastal migration and urbanisation'.

(xi) **Population pressure and demographics:** Exponential population growth over the course of the last century has resulted in the global population nearly tripling within the past 85 years. Future trends in population growth published by the UN and the US Census Bureau predict the world population will be between 8 and 10.5 billion by 2050. Population growth combined with shifts in demographics have led to the increased urbanisation of coastal areas within the WIO countries, and increased demand for ecosystem goods and services, leading to overexploitation of resources (timber, fish), physical habitat damage and loss, the generation of liquid and solids waste, and conflicts in land use. Regional instability and unrest, or rural poverty are exacerbating the expansion of coastal populations. Several countries are recently recovering from or still are affected by civil war; and the affected countries are operating in a governance vacuum. Refugees and illegal immigrants from unstable countries travel to the countries within the WIO region in search of employment and an improved standard of living for themselves and their families. High levels of rural poverty in the WIO countries has also resulted in an increased number of people moving to coastal cities in search of employment opportunities. The expansion of certain sectors, particularly employment opportunities associated with coastal tourism have amplified this effect. Some of the underlying (social, legal, and political) causes associated with the root cause of population pressure and demographics include: Rural poverty, coastal migration (due to regional instability/civil war/rural unemployment/poverty), and urbanisation; Inadequate or lack of land use plans; Lack of ICZM plan/ICZM plan not implemented; Inadequate investment in infrastructure/poor maintenance.

(xii) **Human settlements and migration to the coast:** High rates of rural to urban migration in the WIO Region are forcing people to settle in areas that are already occupied by critical coastal habitats such as mangroves and coastal forests. Human settlements have led to encroachment and degradation of critical coastal ecosystems such as mangroves, coastal forests, wetlands and protected areas. Human settlements have also encroached upon livestock and wildlife migratory routes thus impacting the annual migration patterns of wildlife and livestock. Migration of large number of people to the coastal zone increases pressure leading to unsustainable farming practices (e.g. high rates of cultivating in lowlying areas prone to flooding, over-cultivation, clearing of natural habitat to make room for agriculture, livestock rearing

and fishing, etc). In addition, pastoralists migration towards the coast during the dry seasons leads to high concentration of livestock in coastal plains and deltas. Informal settlements along the coast are sources of sewage and wastewater discharged into the coastal and marine environment.

(xiii) **Intensification of irrigated agriculture:** The coastal plains and deltas in the WIO Region are often targeted for development of irrigation projects intended for crop production and development of unused land. These projects lead to clearance of large tracts of land (often including important wildlife habitats) and abstraction of large volumes of water from rivers draining into the WIO, leading to loss of biodiversity and reduction in river discharges to the coast¹². In addition, irrigation projects are leading to the degradation of water quality due to discharge of irrigation return flows laden with residues of inorganic fertilizers and pesticides. The reduction of flow of rivers due to over abstraction is already having impacts on the aquatic ecosystems including riverine and coastal lowland forests such as those in the lower Tana basin and delta.

(xiv) **Increasing energy demand:** Most countries in the WIO region have experienced an increased demand for energy and especially electricity. The increased consumption of electric energy has been necessitated by recent developments in domestic, commercial and industrial sectors. Consequently, major dams have been constructed or are being constructed in the river basins that drain to the WIO. These dams have reduced or will reduce flood flows to the coastal deltas. Also, there has been a significant reduction in sediment transport into some of the deltas¹³.

(xv) **Transportation infrastructure development:** The infrastructure development in the coastal areas of the WIO such as construction of roads, railways and bridges is contributing to the degradation of critical coastal habitats such as coastal lowland tropical forests and mangrove forests leading to loss of biodiversity and coastal livelihood systems.

(xvi) **Inappropriate land tenure system:** There are three categories of land ownership in most countries in the WIO region: private, communal and public land. There has been large scale allocation of private and public land at the coast for development. Most of the gazetted forests, beach fronts and marine waters occur in public land. The rest of the land is held under communal ownership with recognition of individual titles to cultivated land. The communal ownership of land does not encourage local and external investments including conservation of critical coastal habitats. In addition, the majority of coastal communities are squatters with no land ownership rights and therefore pays little attention to the protection and conservation of critical coastal ecosystems. Large tracts of land are also owned by few people while the majority of people occupy ancestral land with unclear jurisdiction. Due to land tenure insecurity, local communities rarely practice sustainable farming and livestock grazing and coastal forests have been degraded due to mining, charcoal burning and cutting of trees for timber. This has resulted in vast degradation of riverine and coastal forests including mangrove forests. Public land in urban areas is also invaded by informal settlements.

(xvii) **Informal settlements in urban areas:** Informal settlements are common in most of the major cities in the WIO region. Examples include the cities of Mombasa, Dar es Salaam, Maputo, Cape Town,

¹² Kitheka, J.U and K. M. Mavuti (2016): Tana Delta and Sabaki Estuaries of Kenya: Freshwater and Sediment Input, Upstream Threats and Management Challenges. In: *Estuaries: A Lifeline of Ecosystem Services in the Western Indian Ocean*. Springer International Publishing Switzerland 2016. Springer, p.89-111.

¹³ Kitheka, J.U and K. M. Mavuti (2016): Tana Delta and Sabaki Estuaries of Kenya: Freshwater and Sediment Input, Upstream Threats and Management Challenges. In: *Estuaries: A Lifeline of Ecosystem Services in the Western Indian Ocean*. Springer International Publishing Switzerland 2016. Springer, p.89-111.

Antananarivo, among others. The informal settlements are usually found in land that is designated as public land and are sources of sewage and wastewater that is discharged directly into rivers and coastal ecosystems. Poor people living in informal settlements also derive their livelihood through direct extraction of coastal resources leading to depletion.

(xviii) **Intensification of pastoralism and livestock grazing:** The coastal plains and deltas in the WIO Region are often important grazing areas for livestock (cattle, goats, sheep and camel) that are kept by the migratory pastoral communities, some of whom in the recent past have settled permanently in the deltas¹⁴. For instance in the Tana Delta in Kenya, around 220,000 and 75,000 heads of cattle graze in the delta in wet and dry seasons, respectively. High concentration of livestock in coastal deltas including protected areas during dry season leads to overgrazing and destruction of vegetation leading to soil erosion with significant impacts on water quality of rivers and wetlands. High concentration of livestock also has negative impacts on coastal biodiversity.

(xix) **Poverty and inequality:** High levels of poverty and low incomes have led to an increased dependency on the exploitation of natural resources and subsistence living and a reliance on the ecosystem services that natural resources provide. Due to limited incomes and access to appropriate technologies people engage in unsustainable and destructive fishing practices, such as the use of mosquito nets for fishing, reef gleaning activities, and dynamite fishing. Other harmful land-use practices are also often caused by poverty, farming on river banks for example, or slash and burn farming. Lack of access of alternative energy sources has led to overexploitation of mangroves for fuelwood and building materials in many areas at the coast, and this is the root cause of increased soil erosion and sediment load to rivers.

(xx) **Lack of alternative livelihoods:** Most of the coastal communities in the WIO region have limited livelihood alternatives, with over-dependency on few alternatives being the direct consequence. Most of the key sources of livelihood are directly or indirectly linked to the critical coastal ecosystems and hence their degradation directly affects coastal communities. Also, most of the individual land use activities are characterized by low income levels. Increasing populations and limited livelihood alternatives has led to over-exploitation of natural coastal resources and the loss of valuable ecosystem goods and services in the region.

(xxi) **Unemployment or under-employment among the youth:** In most countries in the WIO region, large number of young men and women who have completed formal schooling including university graduates, are either unemployed or under employed forcing them to venture into activities related to the exploitation of natural resources such as fishing, mining, harvesting of trees including overcrowding in beaches for informal and unregulated businesses targeting dwindling number of tourists.

(xxii) **Industrial development:** While most of the countries in the WIO countries are not highly industrialized, the small number of industries found in major urban centers are the causes of some of the major problems facing the coastal and marine ecosystem in the region. Industries are sources of toxic industrial effluents and wastewaters that are discharged directly into the coastal ecosystems without any form of treatment or where treatment is attempted, it is often inadequate. Industries are also sources of solid waste and especially plastic litter that ends up in the coastal ecosystems. In addition, they also consume huge volume of water and energy increasing the need for exploitation of rivers for hydropower development. Some industries leads to direct degradation of the coastal and marine ecosystem for

¹⁴Irungu, P. (2000). Cattle Keeping Practices of the Orma People. A Household Survey in Tana River District, Kenya

instance unsightly quarries abandoned at the coast after mining of coral limestone for cement production and construction.

(xxiii) **Tourism development:-** In most countries in the WIO region, there has been a significant expansion of the tourism in coastal areas. A large number of beach hotels and resorts have been constructed along the coast in some cases in sensitive and pristine areas leading to loss of biodiversity. Large number of tourist hotels and resorts also consumes large quantity of freshwater leading to depletion of groundwater aquifers which in turn is leading to intensification of seawater intrusion into important groundwater aquifers that are also important sources of water for urban areas. In addition, tourist hotels generates a large volume of wastewater (including plastic litter) which is often discharged into the coastal waters without any significant treatment, leading to the degradation of coastal ecosystems such as coral reefs and seagrass beds. In addition, large number of tourist hotels have increased demand for coastal fisheries resources some of which are now overexploited to meet the high demand during peak tourist seasons. Construction of seawalls to protect tourist hotels constructed along the shoreline is intensifying the erosion of beaches leading to significant shoreline change and impacts on seagrass beds and coral reefs. In addition, concentration of large number of unemployed youth on beaches, targeting tourists for trade, is also leading to the degradation of coastal ecosystems through increasing disposal of plastic litter on beaches, some of which ends in the seagrass beds, coral reefs and mangrove forests.

(xxiv) **Ineptitude and inefficiency among government officials:-** The public officials charged with the responsibility of planning, conservation and management of coastal and marine environment are in some cases inept and lack technical competence to generate and implement appropriate ideas and solutions. Funds are therefore spend on unsustainable and ill conceived projects that do not targeted real problems on the ground and projects that are not only costly, but also leads to additional adverse impacts to the critical coastal ecosystems and people. In some instances, political expediency forces government officials to overlook professional advice and allow implementation of projects that are not appropriate.

(xxv) **Excessive bureaucracy in government agencies:-** Most of the government agencies in the WIO countries are characterized by excessive bureaucracy that is highly inefficient, leading to delays in the implementation and enforcement of legislation and regulations for the protection, management and conservation of the coastal and marine environment. Excessive bureaucracy discourages investments and increases corruption, harming the coastal ecosystems and communities.

(xxvi) **Inadequate land use planning at national and sub-national levels:** The system of land use planning and allocation has been inappropriate and ineffective in most of the WIO countries. This has led to inappropriate land use practices in coastal counties resulting in the degradation of the critical coastal forests and landscapes, both directly and indirectly. In most countries, there has not been proper planning for the increased human and livestock population and poor planning for settlements and irrigation agriculture have impacted the forests and other critical habitats such as mangroves.

Climate change: The climate change is an important root cause of alteration and or modification of freshwater flows. There are significant changes in the periods for onset and cessation of rainfall season in the region. Some parts of the WIO region are experiencing a reduction in rainfall while other areas are experiencing an increase. For instance, documented reduction of rainfall in the East Africa highlands is negatively impacting the volume of rivers draining into the WIO. In addition, increased frequency of extreme hydro-climatic events such as El Nino ENSO and Indian Ocean Dipole (IOD) events are leading

to increased variability of river freshwater and sediment discharges, sometimes with catastrophic impacts on critical coastal ecosystems.

(xxvii) **Global warming:** Progressive and significant increase in sea water temperature in the WIO is a major direct cause of coral bleaching and mortality in the region. In addition, increased temperature is leading to increased rates of evaporation/evapotranspiration leading to significant changes in water temperature and salinity in semi enclosed bodies of water such as mangrove-fringed inlets and lagoons. There are also impacts on water volumes occasioned by high evaporation rates e.g. drying of coastal wetlands, lakes and rivers-all leading to significant impacts to ecosystems and livelihood of local communities.

(xxviii) **Sea level rise:** Sea level in the region is rising at an unprecedented rate and according to the Intergovernmental Panel on Climate Change (IPCC) global sea level rose at an average rate of 1.8 mm per year from 1961 to 2003 and the rate increased to 3.1 mm/year over the last decade of the period. The IPCC further projected that sea levels would mount 18–59 cm by 2100. The progressive increase in sea level in the WIO region is directly leading to increased intrusion of salty seawater to estuaries, deltas and groundwater aquifers affecting important sources of freshwater and agricultural fields. Sea level rise is also impacting the critical ecosystems such as mangroves making it difficult for the mangrove forest wetlands to keep up with the rate of sea level rise. In addition, sea level rise is leading to intensification of shoreline erosion, due to increased wave activity on the shoreline, leading to disastrous consequences on critical ecosystems, coastal development infrastructure and livelihood systems.

(xxix) **Personal attitude:** Among some fisher communities and other marine resource users in the WIO region, there is a culture of entitlement, whereby they believe that they have a right to fish regardless of the status of the stocks. This can also often be associated with a culture of blame shifting, where it is always another fishery, or another organisation that is causing the issue. Other underlying causes associated with which this root cause is associated with include bribery, greed and corruption and negligence.

1.6.2 Common Direct Causes

The following are the direct causes of degradation of the coastal and marine environment in the WIO region.

(a) **Increased water abstraction:** There has been an increase in the abstraction of both surface and groundwater resources in most of the participating countries. This has been occasioned by increased demand for freshwater to cater for increased needs in rural and urban centers. The increased exploitation of rivers and groundwater aquifers is leading to reduced freshwater flow to the coast. This in turn is leading to seawater intrusion in estuaries and aquifers leading to contamination of valuable sources of freshwater. Reduced freshwater flow via rivers is also altered coastal sediment budgets leading to intensification of shoreline erosion along the coast and especially in deltas and estuaries.

(b) **Damming of rivers draining to the coast:** There has been an increased damming of rivers for the purpose of increasing storage of water for hydro-electricity generation, water supply and irrigation. Damming of rivers not only reduces freshwater flow to the coast but also reduces the discharge of terrigenous sediment load and nutrients to the coastal waters since most of the sediments and nutrients are retained in dam's reservoirs. These have adverse downstream impacts on the coastal-marine ecosystems and communities.

- (c) **Increased deforestation of critical forests:** Physical removal of mangroves and terrestrial coastal forests through cutting degrades the coastal ecosystems through reduced freshwater flow and increased sediment load discharged into the coast. Degraded forests are losing their importance as sources of livelihood leading communities to venture into other inappropriate practices at the coast such as over-fishing and cultivation.
- (d) **Discharge of wastewater and sewage effluents:** The discharge of wastewater and sewage into the coastal waters (tidal creeks, estuaries and lagoons) degrades the quality of coastal waters leading to major impacts on marine and coastal ecosystems and sources of livelihood. This problem is prevalent in all major towns and cities in the WIO region.
- (e) **Excavation for construction works:** The excavation of soil during the construction of bridges, jetties, roads etc leads to the disturbance of coastal ecosystems. The dumping of huge volume of excavated soil degrades coastal ecosystems such as mangrove forests and wetlands.
- (f) **Dredging of ports and harbours:** The excavation of the seabed to remove sediments to deepen tidal channels, estuaries, lagoons or ports and harbours leads to the degradation of coastal water quality and critical coastal ecosystems. Dredging operations inevitably disturbs bottom sediments, benthic habitats and organism and leads to increased turbidity in the water column. In some cases, disturbance of the bottom sediments leads to release of nutrients, POPs and heavy metals that may have been locked up in the sediments for many years.
- (g) **Harvesting of natural resources:** The increased population at the coast is increasing pressure on the few existing sources of livelihood. There is over harvesting of most of the coastal natural resources such as freshwater, coastal fisheries, mangrove forests for timber and fuel wood leading to degradation of coastal ecosystems and sources of livelihood. In some cases, there is direct removal of corals, seagrasses, shells and other sessile organisms leading to significant impacts on the critical coastal ecosystems.
- (h) **Dragging of fishing nets or trawl nets:** This is common in trawl fishing for prawns leading to bottom sediment resuspension and increased turbidity in the water column, etc. Also leads to significant impacts on benthic organisms, seagrass beds and corals.
- (i) **Fishing using inappropriate nets:** This involves the use of inappropriate fishing nets that leads to over-harvesting of fish in the coral reefs and seagrass beds. Use of inappropriate and illegal nets is common in most countries in the WIO region and this is leading to the depletion of fish resources in coastal waters including lagoons.
- (j) **Dynamite fishing:** Blasting schools of fish in coastal waters inevitably leading to high mortality among non-target species is a common problem in some countries in the WIO region. Dynamite fishing has in the past being attributed to the extensive destruction of fish breeding and spawning grounds in some areas along the Tanzanian coast.
- (k) **Trampling on seagrass beds and corals:** Trampling occurs due to a large number of tourists, fishermen, etc walking in areas that are covered by live corals or seagrass beds. Where this has been done on regular basis, it has led to the degradation of seagrass bed and coral reef ecosystems.
- (l) **Pumping and release of ballast water:** Crude oil tankers may illegally release ballast water laden with alien species into the coastal waters or in ports leading to invasion of critical coastal ecosystems by alien species.

(m) **Wastewater discharged after cleaning of oil tankers and bulk grain carriers after discharge in ports:** Cleaning of crude oil tankers inevitably leads to the discharge of wastewater laden with crude oil products and residues pollutes coastal waters especially in ports and harbours.

(n) **Quarrying and mining activities:** Excavation and removal of coral limestone stones and other rocks, disturbs coastal vegetation exposing the ground to soil erosion agents, leading to increased transportation of sediment materials to the coastal waters during rainy season through surface runoff. This may lead to heavy sedimentation and degradation of water quality.

(o) **Increase in sea surface temperature:** The progressive increase in seas surface temperature due to global warming has a devastating impact on critical coastal ecosystems particularly the coral reef. There has been a significant degradation of the coral reef ecosystem due to extensive bleaching of corals in the WIO. A progressive increase in seawater temperature will definitely be disadvantageous to the coral reef ecosystem in the region.

(p) **Seawater intrusion:** Seawater intrusion affects coastal groundwater aquifers leading to contamination of groundwater which is an important source of freshwater supply in most of the coastal cities and towns. Intrusion of seawater in estuaries is contaminating sources of freshwater located inland with potential to lead to expensive relocation of intakes for water works. In addition, seawater intrusion is degrading soils in lowlying deltas leading to loss of agricultural land with potential to impact on food security and income of the local coastal communities.

(q) **Changes in the discharge channels/distributaries of rivers in deltas:** In some of the main deltas in the WIO region such as Tana and Rufiji deltas, there has been a shift in the points of discharge of terrigenous sediments and nutrient-laden freshwater into the coastal waters. This has led to decline in the supply of freshwater, nutrients and sediments in some parts of deltas leading to the degradation of mangrove forests and agricultural fields. Intrusion of seawater in zones of the delta that no longer receive freshwater also degrades sources of freshwater and leads to degradation of fertile soils that support agricultural production in the deltas.

1.6.3 Common Underlying Causes

The most important underlying root causes of degradation of the coastal and marine ecosystem in the WIO region are as follows:

(a) Increased internal/external market demands for natural resources

Pressure on coastal and marine resources has intensified in the WIO region as a result of population growth, demographics shifts, migration, lack of alternative livelihoods and poverty, but also as a result of increased wealth, urbanisation and consumption rates in some countries (e.g. building materials, food fishes etc.). Increasing competition for dwindling resources to meet the growing internal demand has resulted in progressively more destructive resource use practices. As the global population continues to grow so does the global demand for natural resources, even if at a slower rate than previously. The economies of the countries within the WIO have diversified in response to these external demands. While agriculture, tourism and fisheries continue to be the mainstay of many of the economies, new sectors such as oil and gas and mining are growing. The expansion of new economic sectors provides new and tempting sources of foreign revenue. When this situation is coupled with a high proportion of the coastal population dependent on subsistence living, and a low capacity to plan and manage existing internal demands, there will invariably be an increase in conflicts between existing and new resource users in the coastal zone. For example, the discovery of large liquid natural gas reserves (e.g. at the border between southern Tanzania and northern Mozambique), will require the construction of shore-based gas loading terminals, which will require large security zones, most likely displacing coastal residents from their homes and fishers from their traditional grounds. Increased demand for resources is often the fundamental

driving force that then linked to other contributory social, economic and legal underlying causes, such as 'Weak national planning and regulation frameworks', 'Failure to cost the environment' and 'Lack of monitoring, control, surveillance, and enforcement capacities', 'Lack of alternative livelihoods'.

Recommendations for the SAP

- Provide training and support for Strategic Environmental Assessments (SEA) and Marine Spatial Planning (MSP) to support improved management and minimize future resource use conflicts.
- Provide support for countries to develop their capacity and understanding of cost-benefit analysis and how these economic tools can help inform policy formulation and decision-making.

(ii) High levels of rural poverty, increased coastal migration and urbanisation

The pressure on coastal and marine resources at the national level has intensified as a result of population growth, demographics shifts, a lack of alternative livelihoods and poverty, but also as a result of increased wealth, urbanisation and consumption rates in some countries (e.g. building materials, food fishes etc.).

SAP Recommendations (as above)

(iii) Weak national (strategic) planning and regulatory frameworks for sustainable development

The majority of issues related to water quality degradation, habitats and community modification are due to weaknesses in the national strategic planning systems, often associated with poor inter-ministerial and inter-sectoral coordination. Some of the causes include: (i) outstanding land-use issues associated with historical land tenure; (ii) high levels of private land ownership which impedes government ability to intervene or control land-based activities; (iii) lack of or failure to enforce existing coastal set-back regulations; (iv) lack of or inadequate land use plans and associated environmental policies, and failure to implement and enforce these where these do exist and; (v) lack of or failure to implement ICZM plans. There is a group of closely associated underlying causes related to this cause, as outlined below:

(iv) Inadequate or lack of land use plans and appropriate environmental policy: Only a few countries in the WIO have prepared land use management plans, and where these exist they are often not implemented. The issues where this was identified as a cause were often those where there were conflicts between the need for economic development and environmental protection, associated with a 'Failure to cost the environment' and 'Lack of knowledge, access to technology, and understanding of best use practices'.

(v) Failure to mainstream climate change into planning and decision making: While some WIO countries have prepared coastal sensitivity and vulnerability maps, there is a need for a regional effort to ensure that these maps are finalised for all countries. Coastal vulnerability maps would provide the basis for refining coastal set-back regulations and would better facilitate the preparation of climate proof plans for future coastal development, as well as emergency risk planning, for storm waves or tsunamis, or sea level rise. The sensitivity maps would provide the basis for oil spill disaster management. Kenya, for example, has an Environmental Sensitivity Atlas (KENSEA) that contains information on the sensitivity and vulnerability of marine environment to oil spills and a map showing vulnerability of the Kenyan coast to tsunami (ASCLME 2012b). Despite this, Kenya has also identified the need for vulnerability maps for coastal flooding, storms waves and sea level rise and other climate change related impacts. Ideally the methods need to be standardised and draw on a range of data and information relevant to climate change. These efforts could contribute to those already ongoing by ODINAfrica and other relevant partner organisations.

(vi) Lack of ICZM plan / ICZM plan not implemented: Several countries identified weak capacity for integrated planning and management as a cause for degradation of the coastal and marine ecosystems. While many countries in the WIO have now set-up ICZM Committees, developed or re-drafted policies

and developed action plans, very few countries have actually prepared full ICZM plans and even fewer (if any) have implemented the plans. Even the countries with stronger economies have failed to implement ICZM plans due to the huge costs implications and conflicts with other more pressing priority. Those plans that have been developed within the region have been prepared by external consultancy firms, and they have tended to focus on one sector (e.g. tourism) or on 'hotspots', thereby defeating the purpose of integrated coastal wide planning. The process has however helped to initiate the coordination processes needed and helped countries to identify gaps. Some of the gaps in ICZM capacity identified in the MEDAs include: (i) absence of systematic monitoring programme for the coastal zone; (ii) knowledge gaps in certain aspects pertaining to CZM (e.g., nutrient enrichment and chemical (pesticides) runoff).

Recommendations for SAP

- Provide support for and facilitate wider adoption of internationally recognised standard planning tools to aid the adoption of an ecosystem-based management approach of coastal and marine resources (e.g. SEA, ICZM and MSP);
- Develop a suite of standard regionally applicable methods and tools (where not already available) for land-use planning, coastal vulnerability and sensitivity mapping, ICZM, SEA and MSP;
- Provide long term on-the-job GIS training and support to build national capacity in the preparation and management of spatial datasets, as an aid to planning and management of coastal and marine resources;
- Provide training in techniques such as the assessment of carrying capacities and monitoring of tourism impacts.

(vii) Lack of a robust legal framework

All countries identified inadequacies in their existing legal framework with regards the management of coastal and marine environment and resources. Inappropriate or outdated legislation was a common underlying cause for all the priority issues. In addition there was a lack of integration of international and regional agreements into national legislation, lack of harmonisation of sector specific legislation (e.g. fisheries) at the regional level and between sectors at the national level, creating a conflicting decision making environment that hinders the implementation of ecosystem based management approaches. These concerns are often compounded by weaknesses in the institutional frameworks and technical capacities that prevents effective enforcement of existing regulations. There is also lack of qualified legal experts to prepare/revise the legislation, which results in slow policy development. There is a group of closely associated underlying causes related to this cause, as outlined below:

(a) Outstanding maritime boundary disputes: There are outstanding disputes regarding maritime boundary agreements that need to be resolved, as not all countries in the WIO have concluded the delineation of their EEZ boundaries. Settling these disputes is essential if existing and potential conflicts related to the economic use of coastal and marine resources, fisheries, hydrocarbon exploration and exploitation and mining. Somalia has not yet delineated their EEZ due to internal conflicts. Kenya and Somalia have a maritime boundary and EEZ dispute. Mozambique has not yet established maritime borders with Comoro, France (Mayotte and Europe), Madagascar and South Africa. Seychelles has not yet delineated its EEZ boundaries with Comoro, Tanzania, Madagascar and France, and with France and/or Mauritius concerning the island of Tromlin, as sovereignty over this island has not yet been resolved. Seychelles and Mauritius have submitted a joint extension of the sea bed. Mauritius has not yet resolved the dispute with regards Chagos Archipelago. South Africa has yet to agree on the EEZ boundaries with Mozambique.

(b) Unresolved legal issues related to land ownership: In some countries, there are outstanding issues associated with land tenure, which can create conflicts with non-government led initiatives, or

prevent the governments from being able to implement changes at the national level. In Tanzania, for example, the impact of ongoing Government land tenure reforms on coastal land resources are not yet entirely clear, but could lead to increasing privatisation of state lands, with detrimental effects on community access to resources such as mangrove forests (ASCLME 2012c). Issues of land tenure and the privatisation of state lands for tourism developments are constraining the development of community-based initiatives in prawn farming in Kenya (ASCLME 2012b). In other countries, where there are already high historical levels of private land ownership, the government has limited powers to influence or control the types of activities or land use practices.

(c) Lack of harmonisation of national legislation and with respect to the regional and international agreements: WIO countries are all party to the majority of international conventions, and all are members of the Nairobi Convention. The national legislation however does not always reflect these regional and international agreements and there is a need to identify the gaps in national legislation and harmonise. For example, while most have signed a number of international agreements and Multilateral Environment Agreements (MEAs), there has been little progress in terms of updating laws and in terms of implementation. The national policy and governance reviews conducted in the region have identified some of the gaps that need to be addressed. To achieve this, additional technical protocols could be developed under the Nairobi Convention to “operationalise” the relevant articles and promote regional harmonization of the management of marine pollution, for example (e.g. to strengthen legislation on dredging and especially dredged material disposal; and the environmental impacts of offshore oil and gas activities, liability and compensation related to offshore activities, and monitoring and standards).

(d) Lack of harmonised fisheries legislation: A review of national fisheries legislation completed through SWIOFP, aimed to provide recommendations on provisions that should be included in fisheries legislation to support harmonisation of fisheries management measures. The review showed that fisheries related legislation in the WIO region is generally outdated and weak (Swan 2012). Although all countries within the region have national fisheries laws, many of these laws do not fully implement the binding obligations of international fisheries instruments or regional organisations, nor do they reflect up to date “best practices” of fisheries legislation (Swan 2012). Some of the other concerns raised include: (i) most countries’ laws do not state an objective or principles for fisheries management or encourage international/regional cooperation, nor do they apply the Act to areas beyond national jurisdiction; (ii) while almost all of the laws designate an authority (e.g., the Minister, Director) and process for taking management measures, and specify the type of measures that may be taken (e.g. quotas, effort control, area, gear, seasons, species size), less than half of the countries have made provision for fisheries management plans; (iii) widespread failure to include clear and comprehensive information requirements, including those that would contribute to a regional MCS system or shared/joint management; (iv) the authorities of authorised officers are contained in laws, but this is very uneven, and many of the authorities required for robust enforcement are not provided; and (v) legislation pays almost no attention to the requirements rules of evidence in respect of fisheries offences. Kenya, Madagascar, Mauritius, Mozambique and Seychelles have prepared, or are developing, revised fisheries legislation and it was recommended that the other remaining WIO countries should also consider a revision of national laws (Swan 2012).

(e) Gaps in legislation related to monitoring, control and surveillance and enforcement: The review of national legislation completed through ASCLME and SWIOFP identified gaps in the legislations (and other deficiencies) with regards MCS related to fisheries (Swan 2012), which are also pertinent to MCS and the enforcement of other associated regulations such as those associated with

Marine Protected Areas. For example, authorities of authorised officers are contained in all national laws, but unevenly, and many fisheries authorities do not have sufficient personnel to ensure robust enforcement. There is also a lack of provisions relating to observers in the fisheries laws and the legislation pays almost no attention to rules of evidence in respect of fisheries offences (Swan, 2012). This review considered the need for harmonising the MCS processes in the WIO region (Swan, 2012). The SmartFish programme also examined this issue and analysed the gaps in MCS legislation and MCS readiness throughout the region, with a view to harmonization and implementation of regional arrangements (Swan 2012).

Recommendations for the SAP

- Provide support and advice on building capacity in legal expertise.
- Encourage and facilitate where needed the resolution of outstanding maritime boundary issues;
- Identify the need for, and provide assistance in the revision and harmonization of existing legislation and policies with regards the various regional and international agreements.
- Identify the need and provide assistance in the revision and harmonization of existing fisheries legislation and policies with respect to various regional and international agreements, but also with regards permitting greater community involvement in the management of resources.
- Identify the need for and provide assistance in the revision and harmonization of other existing sector specific legislation and policies, particularly those related to emerging sectors (e.g. mariculture, oil and gas, and exploitation of deepwater resources).
- Identify the need for additional support to help ensure all countries adopt appropriate ICZM legislation.
- Identify the need for additional specific regional protocols to support the implementation of the international agreement.
- Examine legislation and policy gaps with regards to authorization, leasing and regulation of activities on the seabed (construction, operation and use of any installation or structures) within the territorial sea and EEZ.

(viii) Low levels of compliance with existing regulations

Low levels of 'voluntary' compliance with existing national, regional or international regulations is another underlying cause common to many of the top priority issues. Low levels of compliance at the national level often occur as a result of poverty, low levels of education, insufficient outreach, a culture of entitlement, or shift in demographics due to high levels of immigration. In South Africa, for example, the small-scale fishery sector suffers from low levels of compliance, which is believed to be due to poor information dissemination, and lack of trust among coastal communities of the fisheries authorities, resulting from failure to effectively manage this sector in the past (ASCLME 2012e). Increasing outreach and sensitisation activities or establishing processes which engage marine resource users and stakeholders in the management and decision making processes, can help to raise awareness and improve levels of compliance. Non-compliance with coastal set-back regulations is another common challenge, particularly as regards tourism or other types of coastal developments. Low levels of compliance by foreign companies or distant water fishing fleets occurs in the WIO countries EEZs particularly when the governments are perceived to be weak, or as a result of limited monitoring, control, surveillance and enforcement capacity. Foreign companies operating in a governance void, and those without good internal sustainability and corporate social responsibility policies, can maximise profits by cutting corners in the knowledge that they are unlikely to be caught and fined.

Recommendations for SAP

- Provide specific targeted support for region-wide outreach and sensitisation programmes related to the priority transboundary issues.
- Provide support for the development and establishment of regional marine education programme for implementation in primary and secondary schools.

(vix) Complex institutional framework and capacity constraints

The national MEDAs and Causal Chain Analyses identified limitations associated with institutional frameworks and capacity constraints, in terms of inadequate staff numbers or skills, as an underlying cause of the issues of concern. There were examples where Ministries had overlapping and conflicting mandates; lack of inter-ministerial and inter-sectoral communication and coordination; insufficient staff numbers to be able to implement and enforce existing regulations and laws; insufficient staff capacity to be able to domesticate the provisions of international conventions even when they have been ratified. The staff capacity limitations are often due to lack of adequate financial provisions for staffing within the relevant ministries, limited technical training, as well as more fundamental problems with the basic education system.

Practically, increased efficiency and coordination within and between government departments is required. For example, South Africa raised the issue of a split mandate for MCS between a number of different government agencies and local authorities and therefore synergies between various key government departments need to be identified (ASCLME 2012e). The issue of weak human capacity needs to be addressed through comprehensive human resources development planning in each of the WIO countries (ASCLME 2012d). In Madagascar, there is also a recognised lack of coordination between agencies: The various Malagasy institutions involved in coastal management have taken actions that are more or less appropriate for addressing the degradation of the coastal zones but these interventions are generally occasional, isolated and are mainly sectoral (ASCLME 2012f).

Recommendations for the SAP

Provide advice to strengthen local capacity for good governance, and application of science based governance so as to improve decision-making.

(xx) Inadequate monitoring, control, surveillance and enforcement capacity: Monitoring, control, surveillance and enforcement activities present a legal, technical and financial challenge, and all WIO countries raised this as a concern. While lack of MCS is a common cause relating to fisheries, it is also pervasive in relation to all other extractive sectors (e.g. agro-forestry, mining, mariculture) and coastal development activities which may impact upon sensitive coastal and marine habitats (e.g. dunes, coral reefs, seagrass beds, mangroves). The high costs associated with MCS and enforcement demand a substantial commitment from government budgets. Lack of appreciation of the value of coastal and marine resources by policy makers is an important associated contributory cause, which can lead to low budgetary allocation for MCS, and this underlying cause is commonly linked to a 'Failure to cost the environment'. There is a group of closely associated underlying causes related to this cause, as outlined below:

(xxi) Inadequate national capacity monitoring, control and surveillance capacity: Many WIO countries have limited resources (human and financial) to invest in vessels capable of patrolling the waters of their EEZs and employing sufficient numbers of well trained coast guards to enforce existing regulations. The WIO countries' offshore resources are thus vulnerable to illegal, unreported, and unregulated (IUU) fishing, as well as other illegal activities including piracy, with major economic losses both to the state and to local fishing industries. IUU fishing has proven particularly problematic for fisheries that straddle the EEZ and the high seas, or fisheries that migrate across national boundaries.

(xxii) Insufficient regional coordination and cooperation in monitoring, control and surveillance: Effective implementation of the management measures and MCS mechanisms adopted by IOTC, such as the binding Port State Measures, would improve the ability of the member states in the region to contribute in combating IUU fishing in general. Other binding measures for IOTC member States such as mandatory VMS in all vessels above 15m in length overall or the observer programme to monitor transshipment at sea for large-scale longline vessels, could also contribute to the control and reduction of IUU fishing in the region.

(xxiii) Lack of capacity (human and financial) for enforcement: Lack of capacity to enforce existing legislation was cited as a underlying cause that was common to all priority issues. This cause is usually underpinned by lack of resources, in terms of both insufficient budget allocation to support such activities, but also in terms of lack of adequately trained staff, as well as an insufficient number of staff to enforce. For example, shortage of adequately trained personnel in government ministries means that establishment of a Vessel Monitoring System (VMS), revision of fisheries legislation and co-management initiatives would be difficult to implement. Lack of resources for enforcement is a key underlying cause in terms of fisheries management in general, including inadequate MCS.

While this underlying cause is commonly associated with the fact that countries had 'Failure to cost the environment', it was also associated with the underlying cause- 'Lack of transparency/Wealth creation and corruption', as a result of rent-seeking behaviour, particularly with regards fisheries and other extractive industries (e.g. timber) and coastal development activities (e.g. tourism). Lack of appreciation of the value of coastal and marine resources by policy makers results in low budgetary allocation for fisheries management. This suggests that there is a need to increase environmental awareness amongst policy makers and not just amongst the fishing community, but also amongst the governments.

Recommendations for the SAP

- Encourage all countries to prepare and implement a National Plan of Action against IUU including the improvement in fishing licensing and capacity building in all aspects of fisheries management.
- Develop and implement a regional cooperation programme where MCS platforms can be shared including establishing regional or sub-regional VMS systems.
- Provide on-the-job training to enforcement officers (pre-patrol planning, developing sustainable financing systems to cover the costs of patrol vessels and airplanes, use of intelligence information, VMS, use of IUU lists, use of research data in terms of fleet movements, AIS data etc)
- Examine potential sustainable financing mechanisms, whereby a proportion of the licensing fees could be allocated towards MCS and enforcement.

(xxiv) Failure to cost the environment

The services provided by marine and coastal ecosystems in terms of food, regulation of water supplies and climate, breakdown of waste products, recreational opportunities, and positive impacts on health and happiness, are however often undervalued (or disregarded) in economic analyses and decision making. Policy-makers may often be put in a situation where they need to make a trade-off between social and economic policy development objectives, and biodiversity conservation and sustainable. Under certain circumstances, the decision-makers (and legislators) may not even be aware of these trade-offs, as there is lack of awareness, understanding and appreciation of economic value of coastal and/or marine ecosystem goods and services, and knowledge is still incomplete. Recognising the value of sustaining ecosystem services now, and embedding this concept into the collective decision making processes at national and

regional levels, would allow the WIO region countries to move towards a more sustainable future, in which the benefits of ecosystem services are better realised and more equitably distributed. One way the full range of benefits derived from coastal and marine resources could be maintained is through better spatial planning, such as can be achieved through land-use plans, ICZM or Marine Spatial Planning (MSP).

Recommendations for the SAP

- Develop and implement a regional training programme in ecosystem valuation methods and cost benefit analysis tools in partnership with appropriate regional and international organizations.
- Undertake a research study to improve the valuation of critical habitats within the WIO region.
- Develop and provide training in sustainable financing options (green taxes, tourist taxes, levies, trust funds etc) for marine protected areas and other aspects of coastal and marine management (including monitoring, control, surveillance and enforcement).
- Provide advice and support on implementing on carbon offset schemes (e.g. REDD+ scheme) for relevant critical habitats (e.g. mangroves and seagrass beds).
- Other activities linked to 'Weak national (strategic) planning and regulatory frameworks for sustainable development'.

(xxv) Limited or lack of education, training and awareness

Raising awareness about environmental and fisheries-related issues amongst marine resource users may increase sustainable behaviours in the future. It has been shown for example, that in Kenya, higher levels of secondary level education were associated with more positive perceptions of fisheries management (Munga *et al.* 2010, McClanahan *et al.* 2005). A number of environmental education initiatives are in place in the different countries in the WIO, often established by non-governmental organisations and these need to be made available on a wider scale. In addition to fisher communities, environmental education initiatives should also be targeted at the younger generation, who often tend to be more vocal and radical and whose collective voice can often influence older generations and peers, bringing about needed change (Baticados 2004). Education programmes should also ideally target women, as it is now well established that low levels of female education can act as a fundamental cause of population growth. Given the increase in tourism and importance of this sector to the economies of the countries, there is also a need to develop aware raising and education programmes that specifically target this sector, both the tourist and tour operators and tour guides.

Recommendations for the SAP

- Develop a regional marine education training programme for inclusion in primary and secondary school curricula (several good examples already exist in the region which could be built upon in partnership with the NGOs that developed the programmes).
- Develop a marine eco-tour-guide training and certification course (good examples already exist in the region which could be built upon, in partnership with the NGOs that developed the programmes).
- Develop a regional marine education training programme for fishers (good examples already exist in the region which could be built upon, in partnership with the NGOs that developed the programmes).

(xxiv) Limited knowledge, access to technology and understanding of best environmental practices

The main issues related to this underlying root cause are as follows:

(i) Lack of extension officers/ environmental inspectors: Historically, many of the countries in the region employed government extension officers that had the responsibility of undertaking outreach and

education work with regards agriculture and indeed fisheries. Many countries noted that they simply lacked staff required to undertake the multitude of tasks, ranging from education and outreach to monitoring and overseeing ESIA processes and enforcing mitigation measures. Lack of government extension officers or environmental inspectors is most often associated with a 'Failure to cost the environment'. In several countries, these officers have been retrenched and this has left the Ministries unable to communicate knowledge, provide access to newer technologies and advise on best practices. This communication vacuum has been filled at least in part by the voluntary sector in some countries, where there are active NGOs that undertake awareness raising and outreach work with local communities. The capacity of many NGOs is however often insufficient to be able meet the need consistently throughout an entire country, and there is still a need for government extension officers, or the development of more formal collaborations between governments and NGOs to ensure that advice is consistent and stable.

(ii) Lack of capacity for Environmental and Social Impact Assessment (ESIA): Related to the underlying cause above, many countries identified specific inadequacies with regards their ESIA processes, staff capacities and technical knowledge in this regard, and public participation in decision making. Most countries identified weak EIA capacity, as well as mediocre EIA compliance rates, as an underlying cause for concern, and there is a particular concern with regards to this capacity in relation to tourism and new oil exploration activities. In most countries, the Ministry responsible for the Environment defines the necessary scoping process for each EIA. Government departments are generally extensively scoped, but the involvement of civil society is rarely a requirement, except when the EIA is presented for public comment. The public commenting process is however insufficient: EIAs are finalised prior to any public involvement; the public are only given a limited period to comment; the mechanism for commenting is poorly advertised and understood; there is no feedback provided on the comments and; no evidence that comments had any influence on the final decision. Ultimately, people are afraid to speak out against the government projects. The NGOs lack capacity and are technically prevented by the *locus standi* provisions in the EIA legislation which are weak. It was recommended that while it would be beneficial to introduce EIAs as mandatory for future projects, there should also be a requirement for Strategic Environmental Assessment (SEA), as this is an internationally recognized tool to help inform the formulation of environmental policies, by identifying the environmental issues, sectors, policies and laws. This would require additional support to ensure that SEAs are carried out for existing and future policy and legislation so that environmental concerns and opportunities are recognized, understood and integrated into policy and law.

(iii) Lack of adequate and reliable (scientific and socio-economic) data and research to support management: Access to reliable data to support policy making and monitoring and enforcement is a fundamental requirement for effective sustainable and adaptive management. Some of the specific data gaps and research needs have been identified through the ASCLME and SWIOFP some of which are outline below:

(iv) Distribution and status of critical habitats: There a need increase knowledge of the spatial distribution and extent of critical habitats within the WIO region and ideally this would be accompanied by a baseline assessment on the status of such habitats (van der Elst et al. 2012). This type of information is a fundamental requirement for Integrated Coastal Zone Management, Marine Protected Area (MPA) planning as well as Marine Spatial Planning, and for the development of EAF Management Plans. It is also essential for the countries to be able to report to the international conventions (e.g. Nairobi Convention, CBD global MPA targets, etc). While there is some near complete spatial datasets available for certain critical habitats (e.g. coral reef, seagrass and mangroves), other habitats (e.g. estuaries and wetlands, dunes, deep sea habitats) are yet to be mapped, and the extent of the former are yet to be verified on the ground.

(v) **Critical habitat monitoring programmes (Corals, Seagrasses, Mangroves and Beaches):** There have been efforts in the past to coordinate the monitoring of coral reef habitats within the region, but there is limited effort to coordinate monitoring of the status of other critical habitats such as mangroves and seagrass beds. The coral reef monitoring programmes in the region are not well coordinated at present. The modalities through which many countries cooperate include Global Coral Reef Monitoring Programme (GCRMN) and ReefCheck, both of which have regional networks around the world, which are meant to share data and knowledge. In the WIO region, the funding for national GCRMN nodes and for the bi-annual meetings has been intermittent due to a lack of support. While national monitoring programmes continue in many countries, support is often *ad hoc* and dependent on grant funding. There are also methodological conflicts and capacity constraints. Many countries simply lack a sufficient number of trained surveyors to undertake monitoring on an annual basis. ReCoMaP reviewed the GCRMN in the WIO but failed to identify a solution (Post 2007). Very few countries have monitoring programmes for seagrasses and mangroves.

(vi) **Connectivity between habitats:** Other gaps that were identified included the need for improved understanding of the connectivity between habitats (e.g. estuarine/wetland/delta and mangrove systems), in terms of environmental flows, population genetics of priority species and interlinkages between habitats with respect to the ontogenetic pathways of priority commercial species. For example, knowledge about the distribution, extent and status of seagrass habitats has received inadequate research attention in the WIO. The linkages between seagrass bed and commercially important species; the importance of seagrass beds as habitats for juveniles of commercial species; and the effects of destructive fishing methods (van der Elst 2012) are areas requiring further studies. Although there is increasing understanding about the importance of some habitats, and their interlinkages, knowledge about habitats such as those found in deepwater, require further research both within EEZ and in ABNJ.

(vii) **Migration and movement patterns:** A significant regional effort should also be undertaken to identify areas of special interest for marine mammals, sea turtles and elasmobranchs, including more in-depth studies of critical habitats, movements and population structure of the most vulnerable species. This could be achieved in partnership with the Ocean Tracking Network (OTN) (<http://oceantrackingnetwork.org/>).

(viii) **Lack of fisheries monitoring programmes:** All three of the main fisheries types (crustacean, demersal and pelagic) as well as other fisheries lack adequate and appropriate data on priority species required for effective management of the fisheries in the WIO region. Where data do exist, they have not been fully analysed to increase the knowledge and understanding about the priority species (Heileman 2012). For the large and some medium pelagic priority species, IOTC collects data on the majority of catches at the regional scale. However, few data have been submitted to IOTC on the small tuna species (IOTC, 2012). The position is worse for the small and medium pelagic species and other artisanal fisheries which fall outside of the IOTC mandate. Overall there is a serious lack of data on catches with which to assess the status of resources as the basis for managing fisheries for optimal and sustainable utilisation (Cochrane and Japp 2012). It is suggested that for each reef associated fishery, a formal Ecosystem Risk Assessment (EAR) should be conducted. Management of deep-sea fisheries remains complicated due to lack of knowledge on stock status and benthic data. Overexploitation of vulnerable species, high levels of by-catch and damage to benthic communities should however be focal points in deep-sea fisheries management (van der Elst 2012).

There is a need to harmonise sampling strategies across the region with particular recommendations to improve the sampling methods, not only for priority species targeted by pelagic fisheries (Lucas *et al.* 2009), but also to improve collection of catch and fishing effort data for the reef demersal fisheries (Heileman 2012). In pursuing these goals, WIO countries need to identify and implement cost-effective

methods for monitoring and assessing small-scale and multispecies fisheries, such as rapid appraisal methodologies and participatory processes rather than trying to emulate the sophisticated and costly single-species approaches that are usually applied for high value fisheries targeting only one or a few species. Such cost-effective approaches are increasingly being promoted and have been referred to as ‘primary fisheries management’, which aim to use the best-available information in a precautionary way in order to ensure sustainability and to minimize the risks of resource over-exploitation or other undesirable outcomes (Cochrane and Japp 2012, Cochrane *et al.* 2011). Such primary fisheries management should be the immediate goal for the WIO countries for their small-scale and data poor fisheries.

(ix) Impacts of different fisheries: The ecological impacts of trawling are unknown (Fennessy 2012). Almost no attention has been being given to this practice in the WIO, hence the pressing need to develop an understanding of this problem so as to improve environmental management of trawl fisheries to prevent further loss of biodiversity and habitat degradation (van der Elst 2012). There is limited understanding of the relationship between shallow-water prawn catches and environmental factors and the linkage of pelagic fisheries with environmental information and these require further investigation (Fennessy 2012, Lucas *et al.* 2009). Experimental work on mitigation measures should be strongly encouraged such as acoustic alarm testing, TEDs and circle hooks (van der Elst 2012, van der Elst *et al.* 2010). For artisanal fisheries, restrictions on the use of drift gill nets should be encouraged as mitigation measures are less suitable for artisanal fisheries due to their prohibitive cost. These limitations could be either spatial or temporal, and based on scientific information on habitat use of bycatch species (Kiszka 2012). Studies are also needed to improve the understanding of trophic interactions, including predator removal, as it relates to fishing activities in the WIO (van der Elst *et al.* 2010).

(x) Bycatch: There is a requirement for improved monitoring of bycatch and it is recommended that SWIOFP should initiate a regional scientific observer programme for all sizeable fisheries to collect reliable information about fishing impacts on target and non-target stocks. There is a particular lack of quantitative data regarding shark, turtle and marine mammal bycatch and therefore this should be addressed at all levels (the on-going Rapid Bycatch Assessment project developed under SWIOFP, will help to address this issue) (van der Elst, 2012). For fisheries that catch tuna and tuna-like species, IOTC member States have agreed to implement a comprehensive Regional Observer Scheme starting in 2011, to estimate the catches of target and bycatch species by placing observers or establishing sampling programmes on artisanal fisheries. Sufficient resources need to be made available for this Observer Scheme to achieve the agreed sampling coverage targets.

(xi) Vulnerable species: Further studies are also required on the distribution and abundance of vulnerable species in the WIO region. Population boundaries for marine mammals should be better defined and the implementation of a regional project on coastal marine mammal population structure and boundaries should be further encouraged. The genetic stock structures and population dynamics of sea turtle stocks in the region (including hatching success, sex ratios, and natural mortality), should be addressed. Studies on the population structure of shark species are recommended. Shark Assessment Reports should be implemented and a National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks) should be developed in all WIO countries, which have not yet done so. Similarly, member states which have not yet developed NPOA-Seabirds should be urged to initiate assessments of the risks of their fisheries to seabirds, and prepare NPOA-Seabirds accordingly and an FAO Regional Plan of Action for seabirds should also be developed by SWIOFP. A list of vulnerable and endangered teleost fish species should be drawn up (collated *IUCN Red List* species) for the WIO and regional protection strategies developed (van der Elst 2012). IOTC member States have adopted measures to

mitigate the impact on vulnerable species such as marine turtles, seabirds and sharks in the pelagic ecosystem. These binding actions need to be fully implemented by the IOTC member States.

(xii) Limited research into marine invasive species and algal blooms: Few studies have been carried out on invasive species in marine waters of WIO. Baseline studies on invasive species are needed. Few studies have been carried out on productivity in marine waters of WIO. Baseline studies on productivity and bloom species are needed.

(xiii) Lack of knowledge on persistent organic pollutants: The spatial extent, magnitude and significance of different sources of persistent organic pollution of water, sediment and biological tissue are extremely poorly understood. Surveys of persistent organic pollutants in sediment and commonly consumed fish and shellfish and in various potential sources (most importantly effluent and storm water discharges) in and near large coastal cities should be performed as a matter of urgency. Persistent organic pollutant monitoring is expensive and so a suite of persistent organic pollutants that are known to be problematic in terms of the risks they pose to ecological and human receptors (e.g. those defined by the Stockholm Convention). Samples could be archived and analysed for other persistent organic pollutants should the need arise. The data from such a survey will provide an understanding of whether persistent organic pollutants pose ecological and human health risks in the monitored areas, identify important sources and hotspots, and provide a 'baseline' against which to track temporal changes.

(xiv) Unknown impact of agricultural run-off: The importance of agriculture as a source of persistent organic pollutants needs to be determined. Some of the most frequently detected persistent organic pollutants in coastal waters in many regions of the world are pesticides and herbicides. Importantly, nine of the 12 persistent organic pollutants identified in the Stockholm Convention are pesticides. Surveys of the persistent organic pollutants in estuaries will provide valuable information in the importance of pesticides applied to agricultural lands in the hinterland as contaminants of coastal waters.

Recommendations for the SAP

(i) Generating knowledge

- Develop and agree standards, best practice guidelines (where necessary), policy briefs and additional outline legislation (where necessary), for agriculture.
- Develop and agree standards, best practice guidelines (where necessary), policy briefs and additional outline legislation (where necessary), for ports and transportation (to include case studies on schemes from within the region, ballast water handling etc.).
- Develop and agree standards, best practice guidelines (where necessary), policy briefs and additional outline legislation (where necessary), for mining (artisanal and commercial, solid and waste water management).
- Develop and agree standards, best practice guidelines (where necessary), policy briefs and additional outline legislation (where necessary), for oil and gas (particularly with regards offshore exploration and extraction, loading terminals, and re-settlement procedures).
- Develop and agree standards, best practice guidelines (where necessary), policy briefs and additional outline legislation (where necessary), for eco-tourism and related activities (case studies surfing, kite surfing, SCUBA diving, snorkelling, sailing, sea kayaking, beach traders, water quality, and whale and dolphin watching).
- Provide support for the adoption of environment management systems (EMS), audits and verification in schemes for hotels and guesthouses.
- Examine interest and potential for establishing a regional eco-tourism certification brand.

- Encourage the development of land-based eco-tourism development strategies on the islands.
- Undertake a review of the national legislation and institutional framework related to ESIA/SEA, including the procedures and support provided for public participation in these processes.
- Establish a regional training programme for government officers in ESIA/SEA, to build their capacity in providing oversight and guidance in these procedures.
- Support the preparation of awareness raising materials to encourage and support public participation in ESIA/SEA processes, including feedback mechanisms.
- Distribution and extent of critical habitats.
- Provide regional training to government officers in standard methods for mapping and ground-truthing (validating) the distribution of critical habitats (coral reefs, seagrass beds, mangroves) and other habitats not previously mapped (e.g. beaches, sand dunes, wetlands), which should also include a simple method to record the status of each habitat.
- Provide support for national teams to undertake ground-truthing surveys to collect field data to validate existing habitat maps (where available) or to create new habitat maps (where needed), and to assess the status of habitats (linked to establishment of monitoring surveys see below).
- Prepare maps showing the regional distribution and status of critical habitats (coral reefs, seagrass beds, mangroves) and other habitats not already mapped.

(ii) *Monitoring critical habitats*

- Prepare a regional training programme in standard methods for monitoring critical habitats (coral reefs, seagrass beds, mangroves, sand beaches), using the most appropriate tools or those that have already gain wide acceptance in the region (e.g. GCRMN, Sandwatch).
- Identify a cohort of regional trainers, and provide them with training in monitoring, and then support and enable them on the basis of a train-the-trainer programme, to enable them to provide training and ongoing support to relevant national groups (either governmental or non-governmental organisations).
- Provide support for national teams to establish (or indeed re-establish) monitoring programme in countries where there are insufficient monitoring. Or provide support for a review of existing monitoring programmes to ensure that the data collected through these programmes can be effectively be used to support management.

(iii) *Ecosystem Connectivity*

- Prepare a regional research programme to investigate the environmental flows and connectivity between critical habitats, supported by local oceanographic models.
- Prepare a regional research programme on population genetics for priority commercial species.
- Support the implementation of a standardised water quality monitoring programmes, and sediment sampling programme, to measure a fixed suite of key variables, to include nutrients, faecal coliforms, and persistent organic pollutants.
- Prepare a regional research programme to expand understanding of the residency and movement patterns of vulnerable or focal species (e.g. sea turtles, sharks, rays).
- Support a regional research programme to understand population genetics and stock connectivity of priority species.

(iv) *Fisheries Monitoring*

- Undertake formal Ecosystem Risk Assessment (EAR) for reef and demersal fisheries.

- Identify and implement cost-effective methods for monitoring and assessing small-scale and multispecies fisheries, such as rapid appraisal methodologies and participatory processes, aiming to use the best-available information in a precautionary way in order to ensure sustainability.
- Support a research project to explore the relationship between shallow-water prawn catches and environmental factors.
- Support a research project to improve understanding between the pelagic fisheries (small, medium and large) and environmental factors.
- Impact of fisheries on habitats.
- Support a research project to explore and quantify the ecological impacts of trawling and other fishing gear types (e.g. traps) on habitats and vulnerable species.
- Support a research project to determine the ecological impacts of deep water fisheries on vulnerable species and benthic communities.

(v) By-catch

- Support research into the effectiveness of different mitigation measures (e.g. acoustic alarms, TEDs and circle hooks) for gear types known to result in high levels of by-catch.
- Encourage the countries to put restrictions in place on gear types already known to result in high levels of bycatch of vulnerable species (drift gill nets).
- Ensure that future monitoring programmes record by-catch and support and encourage the implementation IOTC Regional Observer Scheme.

(vi) Vulnerable species

- Support a research project(s) into genetic stock structures, residency and migration patterns, of vulnerable species.
- Encourage the countries to put restrictions in place on fisheries that specifically target vulnerable species (e.g. sharks and rays).
- Support and encourage countries to prepare National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks).
- Support and encourage countries to prepare National Plan of Action for the Conservation and Management of Birds (NPOA-Birds).
- Prepare regional protection strategies for IUCN Red listed teleost fish species for the WIO;
- Other research needs.
- In partnership with other organisations (e.g. IUCN Invasive Species Specialist Group) implement research programme to conduct baseline surveys to identify marine invasive species.
- In partnership with other relevant organisations implement a regional research programme to explore the incidents of harmful algal blooms and de-oxygenation events.
- In partnership with other relevant organisations undertake research to investigate the evidence for and impact of agricultural run-off on critical marine habitats (e.g. seagrass, coral reefs, mangrove forests).

(xv) Insufficient capacity to be able monitor and predict climatic events: Climate change is expected to lead to a shift in the timing and intensity of synoptic weather systems, with shifts in regional winds and the distribution of rainfall, ocean dynamics and biogeochemistry. There has also been a warming of surface waters, and a possible poleward migration of the oceanic westerly winds, with an increase of the leakage of Indian Ocean waters into the South Atlantic and beyond (Biajoch *et al.* 2009). This could have potential consequences for the global thermohaline overturning circulation. Capacity of the countries

within this region to monitor these large scale processes has been limited. There is a need for more continuous observations of ocean-atmosphere interactions within the WIO region. To date, while there have been observations, these are often a short term projects, with few measurements being made on a routine basis. Expanded operational oceanography capacity would increase the collection of an integrated set of observations, on a routine basis, with the measurements being disseminated to the marine community in regular state of the marine environment reports. Ocean atmosphere interaction is being investigated in ocean models and there has been a concerted progress towards downscaling global to regional to local models. The eventual objective would be to achieve of operational real-time predictive models, utilising the observations from operational oceanography.

SAP Recommendations

- Support and facilitate research on the effects of climate change on coastal and marine ecosystems (sea level rise, ocean acidification etc.).
- Expand upon the regional ocean-atmosphere monitoring programme commenced during the ASCLME project with support from international partners.
- Establish more coastal monitoring sites.
- Provide training to students etc.

(xvi) Open access resource/'Tragedy of the Commons': Many of the resources in WIO countries (e.g. fisheries, timber, mangrove, beach sand) are effectively 'open access'. This can lead to a situation known as 'Tragedy of the commons', whereby shared resource are depleted by individuals, acting independently and rationally according to their own self-interest, despite understanding that depleting the common resource is contrary to their long-term best interests. This underlying cause is often associated with other underlying causes such as a 'Lack of management capacity in terms of monitoring, control, surveillance and enforcement capacity', 'Low compliance', 'Rural poverty, coastal migration and urbanisation', but also due to a lack of management of these resources.

(xvii) Lack of fisheries management plans for priority species: Fisheries management plans are in place for some priority species, but these may be inconsistent. For example, while there are measures in place for the industrial shallow water prawn trawl sector, in the small-scale sector there is no effort limitation, few management measures and low compliance. The need to improve management of the small-scale sector has been demonstrated in Madagascar where, despite implementation of bio-economic modelling recommendations for the management as well as a strong industry-management association, the trawl fishery continues to decline because of the failure of management to curtail over-fishing by the traditional sector (Fennessy, 2012). Improved management of the small-scale traditional prawn fisheries including the implementation of effort limitations and development of management plans in collaboration with local stakeholders is therefore essential. Surveys of the small-scale sector also need to be improved and stock assessments should include both the small-scale and industrial sectors. Madagascar has made a pre-application for certification of its trawl fishery under the Marine Stewardship Council (MSC) (Fennessy, 2012). The spiny lobster fishery of the Lamu District in Kenya, which is done by the kimean diving methods, has also undergone the pre-assessment. This fishery is currently undergoing full stock assessment and developing a management plan in order to undergo MSC certification process (FAO-SWIOFC, 2012).

(xviii) Lack of regional management strategy for shared stocks: The crustacean, demersal and small-pelagic fisheries are managed at the national level only and there is no regional management strategy, despite the fact that several of the priority species are widely distributed in the WIO region and could be

shared or transboundary. Little information exists on the transboundary nature of the priority demersal and small pelagic species. The stock identity and the spatial and temporal distribution of the priority demersal species needs be determined and this information taken into account in decision-making. Where it is confirmed that stocks are shared, mechanisms should be established for collaboration between the countries concerned, including collection and sharing of data, joint assessment and management (Heileman 2012). SWIOFP undertook population genetic studies of key deep-water crustacean species to assess connectivity and assist in the decision on whether the trawl and trap fisheries should be managed at regional levels in the SWIO. Despite the apparent transboundary distribution of the fished stocks, considerably more information is required to justify a shift in fisheries management strategy, from national to sub-regional or regional management plans for the deep-water crustacean fisheries (Groeneveld 2012a; b). For the shallow-water crustacean fishery, there is no genetic evidence at this stage to indicate that the three priority shallow water prawn species are shared between two or more countries in the region. It is therefore appropriate that the stocks in each country continue to be managed separately until such time as the genetic studies are complete (Fennessy 2012). Some of the small pelagic species that are also species under the mandate of IOTC will benefit from a higher participation of the member States in the region in the activities of the IOTC that are focussed towards assessing the status of these resources, and agreeing to management actions based on the scientific advice.

(xix) Limited progress towards CBD MPA global targets: There are numerous MPAs in the WIO, ranging from small highly protected no-take zones through to larger multiple-resource use areas, the majority of which focus on coral reefs (UNEP-WCMC 2008). Many MPAs in the region were established following a top-down approach and sometimes in a reactive manner. More recently however the tendency has been towards establishing community managed or co-managed MPAs, such as the community led MPAs in Madagascar, Comoros and Rodrigues. An assessment of the effectiveness of a group of eight MPAs in the WIO region, which included MPAs in Kenya, Tanzania, and Seychelles, revealed that while some MPAs were effective, the process of self-assessment was not widespread, and there was lack of monitoring programmes designed to inform management. A study about progress towards the global CBD targets and national and regional MPA networks, revealed that while some countries are making good progress (e.g. 8.7% in Kenya, 7.9% in Tanzania, and 4.0% in Mozambique), and there were national level efforts underway to establish new or retrofit existing MPAs networks in several countries because the existing MPAs were rarely fully representative of the different range of habitats, nor were they designed as a interconnected network (UNEP-WCMC 2008).

Recommendations for the SAP

Crustacean Fisheries

- Surveys and stock assessments for both the small-scale and industrial crustacean fisheries.
- Support improved management of small-scale traditional prawn fisheries through effort limitations and preparation of management plans in collaboration with local stakeholders.
- Provide support to strengthen management systems to facilitate the implementation of eco-certification (Marine Stewardship Council) for crustacean fisheries (and others).

Demersal Fisheries

- Expand the observers programme and provide regular training to observers, data collectors and other relevant persons (fisheries researchers and officers) in species identification and sampling methods, and collection of biological data, using standardised sampling strategies.

- Revise management plans to incorporate the stock assessment information and to explicitly consider the priority species and the major fisheries that target them.
- Experimental work on mitigation measures (acoustic alarm testing, TEDs and circle hooks) should be strongly encouraged.

Pelagic Fisheries

- Address the lack of data on fish catches and effort for small and medium pelagics, for use in assessing the status of stocks to guide fisheries management and sustainable utilisation of these valuable resources.
- Implement a boat-based scientific observer programme for commercial pelagic fisheries to collect data (catches by species, fishing effort, size and sex composition, age and growth, and bycatch), through the IOTC Regional Observer Scheme.
- Implement a shore-based scientific observer programme for artisanal fisheries for small, medium and large pelagics to collect data (catches by species, fishing effort, size and sex composition, age and growth, and bycatch).
- Strengthen the IOTC's Tuna Tagging Programme (using archival pop-up and sonic tags) to track horizontal and vertical movements (particularly for bigeye tuna and swordfish), to determine the habitat and behaviour of medium and large pelagic fishes.
- Improve data collection at ports, sampling stations/landing sites and data analysis and reporting, through bilateral support programme, such as IOTC and Overseas Fishery Cooperation Foundation of Japan, which provided training.

Other fisheries

- Encourage and support countries to undertake stock assessments of key invertebrate stocks (e.g. sea cucumber) and to incorporate this information in the development of management plans.

Marine Protected Areas

- Undertake a regional review to assess progress towards the global CBD MPA targets within the region.
- Provide training and support to mainstream the adoption of national MPA management effectiveness assessments into national processes and reporting mechanism (e.g. NBSAP) within the region.
- Provide support for the countries to establish effective representative networks of MPAs at the national level through rebuilding and sustaining the regional MPA manager knowledge sharing and support networks.
- Provide specific targeted advice to aid the countries to assess and revise their relevant monitoring programmes to ensure these inform adaptive management and management effectiveness assessments.
- Provide training in management plan preparation, how to write and prepare budgets for strategic and operational management plans.
- Provide training in sustainable financing for MPAs.

(xx) Inadequate investment in infrastructure/poor maintenance

This is manifested in the WIO region through the following underlying root causes.

(a) Lack of investment in port/harbour infrastructure: The countries of the WIO all have one or more ports. While some of the more modern ports are well equipped, the majority of others are old and lack

necessary facilities to handle liquid or solid wastes. In Madagascar, for example, maritime transportation is very important and there are numerous harbours dotted around the island. In harbours there are accidental spillages of pollutants (e.g. chemical products and oil) during cargo handling, but there also tends to be a lack of facilities to handle garbage, oil residues and wastewater from vessels, and lack of facilities and infrastructure to remove wrecks (Mong et al. 2009). In Tanzania, Dar es Salaam, Tanga, Mtwara and Zanzibar are the major ports along the Tanzanian coast, with smaller ports situated at Kilwa, Lindi and Mafia (ASCLME 2012c). The port at Dar es Salaam is the largest and also serves the neighbouring countries, but there are high levels of heavy metal and organophosphate levels in port sediments, chemical spills and waste management are also problematic (Mohammed et al. 2008).

(b) Lack of investment/outdated wastewater disposal and treatment infrastructure: The increase in population and demographic changes have significantly affected the demand for land for housing and associated infrastructure (e.g. sanitation and waste management). In South Africa, while cities have well-developed, modern infrastructure, many people in informal settlements and rural areas lack access to basic services (ASCLME 2012e). In Tanzania, the economy has been growing between 6.7% and 7.8% over the past seven years, but despite this, there has been relatively limited improvement in infrastructure, education and health sectors. Although more than 90 per cent of households have toilet facilities, but these are mostly pit latrines (ASCLME 2012c).

(c) Lack of investment in solid waste collection and disposal facilities: The WIO-LaB Project Marine Litter report (UNEP and WIOMSA 2008), noted that Mauritius, Seychelles and South Africa have the institutional and legal frameworks, as well as human and material resources to manage waste fairly adequately, and they contribute relatively little to marine littering. Conversely Comoros, Kenya, Madagascar, Mozambique and Tanzania appear to have very limited waste management capacity (UNEP and WIOMSA 2008). However even those countries with adequate provisions are still finding this a challenge given the continued increase in coastal populations.

(d) Lack of investment in small-scale fisheries infrastructure: Several countries identified challenges associated with the lack of or inadequate post-harvest support and structures, which limits small scale fisheries from being able to maximise the value of their landings and prevents them accessing other more valuable markets such as EU which has requires specific storage and processing requirements. For example, the small-scale fisheries sector in Tanzania is constrained by inadequate infrastructure, including lack of capacity for processing, storage and transportation facilities. The post-harvest fish losses due to lack of storage and processing facilities are estimated to be 20% (ASCLME 2012c).

(e) Lack of investment in alternative technologies (e.g. solar): Several countries in the region are still heavily dependent on non-renewable sources of energy, and in some countries there is still a high level of dependency on diesel generators and kerosene (e.g. ASCLME 2012i). Most countries are however beginning to explore the potential of alternative technologies to meet the growing energy demands. The scale of these investments is however insufficient to date. In Tanzania, fuelwood and charcoal are the main sources of energy for most people in the coastal region, especially for use in cooking. Lack of an alternative energy source, especially in rural areas, has imposed severe demands on forest resources due to unsustainable harvesting of wood.

SAP Recommendations

- Explore the options to promote further private-sector involvement in ports, whether through privatization or joint-ventures.

- Provide support to improve waste water management and treatment, working in partnership with other relevant organizations.
- Provide support to increase the use of rain-water harvesting and grey water recycling scheme.
- Provide targeted support (where needed) to promote national beach cleanup days, through marine education schools programmes.
- Support and encourage the use of alternative technologies.

(xxi) Wealth creation and corruption/Lack of transparency: There were various issues where a lack transparency in Government decision making processes, and wealth creation and corruption, were considered to be an important contributory underlying cause for the issues of concern. While not all countries specifically mentioned corruption or openly described the impact within their MEDA or CLA, this arose as a common underlying cause during discussions at the National CCA meeting. Corruption was identified as a challenge affecting various sectors in the WIO countries. The sectors that appear particularly susceptible to corruption include ports and transportation, mining, fisheries, and tourism.

Another important regional arena where greater transparency could bring widespread benefits, and help lower corruption, is the fisheries access agreements. The terms of these agreements, such as restrictions placed on fishing intensity, gear type, by-catch, and the permitted areas or seasons in which boats can operate are also often not made publically available (Standing 2011). This lack of transparency creates opportunities for corruption and bribe payments, while the general population is oblivious as to how their marine resources are being managed and how the wealth generated from fisheries is being used (Standing 2011). Increasing transparency would support regional collaboration, bolster the bargaining position of weaker host countries, and could be used to strategically target funding gaps, such as FAO Port States Measures.

SAP Recommendations

Provide support to encourage greater transparency in public accounting, especially for key sectors such as agriculture and forestry, fisheries, and extractive industries such as oil and gas and mining.

(xxii) Lack of sustainable alternative livelihoods: Many different alternative livelihoods schemes have been developed in the WIO region and these have attempted to provide fishers with new livelihood opportunities. Examples include the development of aquaculture for crabs, fish, prawns and seaweed, post-harvest processing, ecotourism and handicrafts. These schemes have met with varying levels of success and although they may raise the economic standard of living of coastal fishing communities, examples of where the promotion of alternative livelihoods have resulted in reduced fishing effort are less common, as fishers leaving the fishery are simply replaced by other or, they continue to fish in addition to their supplemental livelihood. Where such schemes do exist, they have been established in combination with resources management strategies limiting entry into the fishery (IBRD/World Bank 2004).

New alternative livelihood strategies should be based on community-driven programmes and offer a wide range of options to fishers. A bottom-up approach that identifies alternative livelihood options through a fishing community-needs assessment should be used taking into consideration local opportunities, fisher's skills, cultural behaviour, and the role of women in the fishery. This should be further complemented by technical assistance to conduct a comprehensive feasibility study on different possibilities in order to make informed decisions about which livelihood options are most feasible. Options outside of the fishing sector should be considered rather than being bound to other subsectors for example, aquaculture and offshore pelagics. However, coastal communities may require extensive socialisation before being accepted by fishers. There is also value in developing projects which produce for the local market (eat local) because they have a stable market and are not reliant on changeable tourist or export demand. On-

going training programmes for fishers are also vital to the success of the development of any alternative livelihood programme. The international donor community can assist developing countries in the establishment of the local empowerment and community-development mechanisms to develop alternative livelihood opportunities. Some of the European bilateral donors such as the International Fund for Agricultural Development (DFID) and the Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation, GTZ) and international agencies such as the International Fund for Agricultural Development (IFAD) and the World Bank, have considerable experience in this area (IBRD/World Bank 2004).

SAP Recommendations

Undertake a review, assessment of existing alternative livelihood programmes established within the region, and identify best practice case studies, and capture lessons learnt.

(xxiii) Limited public participation in governance: Public participation in coastal management has historically been very low in some of the WIO countries while in other countries it has been consistently high. In the Seychelles, for example, there is no statutory provision with regards public consultation, apart from the EPA which allows public participation in the EIA process. Public consultation has been low but has increased over the last decade, as a result of district administrations and individual projects encouraging greater involvement, often facilitated through the establishment of national taskforce committees or coordinating bodies (Seychelles CLA 2012). Private sector participation in coastal management issues has also increased, and several large-scale projects now have the private sector more involved in environmental protection. Some of the businesses have made donations to implement environmental projects, while others have formed partnerships to collaborate in environmental awareness-raising (Seychelles CLA 2012). In general the trend within the WIO is towards greater participation although there is a need to continue to build on these efforts and to ensure greater engagement of stakeholders in marine and coastal related issues.

SAP Recommendations

Undertake a review, assessment of existing co-management efforts within the region, identify best practice case studies, for MPAs, EIAs etc. and capture lessons learnt.