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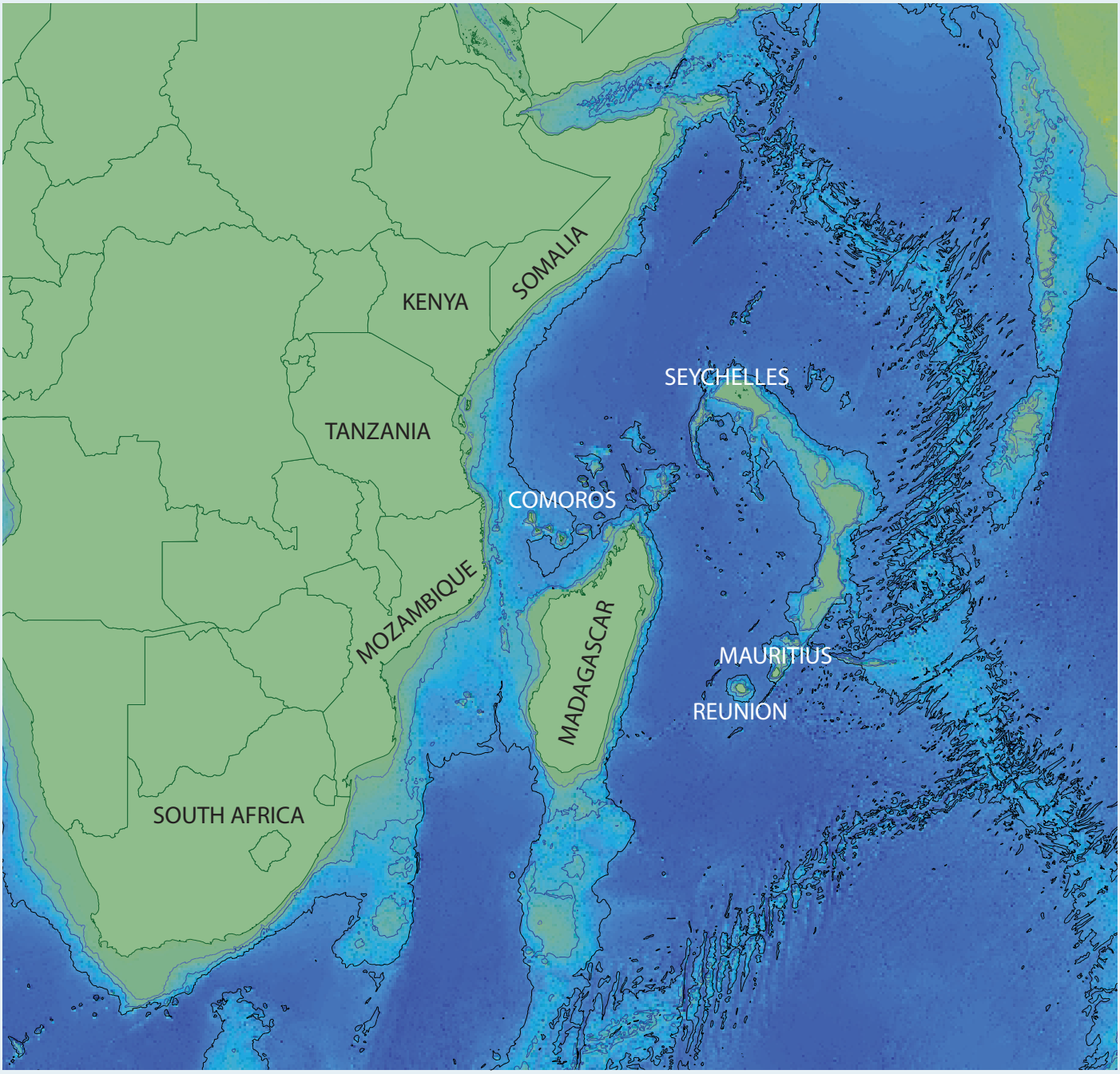
of the Large Marine Ecosystems of the western Indian Ocean



ASCLME
Agulhas and Somali Current Large Marine Ecosystems Project

Volume 2 : Diagnostic Analysis

SWIOFP
SOUTH WEST INDIAN OCEAN FISHERIES PROJECT

TDA

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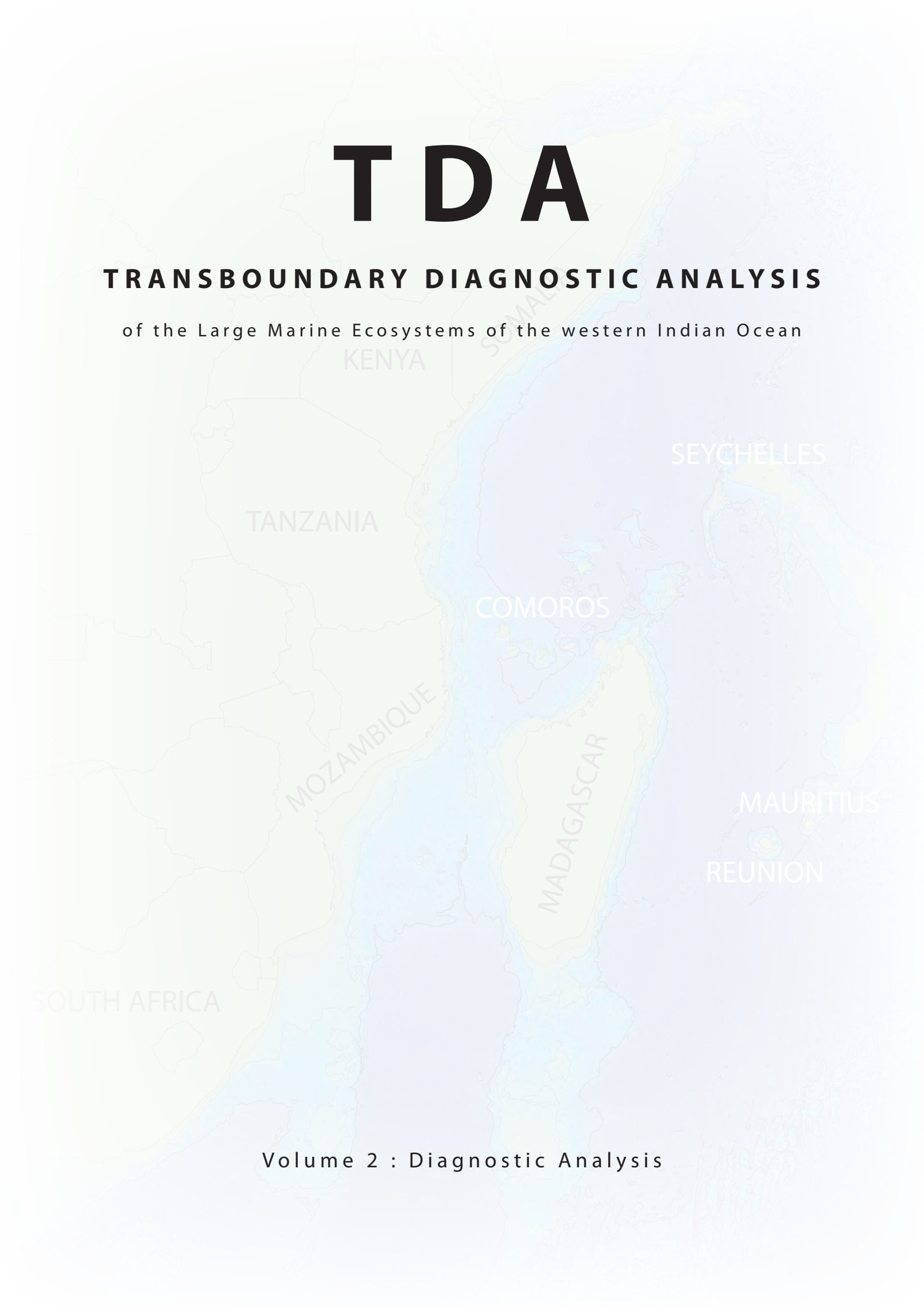

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Appendices are available in digital form from the ASCLME and SWIOFP websites and will also be available at OceanDocs.org.

Note

Volume 1 *of the TDA contains the Biophysical and Socio-Economic review;* ***Volume 2*** *contains a discussion of Areas of Concern, and the Causal Chain Analysis. Page numbering continues from Volume 1.*

8. Prioritisation of main transboundary areas of concern

The issue identification and prioritisation process adopted for the ASCLMEs commenced at the national level. Areas of concern were captured from the national MEDA documents 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 during the National Causal Chain Analysis Meetings held in participating countries in the period between 14th July 2011 and 15th August 2011. The prioritisation process was repeated at the regional level during the Regional TDA-III Meeting held in South Africa (9th to 10th May 2012) and the final results consolidated at the Regional TDA-IV Meeting held in Mauritius (24th to 27th July 2012). The final outcome of this national to regional process was the identification of a suite of 21 top priority transboundary issues for inclusion in the Strategic Action Programme (SAP). At the final regional TDA-IV meeting, priority issues were taken through a process where country representatives identified Ecosystem Quality Objectives (EQOs, Objectives, Targets (5-year and 20-year), proposed actions and proposed indicators. Results are presented in Appendix IV.

This chapter presents a summary of the process and outcomes of the national and regional level meetings, and a summary description of each of the issue categories. For each issue category, there is a general **'Problem Statement'**, which outlines the broad generic characteristics of the issue. This is followed by a summary of the **'National Issue Scoping'** exercise which examines the relevance of each issue at the national level and presents the evidence as derived from the draft MEDA documents (detail is presented in Appendix VI). This is followed by the results of the **'Transboundary Scoping'**, which presents a summary of the key results from both the national and regional prioritisation exercises. The results of the national and regional prioritisation are presented in Appendix VII, and the process is fully described in the 'ASCLME National CCA Meeting Report' (Klaus 2012), the ASCLME Regional TDA-III Meeting Report (Scott 2012a) and ASCLME Regional TDA-IV Meeting Report (Scott 2012b).

8.1 Issue Scoping and Prioritisation Process - National to Regional

The process used to identify and prioritise the issues at the national and regional level is illustrated in the schematic diagram shown in Figure 28 and described below:

8.1.1 Issue Identification and Categorisation

The issue identification process commenced with a thorough review of the MEDA reports of each of the participating countries. The purpose of the review was to capture the full range of issues impacting upon the ASCLMEs in each of the participating countries. Issues or concerns described in the MEDAs, and those highlighted at the end of each subsection of the MEDA were documented for each country. All issues from all 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 that were identified through this process are presented in Table 23 below.

Table 23: Issue Categories identified through the scoping process

MAC01	Water quality degradation
1.1.	Alteration of natural river flow and changes in freshwater input and sediment load
1.2.	Degradation of ground and surface water quality
1.3.	Degradation of coastal and marine water quality
1.3.1	Microbiological contamination from land-based (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) sources
1.3.2	Nutrient enrichment from land-based (domestic , industrial, agriculture, livestock) and marine (mariculture) sources
1.3.3	Chemical contamination (excluding oil spills) from land-based (domestic, industrial and agricultural) and marine (shipping, dumping at sea) sources
1.3.4	Suspended solids in coastal waters due to human activities on land and in the coastal zone
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	**Habitat and community modification**
2.1.	Shoreline change, due to modification, land reclamation and coastal erosion
2.2.	Disturbance, damage and loss of coastal, watershed and upland habitats
2.2.1.	Disturbance, damage and loss of upland / watershed habitats (>10 m elevation)
2.2.2.	Disturbance, damage and loss of coastal forest habitats
2.2.3.	Disturbance, damage and loss of coastal habitats (beaches, dunes, coastal vegetation and flood plain habitats to 10 m elevation)
2.2.4.	Disturbance, damage and loss of wetland habitats
2.2.5.	Disturbance, damage and loss of estuarine habitats
2.2.6.	Disturbance, damage and loss of mangrove habitats
2.3.	Disturbance, damage and loss of subtidal benthic habitats
2.3.1.	Disturbance, damage and loss of coral reef habitats
2.3.2.	Disturbance, damage and loss of seagrass habitats
2.3.3.	Disturbance, damage and loss of macroalgal habitats
2.3.4.	Disturbance, damage and loss of soft sediment habitats
2.3.5.	Disturbance, damage and loss of deep water habitats (including sea mounts)
2.4.	Disturbance, damage and degradation of pelagic habitats (nearshore <30 m, neritic 30-200m and oceanic >200m depth)
2.5.	Increase in the occurrence of harmful or toxic algal blooms (HABs)
2.6.	Introduction of exotic non-native species, invasives and nuisance species
MAC03	**Declines in living marine resources**
3.1.	Declines in populations of focal species
3.1.1.	Declines in populations of marine mammals
3.1.2.	Declines in populations of cetaceans
3.1.3.	Declines in populations of seabirds
3.1.4.	Declines in populations of turtles
3.2.	Declines in populations of commercial fish stocks
3.2.1.	Declines in populations of sharks and rays
3.2.2.	Declines in populations of large pelagic
3.2.3.	Declines in populations of small pelagic
3.2.4.	Declines in populations of deep water demersals
3.2.5.	Declines in populations of reef and demersal fish
3.3.	Declines in populations of commercial invertebrates
3.3.1.	Declines in populations of molluscs (bivalves, gastropods)
3.3.2.	Declines in populations of abalone*
3.3.3.	Declines in populations of cephalopods
3.3.4.	Declines in populations of sea cucumbers
3.3.5.	Declines in populations of sea urchins*
3.3.6.	Declines in populations of prawns and shrimp
3.3.7.	Declines in populations of lobsters
3.3.8.	Declines in populations of crayfish*
3.3.9.	Declines in populations of crabs

3.4.	Excessive bycatch and discards
3.5.	Expansion of mariculture industry (biosecurity, diseases in wild stocks, exotics, habitat implications, water quality)
MAC04	**Unpredictable Environmental Variability and Extreme Events**
4.1.	Climate hazards and extreme weather events (cyclones, storms, rainfall, coastal flooding)
4.2.	Sea level change
4.3.	Ocean acidification
4.4.	Changes in seawater temperatures
4.5.	Changes to hydrodynamics and ocean circulation
4.6.	Changes in productivity (shifts in primary and secondary production)
4.7.	Geohazards (tsunamis, volcanic eruptions, earthquakes)

* Issue that was subsequently removed from the list during the Regional TDA-III workshop

8.1.2 Issue Classification and Preparation of Draft Issues Framework

The 50 issue categories identified (above) 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. This 'Draft Issues Framework' provided one of the first points for discussion at the National CCA meetings.

8.1.3 National Issue Validation and Prioritisation Process

National CCA meetings were held in each of the nine participating countries in the ASCLMEs between 14th July 2011 and 15th August 2011. The National CCA meetings followed the same agenda in each country. The process used and results of these meetings are presented in full in the 'ASCLME National CCA Meeting Report' (Klaus 2012) and briefly summarised below.

Each meeting commenced with a series of presentations to update participants on project progress, to introduce the 'Draft Issues Framework' and to explain the CCA process. Meeting participants were 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 to help the participants to:

- Validate the issues included in the 'Draft Issues Framework' and complete a Level 1 prioritisation process (results presented Appendix VII Table A1 and A2);
- Identify the availability of baseline data or a monitoring programme related to the issue (results presented in Appendix VII Tables A3 and A4)
- Complete a more detailed Level 2 prioritisation process (results presented in Appendix VII Tables A5-A7) 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 ASCLMEs, 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. A summary of results of this national level prioritisation process are presented in Appendix VII.

8.1.4 Regional Issue Validation and Prioritisation Process

At the subsequent Regional TDA-III workshop, 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 level, at the regional level. 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 but not the regional level or vice versa, these 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.

8.2 Results of the prioritisation process

At the Regional TDA-IV workshop, held in Mauritius between 21st and 24th July 2012, the delegates 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 24. These high priority transboundary issues will be taken forward for inclusion in the ASCLME Strategic Action Programme (SAP). In addition to these high priority transboundary issues, the countries identified some emerging issues which they wanted to be captured.

Table 24: 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 pelagics
	3.2.3.	Decline in populations of small pelagics
	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

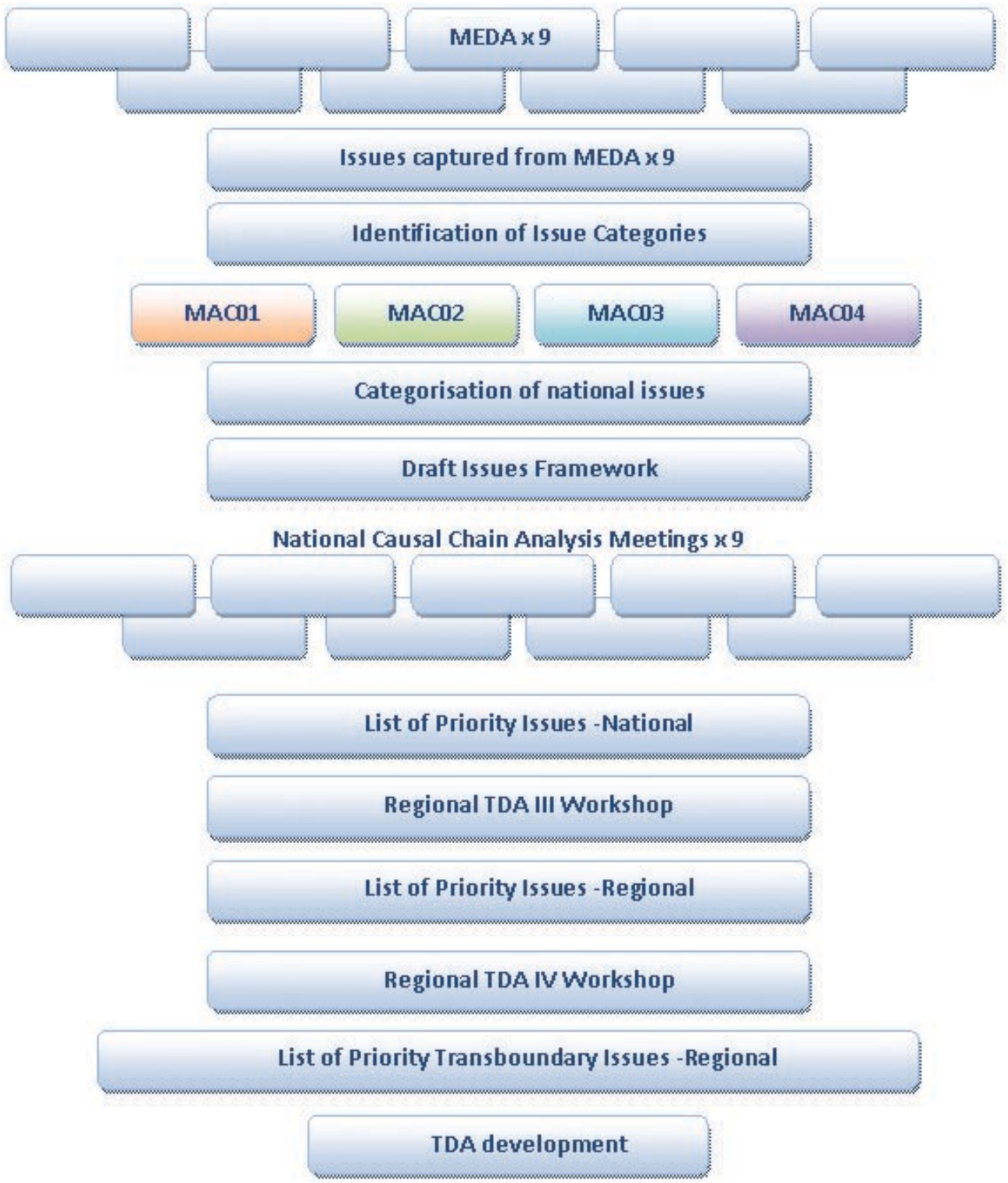

Figure 28: Schematic diagram illustrating the ASCLMEs MEDA to CCA process, showing the analysis of the issues and causal relationships at the national level, before TDA development

8.3 The Issues

In the following section, each of the issues identified in the framework are described and presented along with the results of the prioritisation at the national and regional level. For each issue category, there is a general '**Problem Statement**', which outlines the broad generic characteristics of the issue. This is followed by the results of the '**Transboundary Scoping**', which presents the key results of both the national and regional prioritisation exercises. The results of the '**National Scoping**' exercise, which examines the relevance of the issue at the national level and presents the evidence as derived from the draft MEDA documents is presented in Appendix VI.

MAC01 Water Quality Degradation

Water quality within the WIO region is being degraded by a combination of factors associated with changes in the quality, quantity and timing of river flows, and due to contamination of ground and surface waters and coastal and marine waters from land- and marine-based sources. The issue categories identified from the MEDAs associated with this Main Area of Concern are described below:

1.1 Alteration of natural river flow and changes in freshwater input and sediment load

Problem Statement

The interaction between river catchment and drainage basins and their impact on the coastal and marine environment is an issue of concern affecting all of the countries within the WIO region. There has been a decline in the quality, quantity or timing of natural river flows in many of the drainage basins, impacting upon the salinity levels in estuarine habitats (UNEP/Nairobi Convention Secretariat, WIOMSA 2009), which often serve as nursery habitats for commercially important species of fish and crustaceans. There have also been changes in the sediment and contaminant loads carried by rivers and estuaries, with significant impacts on coastal sediment transport dynamics and shoreline configuration, and resulting in siltation and pollution of nearshore marine habitats (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). In the northern parts of the WIO region (e.g. Somalia and Kenya) the total annual river discharge has been estimated to be in the range of 1.8 to 4.95 km^3/yr. Further South (e.g. Tanzania, Mozambique and South Africa) the annual river discharge is higher and in the range of 2.9 to 106 km^3/yr (Hatziolos *et al*. 1996, Hirji *et al*. 2002). Consequently, the southern parts of the WIO region are characterized by the presence of large estuarine zones supporting extensive mangrove forests.

A reduction in the quality and quantity of river water poses a severe threat to the availability of freshwater for irrigation and human consumption and health. Renewable freshwater resources, as defined by river discharge and estimated groundwater recharge, are already insufficient to be able to meet the current demand in many parts of the region (FAO 2005a, b, UNEP 2010). In the future, it is highly likely that domestic water use will need to increase substantially to meet the growing demand and to help move people out of poverty (Hunter *et al*. 2010). Only 5 % of the arable land in Africa is currently irrigated (Siebert *et al.* 2010), and more water will be needed to meet demands for food production (UNEP 2010, Pfister *et al.* 2011), especially as rainfall reliability declines with climate change (UNEP 2010, Pfister *et al*. 2011).

National Scope

Reductions in the quality, quantity and timing of river flows and freshwater outputs were reported by all of the countries in the ASCLMEs due to the over-abstraction and consumption of water for irrigation, domestic and industrial uses, including mining (e.g. ASCLME 2012a,b,c,i) and due to impoundment for electricity generation (e.g. ASCLME 2012b, ASCLME 2012d). The reduction in the quantity and quality of river flow in the Comoros is already proving problematic and water scarcity has affected domestic use, irrigation, and hydroelectric power generation; there has also been an increase in the prevalence of water- and vector-borne diseases as a result of stagnation (ASCLME 2012a). In South Africa, rapid industrialisation and a burgeoning population have increased the demand for freshwater and altered the flow regime of many of South Africa's rivers. Over-abstraction of river water and impoundments, as well as afforestation and alien plant invasion in the catchment areas, have all resulted in modified river flows and changes in estuarine mouth dynamics, with negative consequences for mangroves and saltmarshes (ASCLME 2012e). In Kenya, there is an increase in the surface area along some sections of the rivers due to impoundment and/or damming, and altered seasonal variations in the flow patterns, due to releases for hydropower-generation during the dry season (ASCLME 2012b). In Mozambique, river flow has decreased progressively year on year, as the water is being used for development in neighbouring countries, and due to irrigation, domestic and industrial use and construction of dams for electricity generation (ASCLME 2012d). In Tanzania, river flows and the quality of water has also reduced, with subsequent environment and socio-economic impacts including social conflicts in some regions (ASCLME 2012c).

Sedimentation of rivers and estuaries as a result of deforestation and poor agricultural practices is of concern in many countries in the WIO, causing modification of shorelines and siltation of coastal habitats. In Kenya, the modification of freshwater river flow and sediment transport budgets has impacted creeks, deltas and estuaries

and contributed towards the degradation of coastal habitats and coral reef associated ecosystems (ASCLME 2012b). In Madagascar, increased deforestation of upland areas has resulted in the loss of top soils and has resulted in huge quantities of reddish orange silt being transported and deposited at river mouths in estuaries or bays, particularly in the Betsiboka estuary. Changes in sediment transport patterns have also contributed to the modification of shorelines and resulted in the silting of reef flats and mangrove forests (Bemiasa 2009, ASCLME 2012f). Shoreline stability in the estuaries and adjacent coast of Mozambique is also being affected, as freshwater shortages and reduced river flows has led to a reduction in sediment transport and resulted in coastal erosion (ASCLME 2012d). While in Somalia, siltation of the rivers as a result of poor land use practices has led to the modification in the configuration of coastal habitats, shifting accretion and erosion patterns and associated ecosystems are changing (ASCLME 2012i). On Mauritius and Rodrigues island, base flow rates of these rivers is typically low due to low levels of infiltration, due to the low retention capacity of the soil and porous basaltic rock (ASCLME 2012h). Flows rates can however increase from a few litres per second to more than 500 m^3s^{-1} during floods. During such floods, sediments are carried out to sea to a distance of over 5 km (ASCLME 2012h).

Transboundary Scope

Some of the major rivers and their catchments within the WIO region cross international boundaries and are therefore transboundary (e.g. Zambezi, Inkomati, Jubba and Shabelle). Modification of river flows and changes in the quality, quantity and timing of flows and sediment loads is also a transboundary issue where the rivers enter the Indian Ocean close to the borders with adjacent countries. Within the ASCLMEs, all countries identified the issue as being 'Relevant' so this issue is also a shared transboundary issue. From the Level 1 prioritisation 6 of the 9 countries ranked the issues as being 'High' importance, and in the Level 2 prioritisation, 7 of the 9 countries allocated 'Overall rating' scores which were above average compared with the other issues in MAC01. The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

1.2 Degradation of ground and surface water quality

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).

National Scope

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.

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' (Appendix VII). 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.

1.3 Degradation of coastal and marine water quality

Degradation of coastal and marine water quality as a result of inputs from various point and non-point sources, from municipal and industrial discharges, surface run-off, leachates, and dumping of solid wastes are widespread issues of concern throughout the region (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). There are a suite of specific issues within this category.

1.3.1 Microbiological contamination from land-based (domestic, industrial, agriculture and live-stock) and marine (mariculture, shipping) sources

Problem Statement

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 (recreation) 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 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.

National Scope

In the Comoros, there is no sewerage, drainage or wastewater treatment (ASCLME 2012a). Households typically use pit latrines which can leak and contaminate groundwater and coastal and marine environments. Some islands, such as Ngazidja, there is a massive risk of groundwater pollution by septic tanks and their seepage (ASCLME 2012a). In Kenya, microbial water quality studies have been completed in a number of locations and microbial pollution levels near urban centres such as Mombasa were several orders of magnitude higher than in coastal waters 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 source of the microbial contamination, whether from drinking contaminated water or coastal recreational, was not always clear (Mwanguni 2002, ASCLME 2012b).

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 *Escherichi coli* were also detected in both marine waters and shellfish tissues in other places within Maputo Bay. In Madagascar, studies conducted around Taolagnaro measured high *E. coli* counts (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 an ongoing problem in some Madagascan coastal areas (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). At present, in Mauritius, 73 % of households use cesspits or septic tanks whilst 2 % use pit latrines; so most of the effluents are discharged directly to the sea or are carried to the sea by runoff and rivers with higher potential for microbial pollution, particularly after heavy rains (ASCLME 2012h).

Transboundary Scope

Microbial contamination can originate from point and non-point sources, and the immediate area of impact may be localised around the source, depending on the amount of mixing and current. All nine countries 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 geographically 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 ASCLMEs. 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 the countries consider this to be a high priority transboundary issue of concern within the ASCLMEs.

1.3.2 Nutrient enrichment from land-based (domestic, industrial, agriculture, livestock) and marine (mariculture, boat based) sources

Problem Statement

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.

National Scope

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 waste water or sewage, agricultural run-off (fertilizers), and the burning of fossil fuels, triggering massive algal blooms (ASCLME 2012b). In Seychelles, high nutrient inputs in the vicinity of Port Victoria, can lead to the formation of algal blooms if the conditions are favourable, eutrophication and fish die-offs (ASCLME 2012g). 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 (ammonium, nitrate and nitrite) throughout the year. 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).

Transboundary Scope

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. 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 is 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 (Appendix VII). 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.

1.3.3 Chemical contamination (excluding oil spills) from land-based (domestic, industrial and agricultural) and marine (shipping, dumping at sea) sources

Problem Statement

Chemical contaminants are defined here as compounds that are toxic, persistent and/or bio-accumulating, which can be grouped in three categories: heavy metals, persistent organic compounds (e.g. pesticides), and

hydrocarbons. This issue covers the first two categories and hydrocarbons are dealt with below under issue 1.3.6. Chemical pollution can cause discolouration of coastal waters, chronic (e.g. affecting growth and reproduction) and acute effects on marine biota and, modification of species compositions in marine biological communities. Sources of chemical contamination in the WIO region are typically linked to agrochemical discharges (e.g. persistent organic pollutants), dredging in ports and harbours (thereby releasing sediment-bound heavy metals and hydrocarbons), atmospheric emissions (containing heavy metals), the discharge of un- or undertreated industrial effluents, and leachates from solid waste dump sites (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). The main industries that contribute towards chemical contamination in the WIO region include: manufacturing, textiles, tanneries, paper and pulp mills, breweries, chemical, cement, sugar and fertilizer factories. Inappropriate utilisation, storage and dumping of agrochemicals is a growing concern (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). The illegal dumping of nuclear and toxic waste is a major concern for Somalia (UNEP 2005b).

National Scope

Sources of chemical pollution in Mozambique include domestic and industrial waste from coastal cities and from agriculture, industries, mining and port operations. Most industries are concentrated around the coastal cities (e.g. Maputo, Matola and Beira) and they discharge un- or undertreated effluents directly into the tidal channels or in coastal waters (ASCLME 2012d). 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 use of pesticides and fertilizers. Pesticides found included 2,4,5-TCB, p,p'-DDT, p,p'-DDE, p,p'-DDD, lindane and HCB. Even though DDT is officially banned, it is still used in Mozambique and neighbouring countries (Massinga and Hatton 1997).

In Mauritius, the main industries (steel mills, galvanizing, electroplating and battery factories) historically released their wastes directly into Grand River North West and St. Louis River which empty into the lagoons. Heavy metals, particularly chromium from the textile industries, zinc and lead from industrial effluent, sewage sludge and landfill leaches are also potentially problematic. Estuarine habitats such as Tombeau Bay and Poudre d'Or Estuary have been exposed to such untreated industrial wastes since the 1980s (Ramessur 2002). WIOLab found evidence of trace metals and organic parameters in sediment samples from the majority of countries. Trace metals were consistently high in Madagascar and Tanzania, compared to other WIO countries (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009).

In Somalia, fish factories, tanneries and slaughterhouses contribute to pollution of the marine environment. Maritime activities also contribute to pollution through the release of oil and ballast waters and soluble PCBs. Noxious oils, organic and inorganic chemical wastes are also dumped into the sea on a regular basis and seepage from dump sites contain significant amounts of dissolved toxic metals and organic chemicals (ASCLME 2012i). The leachates from municipal waste disposal sites pose a serious pollution problem during the rainy season (ASCLME 2012i).

It has been reported that Somalia's long coastline has been used as a dumping ground for toxic and nuclear waste produced by other countries since the early 1980s. Foreign companies have reportedly been dumping barrels of waste on Somalia's coast and in their territorial waters. The waste materials have included uranium, radioactive waste, industrial chemicals and heavy metals such as cadmium and mercury (New Scientist 1992). The companies were reportedly dumping illegally as the local authorities did not have the capacity to police shipments or handle or process the wastes as a result of the long civil war. There were also reports that some of the waste was accepted in exchange for weapons and ammunition. The full extent of the problem only became fully apparent in December 2004, when the tsunami stirred up barrels of waste that were then deposited onto the beaches around North Hobyo and Warshek, south of Benadir. Unusual health problems have been reported from the local communities in proximity to the waste deposits including acute respiratory infections, mouth bleeds and skin conditions (UNEP 2005b).

Transboundary Scope

Chemical contaminants can be transported with 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 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 countries. All 9 countries identified the 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 (Appendix VII). 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 the present time.

1.3.4 Suspended solids in coastal waters due to human activities on land and in the coastal zone

Problem Statement

High concentrations of suspended solids enter the coastal waters of the region from river discharges and surface runoff, particularly during the rainy seasons, and from wastewater discharges. Major rivers from the central highlands, including the Maputo, Incomati, Limpopo, Save, Tana, Athi- Sabaki, Rufiji, Zambezi and Ruvuma, discharge large volumes of siliclastic sediment to the sea (Kairu and Nyandwi 2000). Sediment loads transported by the major rivers in the region range from 5 to 34 million tonnes per annum (UNEP/ Nairobi Convention Secretariat, and WIOMSA 2009). Land-based activities, such as deforestation and poor agricultural practices in the hinterlands, as well as the disposal of un- or undertreated municipal and industrial effluents, including artisanal and industrial mining, can all significantly increase the amount of sediments reaching the marine environment (UNEP/Nairobi Convention Secretariat, and WIOMSA 2009). In the marine environment, activities which mechanically disturb benthic soft sediment habitats, such as dredging (usually associated with ports and harbours) and trawling, re-suspend particles and increase water turbidity (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA 2009, van der Elst 2012).

High concentrations of suspended solids in the marine environment can have both chronic and acute effects on marine biota: suspended particles block the penetration of light through the water column reducing the depth to which light can reach, with serious implications for photosynthetic organisms (Yentsch *et al.* 2002). When the particles settle they can smother benthic flora and fauna, and clog the gills and feeding apparatuses of filter feeding marine organisms (Fabricus 2005, Woolridge and Done 2009). Sedimentation can thus result in the mortality of some species and lead to shifts in community 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 livelhoods of people dependent on these resources (Ahamada *et al.* 2008).

National Scope

In Somalia, poor farming practices upstream increase the siltation of the rivers (UNEP 2009). Destruction of mangrove forests is also increasing siltation and altering nutrients pathways for offshore species, and smothering due to siltation poses the main threat to coral reefs and seagrass (ASCLME 2012i). Municipal wastes containing organic materials and suspended solids and other contaminants are also released directly into the sea as there is no capacity to treat wastes in the coastal municipalities. Mining and dredging also increase siltation of the rivers in Somalia. Limestone mining of fossil coral reefs (beach rock) occurs in the south, in towns such as Marka and Barawe. The lime is used in house construction, whitewashing and decoration. The mining for limestone degrades the coastal landscape and leads to coastal inundation, sedimentation and erosion (ASCLME 2012i). Sand mining activities in South Africa modify flows, produce high suspended solid loading and destroy riparian and in stream habitats (ASCLME 2012e). Seagrass beds and coral reefs in Tanzania are threatened by various natural and human activities including excessive sedimentation, increasing turbidity and reducing light penetration and shoreline dynamics involving sand deposition and removal (Whitney *et al.* 2003, Wells *et al.* 2004, ASCLME 2012c).

Transboundary Scope

Increased sediment loads in coastal waters and increased sedimentation affects transboundary waters, habitats and associated living marine resources. All 9 of the countries 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 is was not considered to be a priority issue by the countries at this time (Appendix VII). The Regional 'Overall rating' score was however marginally above average, indicating that the countries may consider this to be a 'borderline' priority transboundary issue of concern.

1.3.5 Solid wastes / marine debris (plastics etc.) from marine and land-based-sources

Problem Statement

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). These waste materials can causes environmental, economic, safety, health and cultural impacts. The slow rate of degradation of most marine litter items, mainly plastics, together with the continuously growing quantity of the litter and debris disposed, is leading to a gradual increase in marine litter found at sea and on the shores (UNEP 2012).

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 accidently into the sea from vessels or other installations (UNEP and WIOMSA 2008, UNEP 2005b). 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).

In the WIO, with the exception of South Africa, little data exists on the specific quantities, types, trends, sources and sinks of marine litter within the region (UNEP and WIOMSA 2008). 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).

National Scope

The WIOLab Marine Litter report (UNEP and WIOMSA 2008), identified 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). For example, dumping of solid wastes in Kenya occurs around urban areas and tourism centres (ASCLME 2012b). The expansion of coastal populations, and tourism, has increased the amount of waste generated and waste management now presents a major challenge. Garbage collection services only cover only 50 % of the population, collection vehicles are inadequate and dumpsites are poorly located and managed. Coastal municipalities do not have adequate budgets hence the available staff are poorly paid and unmotivated. While the private sector operates on a local scale, small-scale solid waste management groups lack means of transport. Solid waste on the public beaches is a particularly major challenge (ASCLME 2012b).

Countries with the capacity to manage solid wastes are also still challenged. In South Africa, for example, solid waste collection services and disposal sites on land are largely adequate, except for informal settlements (ASCLME 2012e). Compacting, landfill and incineration are used, but this is not sustainable and pressure is

mounting to reduce the waste stream. On the coast, port reception facilities are adequate in the commercial ports, but not in fishing and recreational harbours and; while effective storm water screening devices have been developed and tested they have not yet been installed in most places (ASCLME 2012e). In the Seychelles, over 90 % of the solid waste stream is collected, treated and disposed of in an environmentally acceptable manner (ASCLME 2012g). There are also regular and frequent cleaning programmes for all the rivers and beaches in the Seychelles, and also in the sea and yacht basin. On the outer islands however, debris and solid wastes are washed up from the sea and there have been various instances where marine debris has been swallowed by turtles or found entangled around the animals (Department of Environment 2009, ASCLME 2012g). These remote sources of litter are more difficult for countries in the region to control.

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. In this regard, 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 ASCLMEs 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 (Appendix VII). This suggests that solid waste is considered to be a high priority transboundary issue by the countries in the WIO region.

1.3.6 Oil spills (drilling, exploitation, transport, processing, storage, shipping).

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.

National Scope

There have been several serious oil spills within the region in Comoros, Kenya, South Africa, and Mozambique. In Kenya, a spill from the British tanker *Cavalier* impacted mangrove forests in Mombasa in 1972. There have since been a further five severe spills on this coastline, resulting in mangrove dieback, especially in Mida Creek where the effects of oil spills were still evident 10 years after the last incident (Abuodha and Kairo 2001). A spill in Makupa Creek during 1988 caused extensive death of mangroves. Seagrass habitats have also been impacted (Abuodha and Kairo 2001). The dispersants commonly used to clean up oil spills contain toxic solvents that 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 harmful effects in other benthic biota (Ellison and Farnsworth 1996, Abuodha and Kairo 2001). In Mozambique, more than 16,000 tonnes of

heavy fuel-oil were spilled by the *Katina P* tanker in 1992 and extensive areas of mangrove forest near Maputo were destroyed (Munga 1993). The prevailing south-east trade winds make the Mozambican coast vulnerable to spills in the Mozambique Channel, as evidenced during the Katina-P spill (Massinga and Hatton 1997, ASCLME 2012d). There have also been a number of spills in South African waters. The *Kapodistrias* ran aground off Cape Recife, Eastern Cape in 1985 (Randall and Randall 1986) and at least 137 penguins died from oiling and 1,043 oiled penguins were rescued for rehabilitation. After the *Treasure* oil spill of 2000, more than 40,000 African penguins were caught for rehabilitation, relocation or captive rearing (Crawford *et al.* 2000).

Several countries have already started to produce natural gas (Tanzania, Mozambique, and South Africa) and gas deposits have been found in Somalia and Kenya (ASCLME 2012b, ASCLME 2012i). South Africa is the only country currently producing oil, however, unconventional oil reserves have been found in Madagascar, there are prospective oil fields in northern Somalia, and oil exploration is currently ongoing in Kenya and Tanzania (Busson 2011a, b, c, d, e). Oil and gas exploration in South Africa commenced in 1967 and about 300 petroleum wells have since been drilled (Broad *et al.* 2006). An increase in oil operations (drilling, exploitation, transport, processing, storage, etc) is predicted to increase oil spill risks in the region. For example, oil and gas production commenced recently in the Songo Songo archipelago, off the southern Rufiji delta, and Mnazi Bay, and both pose a threat to marine biodiversity due to general disturbance (e.g. pipe laying) and oil/gas leaks. Numerous companies are currently exploring other potential oil reserves, and 13 offshore blocks are expected to be conceded in the near future. There are concerns about the expansion of these activities in Tanzania, as the country has weak petroleum regulations, human capacity constraints, and an inconsistent EIA framework. Increases in oil operations, both upstream and downstream, will intensify the risk of spills and accidents (ASCLME 2012c).

South Africa has Africa's second largest oil refinery system, comprised of four refineries and two synfuel plants producing 692,000 barrels per day (bbl/d) in 2008. Around 19 million tons of crude oil is imported into South Africa annually, while approximately 120 million tons pass South African coasts bound for world markets, hence there is a significant risk of an oil spill incident. Furthermore, the increase in shipping traffic due to the piracy taking place off the Somalia coast, and port expansions now pose a new concern (ASCLME 2012e). In Mozambique, the port of Beira has a large petroleum refinery (with a capacity of nearly 110,000 m^3) and a pipeline which pumps 1 to 1.5 million tons of petroleum to Zimbabwe every year (ASCLME 2012d). The other ports with oil storage facilities from or to which oil is pumped also have associate risks for oil spills during the course of the operation (ASCLME 2012d). Kenya has a downstream oil industry, and a refinery in Mombasa, which produces 1.6 million tonnes per annum. Kenya has demarcated 17 blocks for petroleum rights negotiations, all offshore exploration is currently being undertaken by the private-sector. The current expansion of Kilindini Port and the development of Lamu as a free port, as well as future exploitation will increase the risk of oil pollution (ASCLME 2012b).

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' (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 at this time.

MAC02 Habitat and Community Modification

The western Indian Ocean 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. 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. The issue categories identified from the MEDAs and included in this Main Area of Concern are described below:

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

Problem Statement

Shoreline change (erosion and accretion) is a major environmental concern that is already affecting countries throughout the WIO region (Kairu and Nyanndwi 2000, UNEP/Nairobi Convention Secretariat 2009b). 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 Nyanndwi 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.

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 Nyanndwi 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 Nyanndwi 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.

National Scope

Kenya, Tanzania and Mozambique rely heavily on energy produced by hydroelectric power schemes. As with dams constructed for water supply, hydro-power dams alter the flow regime of rivers and trap sediments. The Cahora Bassa Dam on the Zambezi River has impacted the delta, many hundreds of kilometers away, resulting in coastal erosion and reduced nutrient supply carried downstream by floods (Turpie 2006, Brown and King 2002). Most of the Somali coastline has been seriously affected by coastal erosion, especially in the eastern and southern regions (ASCLME 2012i). Poor farming practices upstream cause an increase in the siltation of the rivers in addition to mining, urban development and dredging. As a consequence, the coastal configuration, accretion and erosion patterns and associated ecosystems are changing (UNEP 2009). Sand mining is common practice in all coastal towns and fishing villages. The sand is mixed with cement, coastal soil and gravel to make bricks. This destabilizes the coastal sand dunes, which already caused severe coastal erosion (ASCLME 2012i). Lagoon sand mining used to be common practice in Mauritius and has since been banned due to the impact it was having on shoreline stability (ASCLME 2012h).

The majority of countries have examples of poorly designed coastal infrastructure or shoreline defence systems which have either created shoreline instability or aggravated coastal erosion. In South Africa, bridges and causeways for coastal roads and railway lines have disrupted estuarine floodplains in many areas, exacerbating coastal flooding, increasing sedimentation and limiting seawater exchange, which has a range of ecological impacts including coastal erosion. The Durban harbour, Africa's busiest port, interrupted the natural northerly pattern of sediment drift and affected wave refraction, resulting in beach erosion to the north. Durban's beaches are therefore artificially maintained by a sand-pumping scheme that replenishes some 280,000 cubic metres of sand every year (ASCLME 2012e). The harbour development at Richards Bay has also interrupted the natural sediment drift pattern, causing sand to accumulate against the southern breakwater, and destroyed the dune-field where much of the northward-moving windblown sand would have naturally accumulated (ASCLME 2012e). Estuaries and rivers are also exploited by a number of sand-winning operations (ASCLME 2012e).

Flatland reclamation schemes are not particularly widespread or common in the WIO to date as compared to other regions (e.g. Arabian Gulf). The most notable example is the major reclamation works that were carried out off the east coast of Mahé in Seychelles (Bijoux *et al*. 2008a, ASCLME 2012g). These works were undertaken to meet the demands for flatlands for economic development and urbanization purposes. The land was constructed directly on top of the fringing coral reefs and coral rubble was used as infill, which resulted in erosion on one side and accretion on the other. The structures altered the coastal and nearshore hydrodynamics and have resulted in stagnant coastal waters, and exacerbated coastal erosion in other locations (ASCLME 2012g). Unregulated coastal developments and other factors influencing coastal erosion in the Seychelles include changes in wind and wave patterns during the monsoons, and synergistic interactions between spring tides and surges, and sea level rise (ASCLME 2012g).

Transboundary Scope

Shoreline changes, either through modification or increased coastal erosion or sedimentation is prevalent throughout the region and is significantly impacting all the countries in the WIO, suggesting that this is a shared transboundary issue of concern. Some of the worst impacted marine and coastal ecosystems, for example Tanga-Vanga and Lindi-Ruvuma systems, are also cross-border areas (UNEP/Nairobi Convention Secretariat 2009b). 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 (Appendix VII). The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

2.2 Disturbance, damage and loss of coastal, watershed and upland habitats

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.

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

Problem Statement

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.

National Scope

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/km^2), 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 a reduction in groundwater supplies. To control deforestation, different projects have focused on sustainable techniques for forest restoration and better agricultural practices have been undertaken. However, the migration of farmers between islands is increasing and necessitates the expansion of farming areas (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 for instance, have resulted in the increased discharge of huge volume of sediments in Malindi Bay with far reaching ecological and socio-economic consequences. Massive sedimentation interferes with growth of mangroves and also smothers coral reefs and sea-grass beds (ASCLME 2012b).

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. For example, poor cultivation techniques used by rice growers along the river banks resulted in hyper-sedimentation around the Onilahy river mouth in the 1990s. The proliferation of invasive insects, leading in turn to the reduced variety of insects, following bush fires and deforestation, were considered to be factors which contributed to the high erosion rates (CNRE/CNRIT/IHSM 2000, ASCLME 2012f).

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 (Appendix VII). The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a priority transboundary issue of concern.

2.2.2 Disturbance, damage and loss of coastal forest habitats (non-mangrove)

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.

National Scope

Coastal forests in Kenya cover 139,000 ha and important areas include Arabuko Sokoke, Diani, and Shimba hills (ASCLME 2012b). These unique lowland tropical forests are known locally as *Kayas*. The *Kaya* forests are distributed in few remaining patches along the coast which have a high cultural significance to the local Mijikenda community 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. These cultural beliefs are progressively being eroded, which is threatening the traditional management and conservation of these important indigenous forests. 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).

In Tanzania, coastal forests are now recognised as a key resource under threat by the Government. Fuelwood and charcoal are the main sources of energy for most people in the coastal region of Tanzania. The lack of an 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 southern Cape of South Africa has remnants of Afromontane forest, while the Eastern Cape has large areas of subtropical thicket. The high-lying interior is dominated by grasslands, while KwaZulu-Natal has lush subtropical forests interspersed with savannah, which also occurs in the far north of the country. Coastal habitats, including coastal forests, are vulnerable to the increasing pressure of increased population density and the associated development, mining, agriculture and afforestation, habitat fragmentation and alien plant invasion (ASCLME 2012e).

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 km^2) 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). Conversely, much of the upper mountainous slopes of the inner Seychelles are protected (ASCLME 2012g).

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 (Appendix VII). 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.

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

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.

National Scope

The accelerated growth of the tourist industry along the coast of Mozambique promotes very high disturbance levels and represents a serious threat to the status of these habitats and the conservation of shore birds. Exploitation of littoral organisms by the local population, a very common activity along the Mozambican coast, also represents a potential threat to their conservation (ASCLME 2012d).

The most threatened coastal habitats of the Seychelles are around the inner islands which are the most populated (ASCLME 2012g). Various development pressures along the coast, especially for tourism are currently posing threats to diverse marine habitats. The inner islands' geomorphologic features (mountainous with coastal plateaus) and the protection plan (mountainous parts normally falling into National Parks), are such that the majority of the developments for local residences or rural expansions are taking place along the coast. This, albeit non urban and controlled expansion, should still be carefully considered as it could cause additional stress on the coastal areas if not monitored and controlled accordingly. Increases in urban development have been shown to cause an increase in the volume of water flowing into the lower drains, with the potential for coastal flooding (ASCLME 2012g).

Coastal habitats of Mauritius include sandy beaches, rocky shores, and fossil reef beach rock. Most of the pristine coastal sites and the most expansive sand beaches have been exploited and now hotel planners are examining areas less touched by the imprint of change. Urban developments in floodplain areas which are actually below mean sea level (e.g. Flic en Flac) have created drainage problems (ASCLME 2012h). In Mauritius, cyclonic waves are responsible for removing large quantity of sand from the beach and lagoons. Mauritius also suggests that ocean acidification threatens coral reef growth around the island and may therefore reduce the supply of sand to the lagoon and beaches (ASCLME 2012h).

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.

2.2.4 Disturbance, damage and loss of wetland habitats

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.

National Scope

The largest and most important coastal wetland in Kenya is the Tana Delta. The Tana River is the largest and longest river in Kenya (nearly 1,014 km long). The Delta covers about 130,000 ha and supports 100,000 people, consisting mostly of farmers, pastoralist and fishermen. While there are some important coastal lakes, some of the oxbow lakes are also wetlands (e.g. Lake Mahe in Umba flood plain, and Ziwa la Chakamba and Ziwa la Ndovu in Tana flood plain) (Kitheka 2002). The shores of both deltas and estuaries are characterized by the presence of mangrove forest ecosystem (Kokwaro 1985). The Tana River volume has fallen by 20 % in 10 years. The Kenya MEDA (2012) recognised that climate change and natural variability is already influencing rainfall patterns and the flow patterns of rivers, impacting on floodplains, deltas and coastal ecosystems and; that there was limited knowledge and information on the hydrological functions of coastal wetlands.

On the inner granitic islands of the Seychelles, the ever growing human population coupled with the tourism industry (Rocamora and Skerrett 2001) leads to land clearing and drainage of wetlands for developments such as housing. This can be exacerbated by the additional threat from global warming and sea level rise which can particularly affect the outer low-lying coralline islands.

The Rufiji-Mafia-Kilwa Marine RAMSAR Site in Tanzania is located across the three named districts, within the coastal and Lindi regions of southeast Tanzania. It has an area of 596,908 ha (URT 2009). According to the Wetlands International, this site is a representative wetland of East Africa as it contains a large diversity of wetland types, which are ecologically interlinked, and includes the threatened estuarine, coastal and marine wetland habitats (Directory of Wetlands of International Importance 2004).

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.

2.2.5 Disturbance, damage and loss of estuarine habitats

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.

National Scope

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).

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' (Appendix VII). 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.

2.2.6 Disturbance, damage and loss of mangrove habitats

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 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).

National Scope

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 hypersedimentation 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 consistutes 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 *Lumnizera sp.*

Transboundary Scope

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.

2.3 Disturbance, damage and loss of subtidal benthic habitats

2.3.1 Disturbance, damage and loss of coral reef habitats

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 plancii* 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 CO_2 concentration in ocean water causing a decrease in pH value of the sea water, known as ocean acidification. Under the current forecast of CO_2 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.

National Scope

In the northern part of the WIO region, coral reefs and coral communities are found along the coast of Somalia between Adale and the Somalia-Kenya border, and around the Bajuni Archipelago. Coral communities are well developed, with 27 genera and 63 species reported to date. The main threats to these communities include destructive fishing practices, over-fishing, global warming, and smothering due to sedimentation and pollution. Limestone mining exists in southern towns, such as Marka and Barawe, and the lime is used for house building as well as for whitewashing houses. The reefs on the coast to the east of Berbera suffered extensive coral bleaching, and almost total mortality in parts (Schleyer and Baldwin 1999).

There is a near continuous fringing reef that extends southwards from the Somali-Kenya border to Mocambo Bay in Mozambique in the south. Reef development tends to be more extensive where the shelf broadens and around islands. Inhaca Island is reported to be the southernmost coral reef of the African mainland, although coral communities on offshore rocky reefs occur between 3-30 m depth southwards into South Africa (ASCLME 2012d). The gaps in coral distribution along this coast are found at river openings. At the Sofala Bank, for example, a shallow wide continental shelf and turbid waters are associated with the discharge of Zambezi River. Coral reefs of Kenya, Tanzania and Mozambique were all subject to extensive coral bleaching during the 1997-1998 El Nino (Schleyer *et al*. 1999, Motta *et al*. 2002). Coral mining, sedimentation, coastal flooding, beach seining, fishing nets, trampling and tourism pose an ongoing threat to coral reefs in Mozambique. Outbreaks of Crown-of-Thorns starfish (COTS) have been reported from Mozambique, Tanzania, and Mauritius. COTS outbreaks in Mozambique occurred in 1995-1996 and extensive reef damage was found at Bazaruto (80 %) and Inhambane (95-98 %) (Schleyer *et al.* 1999).

Dynamite fishing in Tanzania has degraded the coral reefs to such an extent that only two of the eight coral reef sites recommended for marine parks in 1968 had intact coral reefs in 1983, the rest had been reduced to rubble (Salm 1983). Damage is also caused by ambulatory fishers collecting shells or octopus or algae;

they trample the seabed, break corals and overturn rocks and stones. Significant coral bleaching was reported between March and September 1998 when live coral cover was reduced from 52 % before bleaching to 27 % after the event (Wells *et al.* 2004).

In the Comoros, coral reefs occupy about 60 % of Grande Comoro's coast, 80 % of the Anjouan coast and 100 % of Mohéli's coast. The lack of a continental shelf has resulted in weak reef development around Grande Comoro. Currently, the status of the Comorian coral reefs is poor, consisting of 60 % dead coral and 40 % live coral. In some sites, the proportion of dead coral reaches between 80 and 90 %. Repeated coral bleaching has been observed, probably due to seawater temperature. Other pressures include the use of dynamite, uncontrolled anchoring, trampling, fishing pressure, the dumping of garbage directly into the sea and terrigenous deposits linked to land erosion (ASCLME 2012a).

The main threats to the reefs in the Seychelles are from climate related changes such as increases in sea water temperature. During the 1997/1998 event the degree of coral bleaching was highly variable with the inner islands being much more affected by the bleaching event than the outlying islands (Spencer *et al*. 2000, Turner *et al*. 2000a, b). Live coral cover was reduced by 90 % in the inner islands (Turner *et al*. 2000a, b). This warming also significantly affected reefs in the outer islands, although to a lesser extent (Spencer *et al*. 2000, Bijoux *et al*. 2008b). Other impacts include destructive fishing practices, coastal development activities, dredging and flat-land reclamation.

Transboundary Scope

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 (Appendix VII). The Regional 'Overall rating' score was also above average, indicating that the countries consider this to be a high priority transboundary issue of concern.

2.3.2 Disturbance, damage and loss of seagrass habitats

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 (Gullstőm *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 (Gullstőm et al. 2002). Seagrass degradation occurs throughout the ASCLME 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.

National Scope

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 *Thalassodendon ciliatum, Halodule wrightii* and *Halophila minor* (Obura 2001, Gullstőm *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/m^2, while healthy sites had a density of 4 individuals/m^2 (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 Erftemeijer 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).

Transboundary Scope

Seagrass beds serve an important functional role in tropical marine ecosystems, considered to be of equivalent value to coral reefs. Although the degradation and loss of seagrass beds is frequently overlooked, it can have serious implications for the status of other associated habitats, such as mangroves and coral reefs, and other species that depend on these beds for different ontogenetic life stages. Endangered species, such as the dugong and sea turtles depend on seagrasses as foraging grounds, and many commercially important fish species utilise seagrass beds as a nursery ground. All 9 of the countries identified concerns related to seagrass habitats as 'Relevant' although only 5 of the 9 countries ranked the issues as being of 'High' importance, with the exception being South Africa. In the Level 2 prioritisation, only 3 of the 9 countries assigned the issue an 'Overall rating' score that was above average (Appendix VII). There was a discrepancy between the National and the Regional 'Overall rating' score, which was above average, indicating that the countries consider this to be a priority transboundary issue of concern within the WIO at the present time.

2.3.3 Disturbance, damage and loss of macroalgal habitats

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 increasing 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.

National Scope

In Tanzania, several studies have been conducted on the impacts of heavy metal on flora and fauna in polluted habitats in Dar es Salaam coastal areas (Mwandya 1996, Wekwe *et al*. 1989). The environmental impacts of Pb, Hg and Cd on calcification rates of the reef building calcareous algae *Amphipora tribulis* have been investigated in Dar es Salaam (Kangwe 1999). Effluents from a fertilizer factory, municipal sewage and sisal decortication plants have enriched coastal waters causing proliferation of macroalgae in Tanga coastal waters (Munisi 1999, Shilungushella 1993).

There is farming of exotic species of macroalgae in Mozambique, such as *Kappaphycus alvarezii* and *Eucheuma spinosum* which were introduced from Zanzibar, Tanzania in the late 1990s. These species are farmed in northern Mozambique (Cabo Delgado and Nampula Provinces) in shallow areas close to the shore. In 2008 the total production of seaweed was about 70 tonnes (ASCLME 2012d).

In South Africa, kelps are the largest and fastest-growing algae, and support a rich community of organisms including commercially important species. Four species occur in South Africa, only one of which is found in the WIO, spined kelp *Ecklonia radiata* (ASCLME 2012e). It is found in deep rock pools and gullies, and seldom forms solid stands. Although herbivores such as limpets, abalone and sea urchins are able to graze on kelp, most of the animals in kelp forests are filter-feeders such as mussels, which are in turn eaten by the commercially valuable rock lobster. In South Africa, siltation as a result of poor catchment management can cause smothering of benthic algal communities.

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 (Appendix VII). 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.

2.3.4 Disturbance, damage and loss of soft sediment habitats

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.

National Scope

Bottom trawling is limited to the mainland East African coast (Kenya, Tanzania, Mozambique and South Africa) and Madagascar (Mackay 2012). Although trawling is not permitted off the island states of Mauritius, La Réunion, Comoros and the Seychelles, different types of seine nets are used in most of these countries. In Madagascar, trawls have been used since 1967, and this has impacted natural habitats and associated biodiversity. Shrimp trawling in mud flats leads to the destruction of bottom micro-habitats, affecting ecological niches and the diversity of fish and other communities (ASCLME 2012f). Information on sediment composition, distribution and morphology in Tanzania is generally scarce apart from limited studies conducted in the Zanzibar channel and between Pangani and Wami rivers (Shaghude *et al*. 1998, Shaghude 2003, 2004a, b). Dredging is a particular concern in Tanzania, where the predominant effect is the burial of the resident fauna (ASCLME 2012c).

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.

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

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.

National Scope

Deeper water fisheries in the WIO typically consist of mid-water and bottom trawl fisheries, targeting alfonsino (*Beryx splendens*) and orange roughy (*Hoplostethus atlanticus*). A deep-sea long line fishery has also recently developed which targets deepwater longtail red snapper (*Etelis coruscans*) (Bensch *et al*. 2008). Examples of other deep-water fisheries within the WIO includes the lobster fishery in Tanzania, which targets two species (*Linuparus somniosus* and *Metanephrops andamanicus*), in depths of 250 to 320 m at the southern end of the Zanzibar Channel (ASCLME 2012c); and the deep water crustacean trawl fishery, a lobster trap fishery and a deep water hake fishery in South Africa (ASCLME 2012e).

In Madagascar, exploratory fisheries surveys on shelf and slope in the 1970s and 1980s discovered >50 species (FAO 1998). More recently a South African company launched a new industrial fishery using deepwater trawling techniques to catch alfonsino (*Beryx splendens*). The fishery targeted sites including seamounts to the south of Madagascar, and there is concern about the impacts of this deepwater gear on these habitats, and little capacity to manage (ASCLME 2012f). Tanzania has formed Deep Sea Authority (DSA), which is a corporate body with powers to regulate and control fishing activities in the country's Exclusive Economic Zone (EEZ). For the high-seas fishing, mainland Tanzania and Zanzibar are both issuing licenses to foreign fishing vessels. The royalties received from licensed foreign vessels provide foreign currency. However, there is complete lack of control over the operations of these vessels while in offshore waters (ASCLME 2012c).

Shelf habitats in South African waters include deep reefs, banks that support deepwater coral and sponge communities, and unconsolidated sediments of sand, gravel, mud and various intermediate and mixed sediments (Sink and Attwood 2008). The deep reefs are targeted by commercial line fishery including several endemic and threatened species. Rocky areas of the upper slope support rock lobster trap fisheries and soft-sediment offshore banks on the east coast support a crustacean trawl fishery. The demersal trawl fishery, which is the most valuable fishery in South Africa, targets deep-water and shallow-water hake. Deepwater trawls targeting the newly found deepwater species have a unique set of biodiversity impacts and significant bycatch (ASCLME 2012e).

The intensification of fishing pressure on the seamounts of the South West Indian Ridge resulted in decline of orange roughy and other fish stocks. The Southern Indian Ocean Deep-sea Fishers' Association (SIODFA) has established benthic protected areas (BPA). These BPAs are regions where bottom trawling, mid-water trawling and dredging are forbidden (Floros and Schleyer 2012).

In addition to the fisheries impacts, marine effluents and dredged spoils are also often disposed of in deep water. Monitoring off the east coast of South Africa of these deep water disposal sites, showed that although water, sediment and biological tissue were sometimes contaminated by various metals and persistent organic pollutants, the magnitude and spatial extent of this contamination was usually low and temporally variable (ASCLME 2012e).

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.

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

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.

National Scope

Noise pollution is reported to be threatening marine mammal population in Kenya and Madagascar (ASCLME 2012b, ASCLME 2012f). Noise disrupts the orientation, feeding and communication ability of marine mammals, by causing interference which may lead to strandings and physical damage to the ear of the animals if they are close to the source noise (ASCLME 2012b). In Madagascar, noise pollution in pelagic habitats is a concern around major ports and specific activities producing underwater noise, particularly industrial shrimp trawling and seismic and sonar studies undertaken by the oil industry. Sea turtles are sensitive to noise and in Madagascar, turtles were observed to flee 1 to 2 km from the noise source during seismic studies.

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.

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

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 in 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).

National Scope

Coastal waters in Kenya are increasingly being impacted by land-based pollutants, more specifically wastewater (ASCLME 2012b). This creates eutrophic conditions, which could promote HAB development and prolong the duration of their occurrence. An extensive survey carried out in Kenya reported a total of 24 species of potentially harmful microalgae. A bloom mostly comprising of *Gymnodinium sp*. was observed in the Kiunga National Marine Reserve in 2004 (IUCN 2004). The bloom lasted for 10 days causing extensive marine life mortality due to hypoxic conditions that created dead zones (ASCLME 2012b).

In 1990 the coastal waters and ecosystems of Port Louis (Mauritius) suffered from severe eutrophication as a result of nutrient-enriched runoff and sewage effluent, as did seagrass beds in Bain des Dames and Point Moyenne (Ramessur 2002). Domestic sewage released to coastal waters from urban areas and poorly planned housing developments on reclaimed wetlands can cause eutrophication/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. Frequent discharge of pollution and nitrates from agriculture and coastal hotels give rise occasionally to algae bloom and red tides.

Mauritius is an endemic region of fish toxicity, especially ciguatera, as a result of the presence of potentially toxic benthic dinoflagellates. Anthropogenic eutrophication and industrial development can trigger toxic algal blooms. Introduction of new toxic species from ballast water is also a potential threat and the effect of global warming and associated effects on climate could cause an increase in coral bleaching and mortality thus contributing to favourable habitats for *G. toxicus*. The tourism industry could suffer in the event of an outbreak of ciguatera fish poisoning (ASCLME 2012h).

In January, 2002, a HAB occurred along the East African coast from Mogadishu in Somalia to Lamu in northern Kenya, associated with the strong upwelling of the Somali current and an unusual strong NE wind (force 5-6) that may have blown it onshore. This bloom lasted for 10 days, with extensive fish mortalities during the first three days, and numerous fish and other marine animals, such as turtles being washed up on the beaches or found floating on the ocean (ASCLME 2012i).

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.

2.6 Introduction of exotic (non-native), invasive and nuisance species

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 of marine algae may impact on marine habitats, reducing coral growth and excluding native algal species.

National Scope

In Tanzania, the Invasive Species Specialist Group of the IUCN Species Survival Commission identified the following species: *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 a recent study found 36 exotic species, although only *V. cholera* was considered to be invasive (ASCLME 2012b). In South Africa, over 85 alien marine species have been reported (Appendix III). The threat from new alien species in the region remains high due to the high volume of shipping processed at Richards Bay and Durban harbours (ASCLME 2012e). An assessment of the impacts caused by ballast water in Mozambique has not yet been completed but the country possesses 3 large harbours where large vessels arrive and depart daily (ASCLME 2012d).

The historical introduction of various animals on the Seychelles, such as *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 been more recent 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 (Mozamique 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 (ASCLME 2012b), Tanzania (ASCLME 2012c), Mozambique (ASCLME 2012d), South Africa (ASCLME 2012e) 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 been subject to several COTs outbreaks, the first of which was in the 1970s (Fagoonee and West 1983, Fagonnee *et al.,* 1985, Fagoonee 1990). Between 1971 and 1980, COT densities increased from 30 per 10,000 m^2 in 1971 to 416 per 10,000 m^2 in 1980 at Trou aux Biches (north east of Mauritius) (Fagoonee 1990). Contributory factors for the

outbreaks were declines in the predator numbers, in particular the gastropod mollusc (*Charonia tritonis)* and contaminated land-based sources of pollution (agricultural fertilisers, pesticides, and industrial chemicals) and sedimentation (Fagoonee 1990). COTs were found during more recent surveys but at much lower densities.

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 (Appendix VII). 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.

MAC03: Declines in Living Marine Resources

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:

3.1 (Risk of further) Decline(s) in 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.

3.1.1 (Risk of further) Decline(s) in populations of marine mammals (excluding cetaceans)

Problem Statement

There are five marine mammal species other than whales and dolphins found within the region, which include: one species of Sirenidae (*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 be 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.

National Scope

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 dugong 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).

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.

3.1.2 (Risk of further) Decline(s) in populations of cetaceans

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.

National Scope

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 truncates*), 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).

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 ASCLMEs.

3.1.3 (Risk of further) Decline(s) in populations of seabirds

Problem Statement

There are eleven seabird families within the WIO region including, penguins (Spheniscidae), albatrosses (Diomedeidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), tropicbirds (Phaethonidae), gannets and boobies (Sulidae), cormorants (Phalocrocoracidae), 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.

National Scope

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).

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.

3.1.4 (Risk of further) Decline(s) in populations of turtles

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).

National Scope

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.

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.

3.2 (Risk of further) Decline(s) 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.

3.2.1 (Risk of further) Decline(s) in populations of sharks and rays

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).

National Scope

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 (Carcharhnidae), 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 nest 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).

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.

3.2.2 (Risk of further) Decline(s) in populations of large pelagics

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 gear*s". 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).

National Scope

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 transhipments.

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 ASCLMEs.

3.2.3 (Risk of further) Decline(s) in populations of small pelagics

Problem Statement

Small pelagic fisheries may target small tuna-like species including horse mackerel and mackerel, (Scombridae), barracuda (Sphyraeindae), 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.

National Scope

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., Sphyraeindae, 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).

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.

3.2.4 (Risk of further) Decline(s) in populations of deep demersal fish species

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.

National Scope

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 alfonsino *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).

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.

3.2.5 (Risk of further) Decline(s) in populations of reef and demersal fish

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 fresh 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.) (e.g. 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.

National Scope

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, Sigganids, 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).

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.

3.3 (Risk of further) Decline(s) 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.

3.3.1 (Risk of further) Decline(s) in populations of molluscs (bivalves, gastropods)

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.

National Scope

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 plancii)*, 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).

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.

3.3.2 (Risk of further) Decline(s) in populations of cephalopods

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.).

National Scope

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).

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.

3.3.3 (Risk of further) Decline(s) in populations of sea cucumbers

Problem Statement

Sea cucumber fishing is not a traditional fishery within the ASCLMEs, 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.

National Scope

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).

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.

3.3.4. (Risk of further) Decline(s) in populations of prawns and shrimp

Problem Statement

Prawns and shrimp are targeted by both industrial and artisanal fisheries in shallow water throughout the WIOs, and in shallow (Fennesey 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

National Scope

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).

Transboundary Scope

Prawn and shrimp stocks may be shared between some of the countries within the ASCLMEs, 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.

3.3.5 (Risk of further) Decline(s) in populations of lobsters

Problem Statement

Several species of lobster are targeted within the ASCLMEs 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).

National Scope

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 elisabethae* and red crab *Chaceon macphersoni* as a retained bycatch. The fishery was unstable, with declines in catches, and is currently inactive (ASCLME 2012d).

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. elisabethae, 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.

3.3.6 (Risk of further) Decline(s) in populations of crabs

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.

National Scope

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.

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 ASCLMEs.

3.4 Excessive bycatch and discards

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.

National Scope

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 pritiosus* 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).

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 ASCLMEs.

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

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 (see Volume I Section 4.3). 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 Secyhelles 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).

National Scope

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).

Transboundary Scope

Many of the countries within the ASCLMEs 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.

MAC04: Unpredictable Environmental Variability and Extreme Events

The issues of concern that were identified by the countries related to MAC04 Unpredictable Environmental Variability and Extreme Events are causes which contribute to, and indeed exacerbate, many of the other issues that were identified. These include:

4.1. Climate hazards and extreme weather events
4.2. Sea level change
4.3. Ocean acidification
4.4. Changes in seawater temperatures
4.5. Changes to hydrodynamics and ocean circulation
4.6. Changes in productivity (shifts in primary and secondary production)
4.7. Geohazards (tsunamis, volcanic eruptions, earthquakes)

A summary overview of each of these is presented in Chapter 10.

8.5 Emerging Issues

During the Regional TDA-IV workshop, held in Mauritius between, there were several of the issues, which had not been identified as a top priority issue at the regional but which the countries felt should be captured as emerging issues. The emerging issues which may become a greater concern in the future included:

'1.3.7 Noise pollution': The marine environment is becoming increasingly noisy, with the expansion of certain sectors. The nearshore coastal marine environment can be affected by noise associated with the expansion of tourism and associated recreational activities, such as jet-skis, speed boats, as well as activities such as dredging in ports and harbours. In the offshore environment, various sectors create noise, including fishing (e.g. trawling), shipping (engine noise), mining (drilling and suction dredges), oil and gas exploration (seismic surveys, wild cat drilling) and exploitation activities (drilling and extraction etc). Although noise was not identified as a high priority transboundary issue at the present time, it could become an issue of greater concern in the future, affecting vulnerable species, such as whales, dolphin, sea turtles, as well other commercial species. It is now known for example that coral reef larvae use the noise emanating from reefs as a sensory cue to help them navigate towards a suitable habitat (Vermeij *et al*. 2010)

'1.3.8 Thermal pollution': Thermal pollution was not identified as a priority issue of concern by the countries within the WIO. It could however become an issue of shared concern, if there is an increase in coastal industry.

'1.3.9 Radioactive contamination (risk of dumping)': Only Somalia identified a concern with regards the dumping of radioactive materials, which has reportedly been carried out by foreign countries within Somalia's EEZ over the last 30 years. Evidence for the occurrence of this practice was washed up on the beaches following the tsunami in 2004. There are various other potential sources of low level radioactive waste in the marine environment (including the dumping of hospital wastes) which may affect other countries although information on this is limited. This issue was not identified as a priority concern.

'3.5 Expansion of mariculture industry (biosecurity, diseases in wild stocks, exotics, habitat implications, water quality)': As described above, the mariculture sector is rapidly expanding in the WIO, with different types of aquaculture having now been established in most countries. There are generally two types of aquaculture: commercial operations, which aim to generate profits, to offset declining landings of wild caught fish or invertebrates through supplying an alternative source that could supply the local and tourist market (e.g. in Mauritius) and; the low-tech types of aquaculture for seaweed or sea cucumber, which aim create alternative livelihoods for displaced or un-employed fishers, and to supplement their household incomes While the countries did not identify this as a high priority issue of concern they did identify that it was potentially an emerging issue that could become a greater concern in the future**.**

Bio prospecting: A quietly expanding issue in the WIO and elsewhere is 'bio prospecting' for biologically active chemical compounds and genetic resources extracted from marine organisms for use in biotechnology sector, for the commercial development of pharmaceuticals products and other purposes (UNU-IAS 2005). There have been various reports of scientific cruises within the wider Indian Ocean basin, which collected a broad range of samples, for use in testing for bio-active compounds and for genetic purposes, and some of the cruises were reportedly funded by international biotechnology or pharmaceutical companies. There is however no specific international or regional instrument that addresses bio prospecting of the deep seabed in areas beyond national jurisdiction. A number of international instruments have provisions that are relevant (e.g. under UNCLOS, the UN General Assembly, the CBD), and there are instruments that address intellectual property rights, but none of these fully address, the conservation of, access to, and benefit-sharing related to, deep seabed resources (UNU-IAS 2005).

9. Regional summary of proximal and root causes

Introduction

Following the identification and prioritisation of the main transboundary issues as identified in Chapter 8, the next stage in the TDA process was to identify the causes, so as to help focus the development of appropriate policy interventions that will bring greatest benefit to the region. This 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 (social, political, and legal) causes, and finally, the root causes that determine the behaviour of those sectors. Once the important causes of each prioritised issue have been 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, and target actions designed to address these common causes will in theory be most effective and cost effective.

The aim of this chapter of the TDA is to present the cause and effect pathways for the 21 high priority transboundary issues of concern within the WIO countries, in order to assist in the development of appropriate management interventions to reduce or rectify these transboundary issues for inclusion in the Strategic Action Programme (SAP). As outlined in the previous chapter (Chapter 8) the CCA was commenced at the national level first before the results were consolidated and validated at the regional level. In this chapter, the method used to construct the chains is presented and then the chains for all 21 priority transboundary issue of concern within the WIO. The CCA results for each issue are presented using the same format, which includes **impact 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). The tabulated results of the analyses for MAC01, MAC02 and MAC03 are presented in Appendix VIII, Appendix IX and Appendix X.

Methods

During the National CCA meetings, countries identified their top ranking issues through the prioritisation process as described in Chapter 8. Causal Chain Analysis was 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 most likely to be affected by that environmental impact; the resulting socio-economic consequences in terms of the economic impacts (welfare), social impacts (wellbeing) and ecological impacts (sustainability) aspects and; finally which of the stakeholder groups they thought would be impacted (Appendix VII). To assist in this purposes each group was provided with a standard list of ecosystem system services (TEEB 2011, Raymond *et al*. 2009, De Groot *et al*. 2002, MEA 2005, Daily *et al*. 2009), and some generic lists of environmental and socio-economic impacts, derived from the WIO-Lab TDA (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 a particular resource use practice or had persisted, and repeating this process until eventually the root cause was revealed (Appendices VIII, IX, X).

Once the CCA were completed, the national results were captured and transferred into a tabular format. The national results were consolidated into generic chains (both tables and problem trees). These were the validated by the participants at the Regional TDAIII Meeting (9th to 10th May 2012) (Scott 2012a) and Regional TDAIV Meeting (24th to 27th July 2012) (Scott 2012b).

MAC01. Water Quality Degradation

The following section presents the impact and causal chain analysis for the top priority transboundary issues related to MAC01 Water Quality Degradation. The top priority issues identified by the countries within MAC01 were as follows:

1.1 Alteration of natural river flow and changes in freshwater input and sediment load
1.2 Degradation of ground and surface water quality
1.3.1 Microbiological contamination from land-based and marine sources
1.3.5 Solid wastes / marine debris from shipping and land-based-sources
1.3.6 Oil spills (drilling, exploitation, transport, processing, storage and shipping).

A summary of the environmental impacts, the ecosystem services affected by these impacts, and socio-economic impacts and the causal chain analysis is presented for each issue. Appendix VIII contains further detail.

1.1. Alteration of natural river flow and changes in freshwater input and sediment load

Impact Analysis

The **environmental impacts** that occur as a result of alteration of natural river flow and changes in freshwater input and sediment load include: reduction in freshwater discharge; altered coastal dynamics; shoreline changes (erosion / accretion); increased siltation; reduction in clarity of coastal waters (light available for photosynthetic organisms); salinisation of soils; degradation of floodplains; degradation of deltas; degradation of saltmarshes; degradation of estuaries; degradation of mangroves; degradation of seagrass; altered extent of mud beds; 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 changes in freshwater input and sediment load 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); 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 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); and bequest, intrinsic and existence.
The **socio-economic impacts** that occur as a result of alteration of natural river flow and changes in freshwater input and sediment load 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).

Causal Chain Analysis

The most important **direct causes** of alteration of natural river flow and changes in freshwater input and sediment load are:
- Rainfall variability;
- Natural topography;
- Obstruction of natural flows;
- Changes in land use and vegetation cover; and deforestation;
- Increased sediment loads.

The **sectors** responsible for causing alteration of natural river flow and changes in freshwater input and sediment

load are: industry, agriculture and forestry, mining, energy, tourism, urbanisation, transportation and shipping, and natural environmental variability. The **resource use practices** and **underlying (social, legal and political) causes** (Figure 29a and b) 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 the 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 practices (diversion of water courses, damming / impoundment of rivers and high abstraction and water use) as a result of the expansion of the agriculture and commercial agriculture sector, occurs due to the increased demand for food and other agricultural produce. A lack of technology and the use of inappropriate irrigation and farming methods persists due to incorrect incentives for water use and cultural and traditional practices. There is inadequate planning, a 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 a 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 a lack of monitoring and control capacity.

Degradation due to (4) traditional land use practices (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 a lack of education and awareness, a lack of outreach and a lack of technology. 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 and there is a lack of technology.

Degradation due to (7) seasonally inappropriate farming activities (e.g. ploughing before rain) occurs due to a lack of education and awareness and a lack of outreach (extension officers). There is also low compliance with regulations due to weak regulatory frameworks and a lack of appropriate information about 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 a 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 an expansion of this mining sector as a result of the external market demand for natural resources. It is also an income generating livelihood. A 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 / impoundment 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 a lack of investment in alternative technologies (e.g. solar), mainly due to poor energy legislation.

Tourism: (13) High water consumption by the tourism sector arises due to the increased number of tourists, a lack of regulation to encourage water saving measures and low uptake of alternative technologies (e.g. rain water

harvest 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 an increased demand due to the expansion of the tourism sector and economic development pressures. There is a 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, a lack of land use plans and suitable environmental policies, as well as low enforcement of regulations, due to a lack of capacity for monitoring and control.

Urbanisation: The expansion of urban areas results in an increased demand for domestic piped water results and increased (16) domestic water usage, (17) domestic wastewater disposal and (18) damming for water supply to meet the demand for piped water. 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 a 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, investment in upgrading 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 the use of inadequate road construction practices. There is poor planning and poor compliance due to a lack of or inadequate regulations.

Natural environmental variability and change: Alteration of natural river flow and changes in freshwater input and sediment load are being exacerbated due to high rainfall variability, increased evaporation, flooding and fires.

The main **Underlying Causes** of the alteration of natural river flow and changes in freshwater input and sediment load can be summarised as follows:

- Rural poverty, increased coastal migration and urbanisation
- Inadequate investment in infrastructure / poor maintenance
- Increased external market demands for (use of) natural resources / materials
- Increased internal market demands for (use of) natural resources / materials
- Limited knowledge and lack of 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 freshwater and 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
[H] Climate change and natural processes

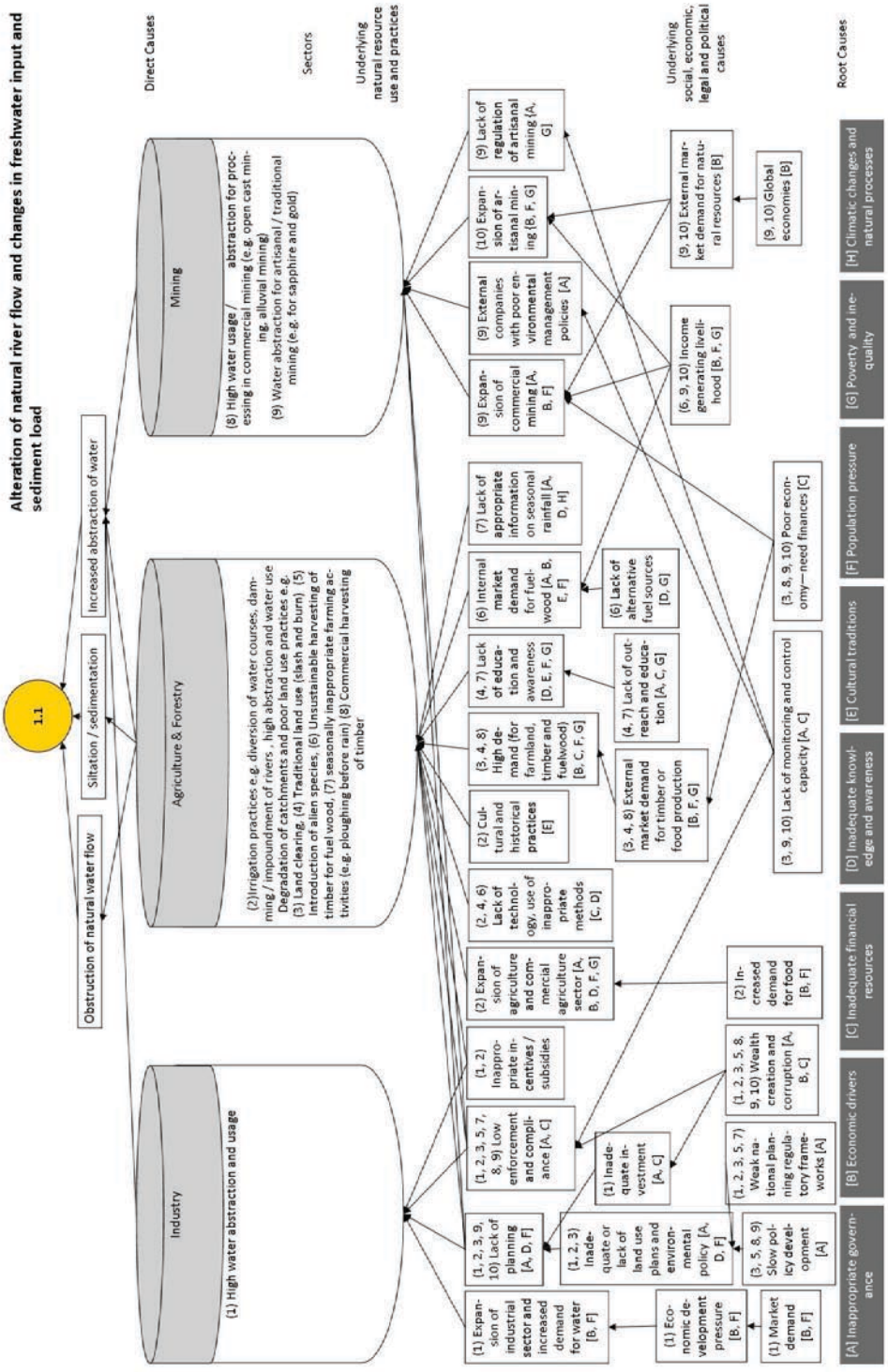

Figure 29a: Causal Chain Analysis for the issue (1.1) Alteration of natural river flow and changes in freshwater input and sediment load (part 1 of 2).

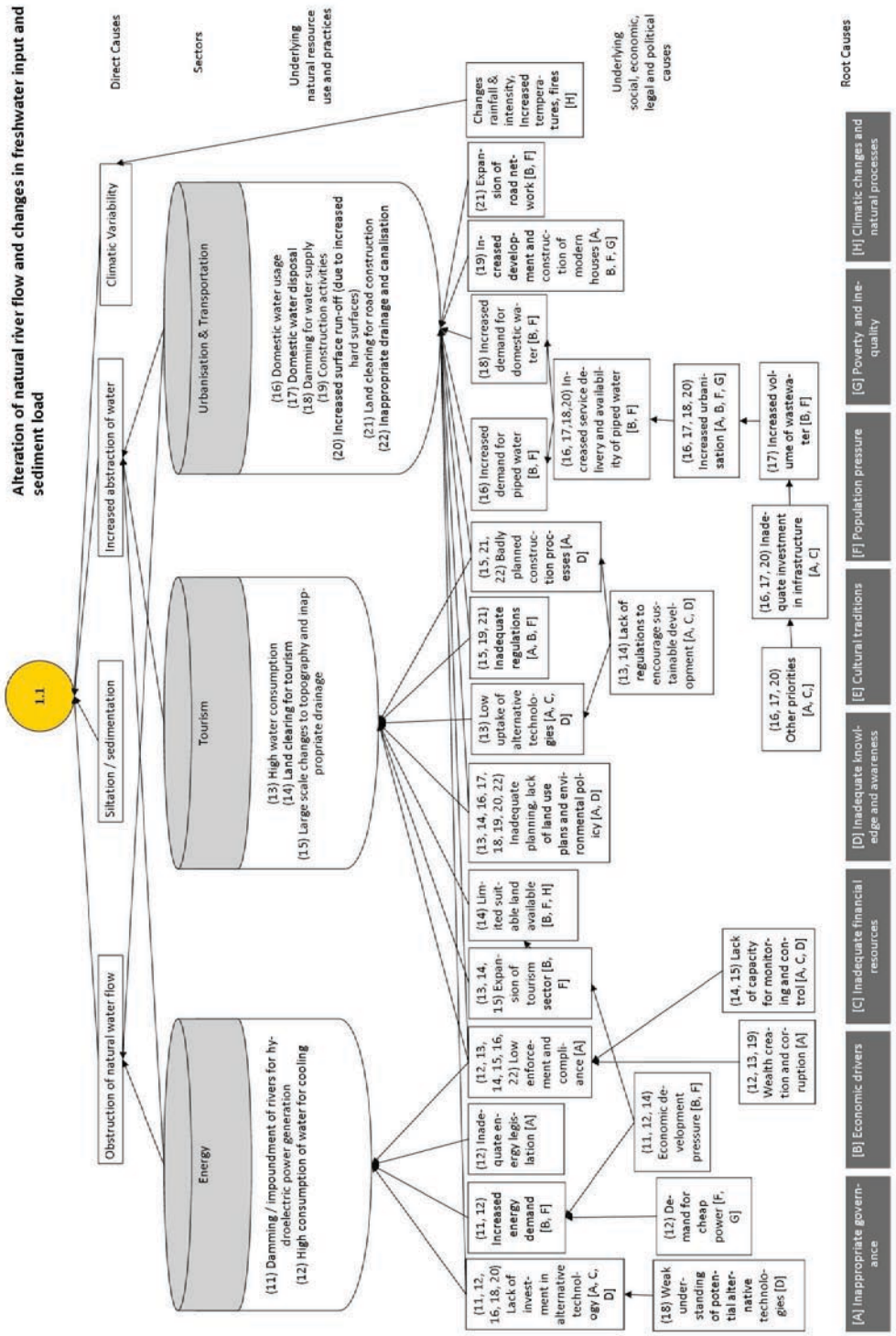

Figure 29b: Causal Chain Analysis for the issue (1.1) Alteration of natural river flow and changes in freshwater input and sediment load (part 2 of 2).

1.2. Degradation of ground and surface water quality

Impact Analysis

The main **environmental impacts** caused by degradation of ground and surface water quality include: degradation of freshwater, degradation of estuaries, salinisation of soils; degradation of soil quality; and decreased natural productivity.

The **ecosystem services** likely to be affected by the environmental impacts resulting from a 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 (incl. soil formation); and biological control (e.g. seed dispersal, pest and disease control).
Supporting / Habitat Services - maintenance of life cycles (incl. 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 / irrigation etc; 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:
- Rainfall variability
- Changes in land use and vegetation cover
- Deforestation
- Release of un- undertreated effluents from point sources / non-point sources
- Surface run-off (from agricultural land and urban areas)
- Sediment loads.

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** are as follows:

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 a lack of education, knowledge and awareness, and a lack of incentives for good practice. There is now a lack of agricultural extension officers within the region, and this contributes to a lack of 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 un- and under treated 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 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 a global economic market demand. The expansion of this sector results in increasing (10) disposal or seepage of un- or under treated 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 a lack of capacity for planning, as a well as a lack of capacity for monitoring and enforcement especially of EIA regulations.

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

Natural environmental variability and change: 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 urbanisation
- 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
[H] Climate change and natural processes

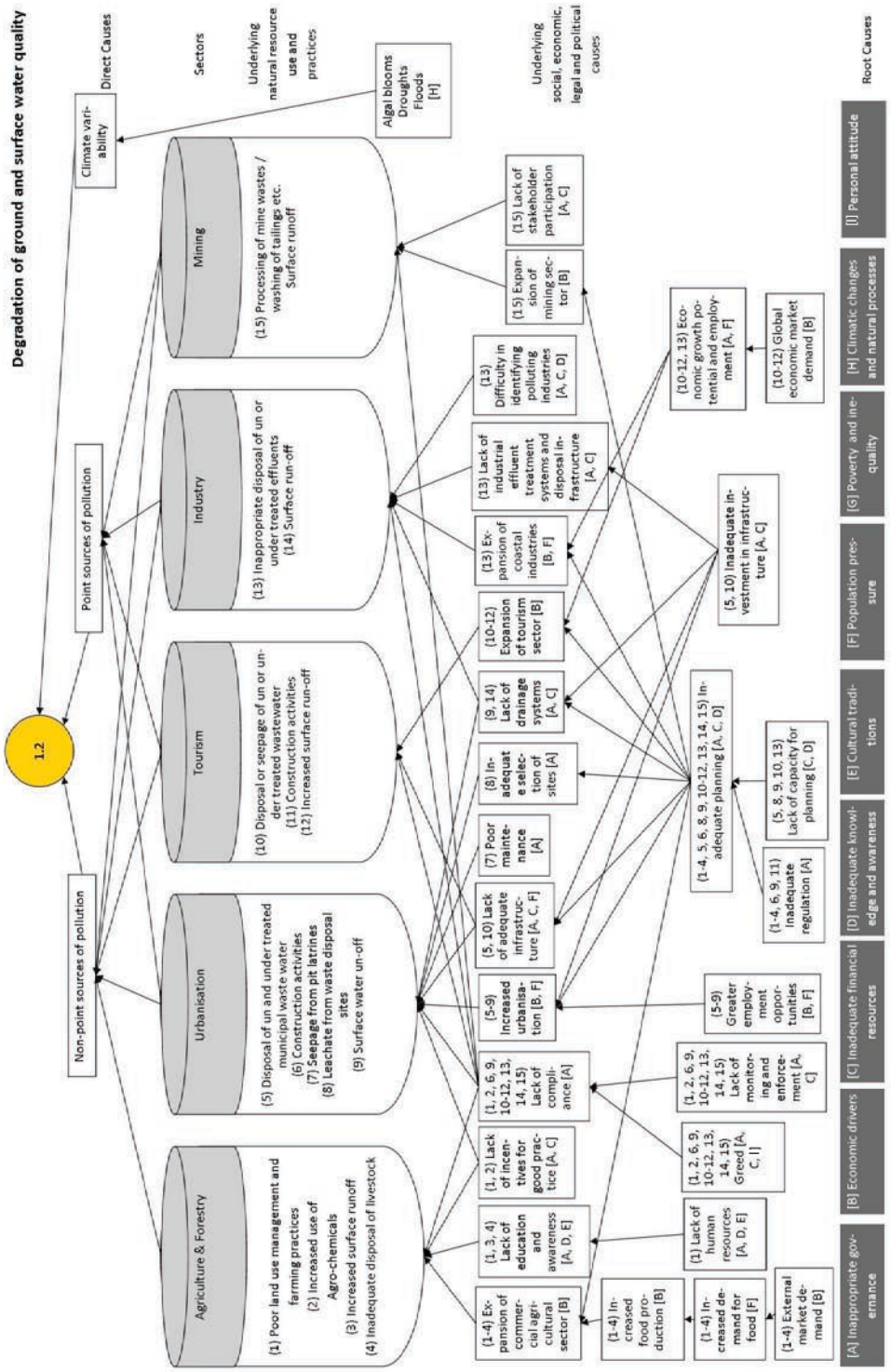

Figure 30: Causal Chain Analysis for the issue (1.2) Degradation of ground and surface water quality.

1.3.1 Microbiological contamination from land-based (domestic, industrial, agriculture and live-stock) and marine (mariculture, shipping) sources

Impact Analysis

The **environmental impacts** caused by microbiological contamination from land-based (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) sources 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 solid wastes / marine debris (plastics etc.) from shipping and land-based-sources include:
Provision 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 –Waste treatment (especially water purification); Nutrient cycling and maintenance of productivity; biological control (e.g. disease control)
Supporting / Habitat Services –maintenance of life cycles (incl. nursery, spawning, breeding, feeding); 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 (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) 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.

Causal Chain Analysis

The most important **direct causes** of microbiological contamination are:
Release of un undertreated effluents from point sources
Release of un undertreated effluents from nonpoint sources
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 through 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-capacity or out-of-date and unable to cope with the expanding urban populations of urban. This is due to a lack of planning but also a lack of investment in the necessary waste water infrastructure, which can be due to corruption.

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

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

Transportation and Shipping: (7) Disposal of liquid wastes from ships at sea occurs due to a lack of compliance with international maritime legislation, due to a lack of awareness, carelessness and lack a lack of capacity for the countries to enforce such laws in their EEZ. There is also a 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 urbanisation
- Inadequate or lack of land use plans and appropriate environmental policy
- Weak national planning and regulatory frameworks

The **Root Causes** of solid wastes / marine debris (plastics etc.) 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
[I] Personal attitude

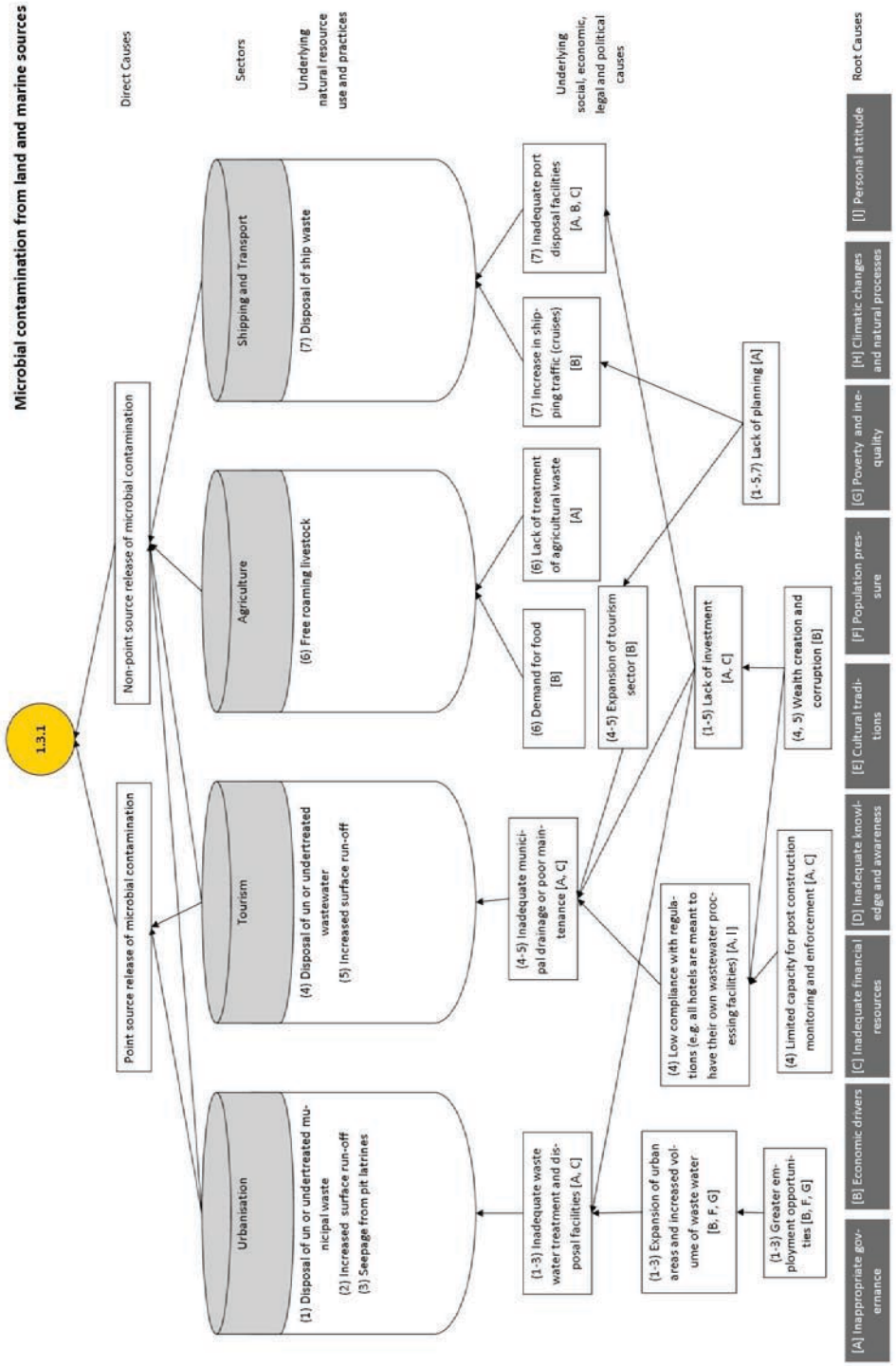

Figure 31: Causal Chain Analysis for the issue (1.3.1) Microbiological contamination from land-based (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) sources.

1.3.5 Solid wastes / marine debris (plastics etc.) from shipping and land-based-sources

Impact Analysis

The **environmental impacts** caused by solid wastes / marine debris (plastics etc.) from shipping and land-based-sources is declines 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; 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 (plastics etc.) from shipping and land-based-sources 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 etc.)
- Regulating Services – 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 – 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); bequest, intrinsic and existence; and social relations.

The **socio-economic impacts** caused by solid wastes / marine debris (plastics etc.) 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.

Causal Chain Analysis

The most important **direct causes** of solid wastes / marine debris (plastics etc.) from shipping and land-based-sources are:

- Inappropriate disposal of solid wastes
- Increased sediment loads, and
- Surface run-off (from agricultural land and urban areas).

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 a lack of planning for increased urbanisation and the increased volume of waste generated. The issue is compounded by a lack of awareness and understanding about the impacts of solid wastes on the environment, and a limited social attachment to the 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 disposal sites, due to either other political priorities. The (2) dumping of garbage occurs due to a 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, due to a lack of capacity.

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

Transportation and Shipping: (10) Throwing solid wastes overboard occurs due to a lack of facilities for collection and disposal of solid wastes at ports, a lack of awareness, carelessness and inadequate monitoring and enforcement due to a lack of capacity. (11) Waste disposal at sea / dumping takes place due to a lack of compliance with international maritime legislation and a 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 urbanisation
- 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] Personal attitude

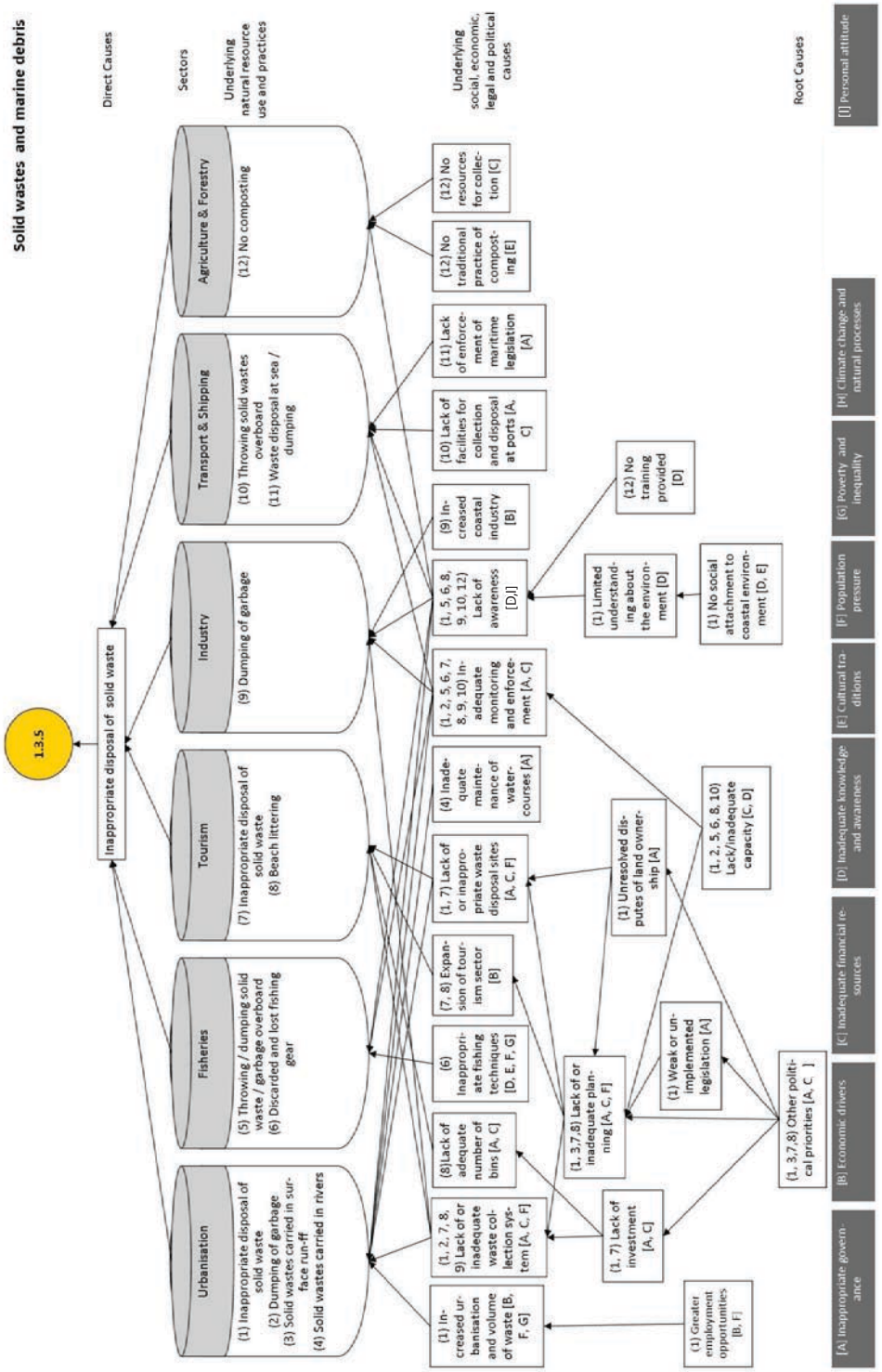

Figure 32: Causal Chain Analysis for the issue (1.3.5) Solid wastes / marine debris (plastics etc.) from shipping and land-based-sources.

1.3.6 Oil spills (drilling, exploitation, transport, processing, storage and shipping).

Impact Chain Analysis

The **environmental impacts** caused by oil spills (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 (smells and colour).

The **ecosystem services** impacted by oil spills (drilling, exploitation, transport, processing, storage and shipping) 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 (drilling, exploitation, transport, processing, storage, shipping) 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.

Causal Chain Analysis

The **direct cause** of oil spills (drilling, exploitation, transport, processing, storage and shipping) is:
- Accidental release of oil during extraction, refining and transport.

The **sectors** responsible for oil spills (drilling, exploitation, transport, processing, storage and shipping) 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 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 these 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, a lack of proper equipment and maintenance and a lack of appropriate safety procedures as a result of limited knowledge, skills and use of best practices and inadequate investment. There is 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 (which means the oil tankers are increasingly using routes through southern Indian Ocean). The (7) risk of a large scale oil spill within the ASCLMESs is increased due to the expansion of the oil industry within the region, and increased shipping traffic (as above) as a result of global economies and economic development pressure. Navigational resources within the region are inadequate due to a lack of information about possible natural hazards and a 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 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
- Negligence
- 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 oil spills (drilling, exploitation, transport, processing, storage, shipping) 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
[I] Personal attitude

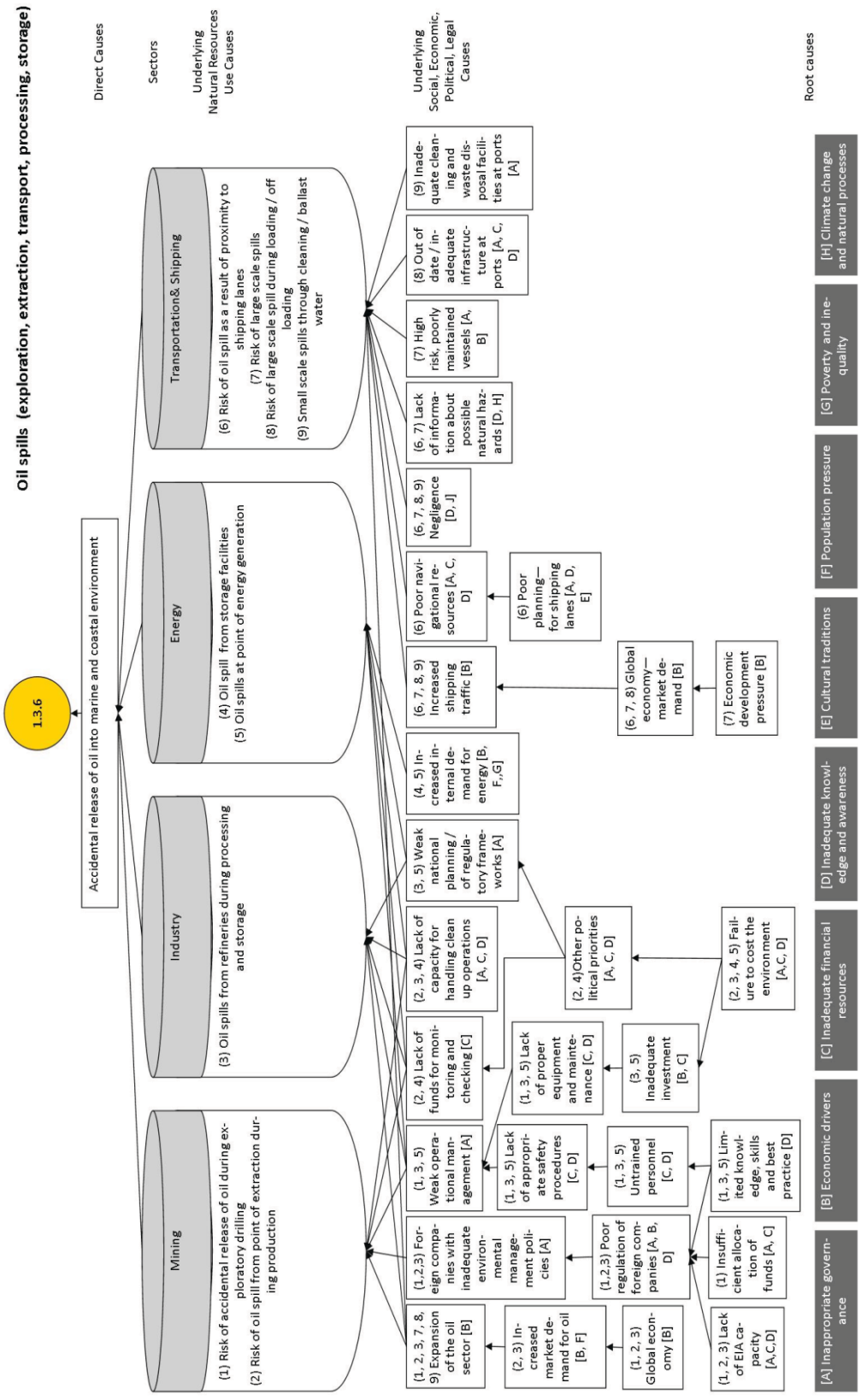

Figure 33: Causal Chain Analysis for the issue (1.3.6) Oil spills (drilling, exploitation, transport, processing, storage and shipping).

MAC02: Habitat and Community Modification

The following section presents the impact and causal chain analysis for the top priority transboundary issues related to MAC02 Habitats and Community Modification. The top priority issues identified by the countries within MAC02 were as follows:

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 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
2.6. 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 impacts) and the causal chain analysis (direct causes, sectors ad resource use practices, underlying social, legal and political causes, and root causes) is presented for each of these issue. The tabulated results for the impact and causal chain analysis for MAC02 are presented in Appendix IX.

2.1. Shoreline change due to modification, land reclamation and coastal erosion

Impact Chain Analysis

The **environmental impacts** caused by shoreline change due to modification, land reclamation and coastal erosion include: reduced water clarity and light available to photosynthetic organisms (turbidity); loss of biodiversity; increased risk of extinction of vulnerable / focal 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 / siltation); modification of coastal hydrodynamics; and phase shifts and changes in community composition.

The **ecosystem services** likely to be affected by the environmental impacts resulting from shoreline change due to modification, land reclamation and coastal erosion 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 (incl. 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 (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 **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.

Causal Chain Analysis

The most important **direct causes** of shoreline change due to modification, land reclamation and coastal erosion are:

- Shoreline erosion and
- Coral reef degradation.
- Physical removal of sediments;
- Cyclones;
- Increased frequency and intensity of storm waves (e.g. cyclones, tsunami etc.); and
- Sea level rise.

The **sectors** responsible for causing shoreline change due to modification, land reclamation and coastal erosion are: urbanisation, tourism, industry, mining, transport and shipping, agriculture and forestry, energy and natural environmental variability.

Tourism: (1) Infilling of sea frontages to increase land for recreation take place 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 a lack of human resources (extension officers and environment inspectors) and lack of knowledge of staff. (3) There are also gaps in the 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 a lack of training in EIA procedures and a lack of capacity in this regard.

Urbanisation: Unplanned coastal development occurs due to an increased coastal population and non-compliance with coastal set-back regulations. (6) Sand-mining from coastal rivers and beaches for construction arises due to a high local demand for sand for the construction industry. There is non-compliance with regulations concerning sand mining as a result of weak enforcement of sand mining in designated sites; this is due to a lack of knowledge and awareness by Governments. In addition, sand mining is a low skilled and low technology livelihood 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 a 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 a lack of human resources (extension officers).

Agriculture and Forestry: (11) Increased runoff from agricultural land and (1) inadequate land use management occurs due to economic development priorities, the lack of land-use plans and / or the inability to enforce good land use management practices, due to the high percentage of private land ownership in some countries, and a 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 urbanisation
- Lack of awareness of the longer term implications in Govt.
- 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
[H] Climate change and natural processes

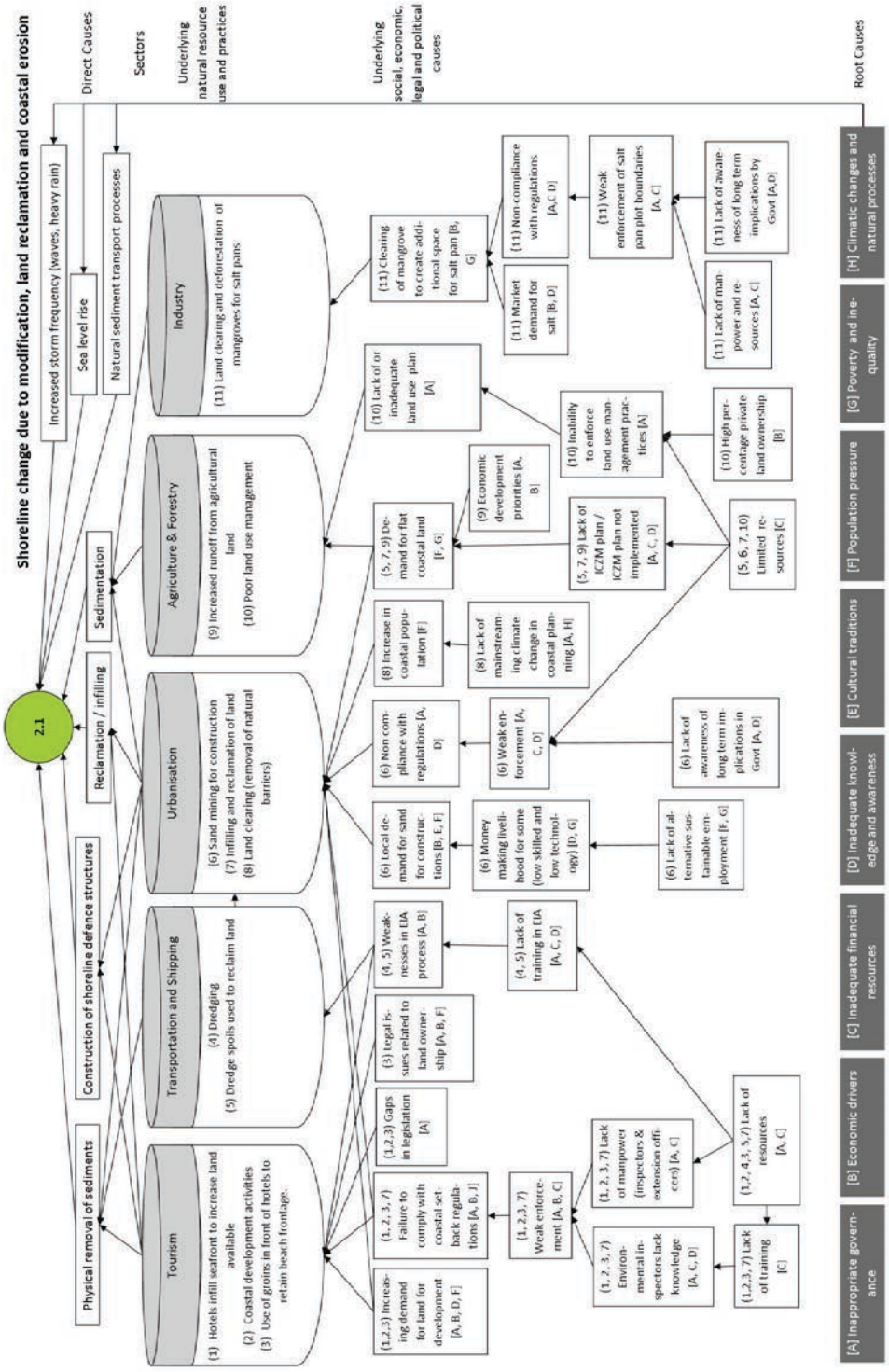

Figure 34: Causal Chain Analysis for the issue (2.1) Shoreline change, due to modification, land reclamation and coastal erosion

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

Impact Chain Analysis

The most severe **environmental impacts** caused by disturbance, damage and loss of upland / watershed habitats (>10 m elevation) 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 / siltation); reduced water quality (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); increased salt water intrusion (and salinisation of soils); 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 (>10 m elevation) 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 (salinisation).

Causal Chain Analysis

The most important **direct cause** of disturbance, damage and loss of upland / watershed habitats (>10 m elevation) 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
Cyclones
The **sectors** responsible for causing disturbance, damage and loss of upland / watershed habitats (>10 m elevation) 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, the lack of land use management plans or failure to implement the plans, due to a lack of capacity and resources, 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 ('slash and burn'). These practices result from a lack of awareness, due to the loss of traditional knowledge bit also due to a lack of education and outreach, as a result of no investment in extension officer, due to other political priorities. Another cause is (4) unsustainable intensive commercial land uses (i.e. forestry, sugarcane and livestock).

Natural environmental variability and change: Disturbance to upland and 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 (>10 m elevation) 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 Govt.
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 (>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
[H] Climate change and natural processes

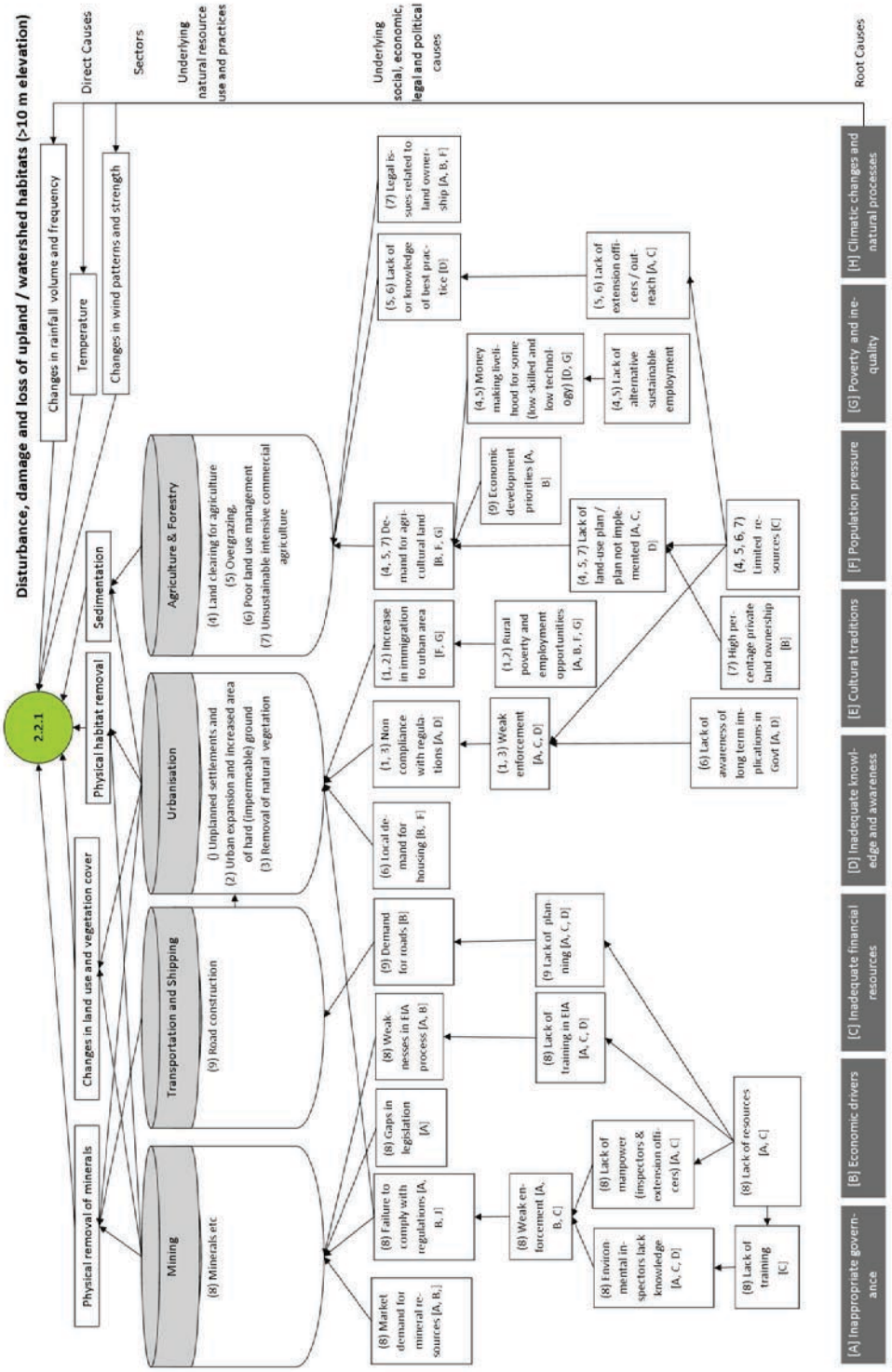

Figure 35: Causal Chain Analysis for the issue (2.2.1) Disturbance, damage and loss of upland / watershed habitats (>10 m elevation)

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

Impact Chain Analysis

The most severe **environmental impacts** caused by the disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) are: increased risk of extinction of vulnerable / focal 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 / siltation). 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 disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) 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.

Causal Chain Analysis

The most important **direct causes** of the disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation)
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
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 / sedimentation
Cyclones
Increased frequency and intensity of storm waves (e.g. cyclones, tsunami etc.)
Light / noise
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 a failure to comply with coastal set-back regulations, deficiencies in EIA process, a lack capacity for monitoring and enforcement of mitigation measures, and a lack of transparency, and corruption in the planning system. As a result of increased tourism there has also been an increase in the activities offered by local (2) tour guides, who may lack awareness as a result of a lack of training.

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 ASCLME as a result of 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 groups such as turtles, seabirds and shorebirds utilizing the coastal environment. Urban development in the coastal zone and the expansion of the cities increase (9) garbage dumping on the 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; 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.

Natural processes and environmental variability: Disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation) 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 Govt.
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 urbanisation
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 disturbance damage and loss of coastal 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
[H] Climate change and natural processes

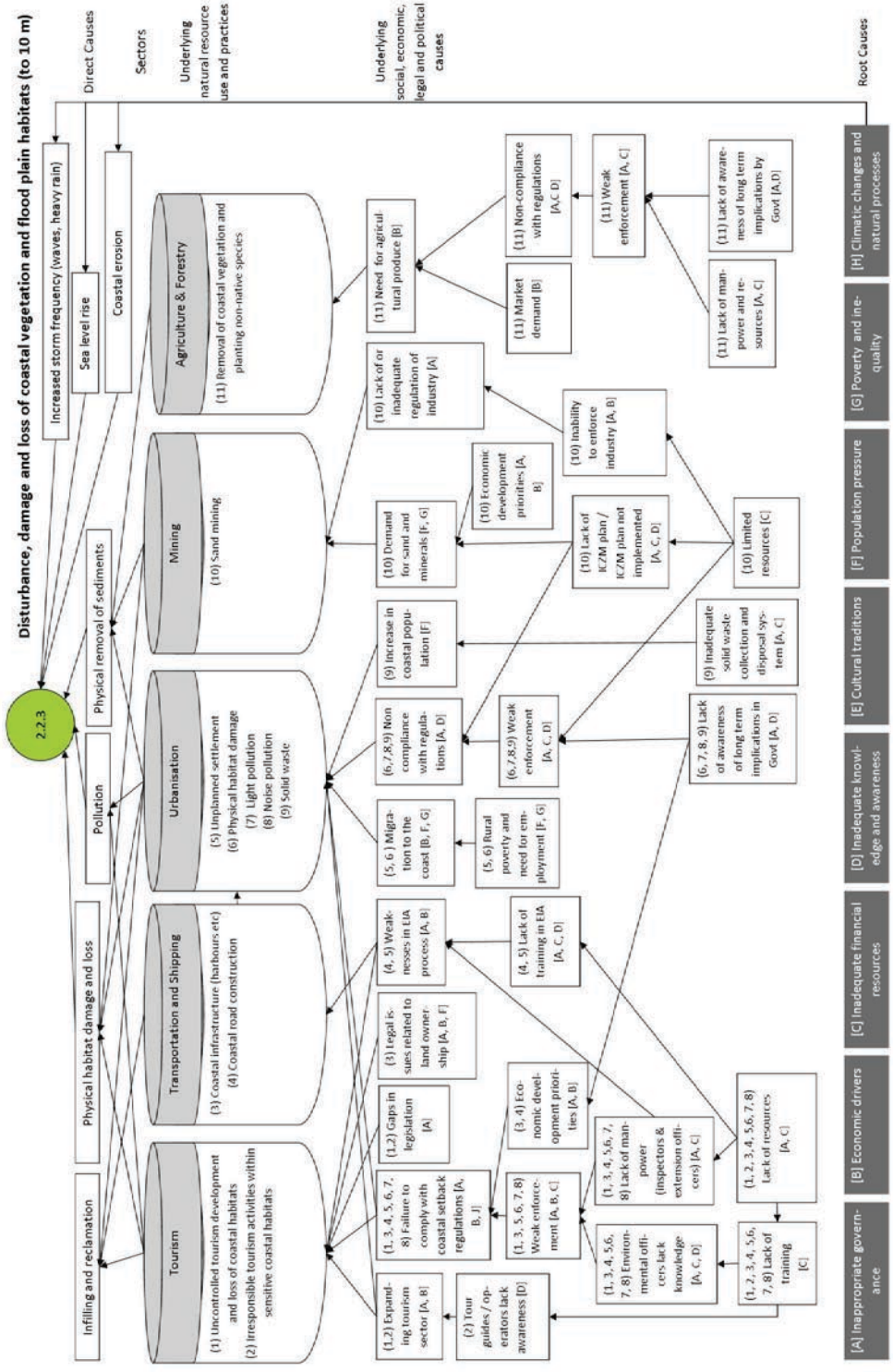

Figure 36: Causal Chain Analysis for the issue (2.2.3) Disturbance, damage and loss of coastal vegetation and flood plain habitats (to 10 m elevation)

2.2.6. Disturbance, damage and loss of mangrove habitats

Impact Chain Analysis

The most severe **environmental impacts** caused by disturbance, damage and loss of mangrove 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 / siltation). Other severe impacts, which are likely to seriously degrade parts of the ecosystem are: increased risk of extinction of vulnerable / focal 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 disturbance, damage and loss of mangrove 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.

Causal Chain Analysis

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
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.)
Disease and plague organisms
The **sectors** responsible for of disturbance, damage and loss of mangrove 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 mangrove due to (1) overcutting occurs as a result of the increased demand for fuel and timber, due to the loss and overexploitation of inland forests, as a result of inadequate regulations. The (2) clearing of land for cultivation, and (7) grazing, free-roaming livestock, 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 a lack of access to suitable technology, contribute towards the decline in mangroves. The (9) clearing of mangrove habitats for aquaculture ponds occurs as a result of market opportunity and a lack of knowledge and awareness. (10) Overexploitation of mangroves by fisher communities for fuel-wood, timber and traps, occurs due to the lack of affordable alternatives for building traps, shelters or boats, and due to the 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 meet with 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, with the capacity to cope with coastal industries. The (17) clearing of mangroves for the creation of salt pans is because of the money that can be made from this industry; it occurs due a failure of the companies to comply with existing regulations, and due to a 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, a lack of knowledge and greed.

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

The main **Underlying Causes** of damage and loss of mangrove 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 urbanisation
Lack of education, training and awareness
Lack of awareness of longer term implications in Govt.
Lack of ICZM plan / ICZM plan not implemented
Weak national planning and regulatory frameworks

The **Root Causes** of damage 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
[H] Climate change and natural processes

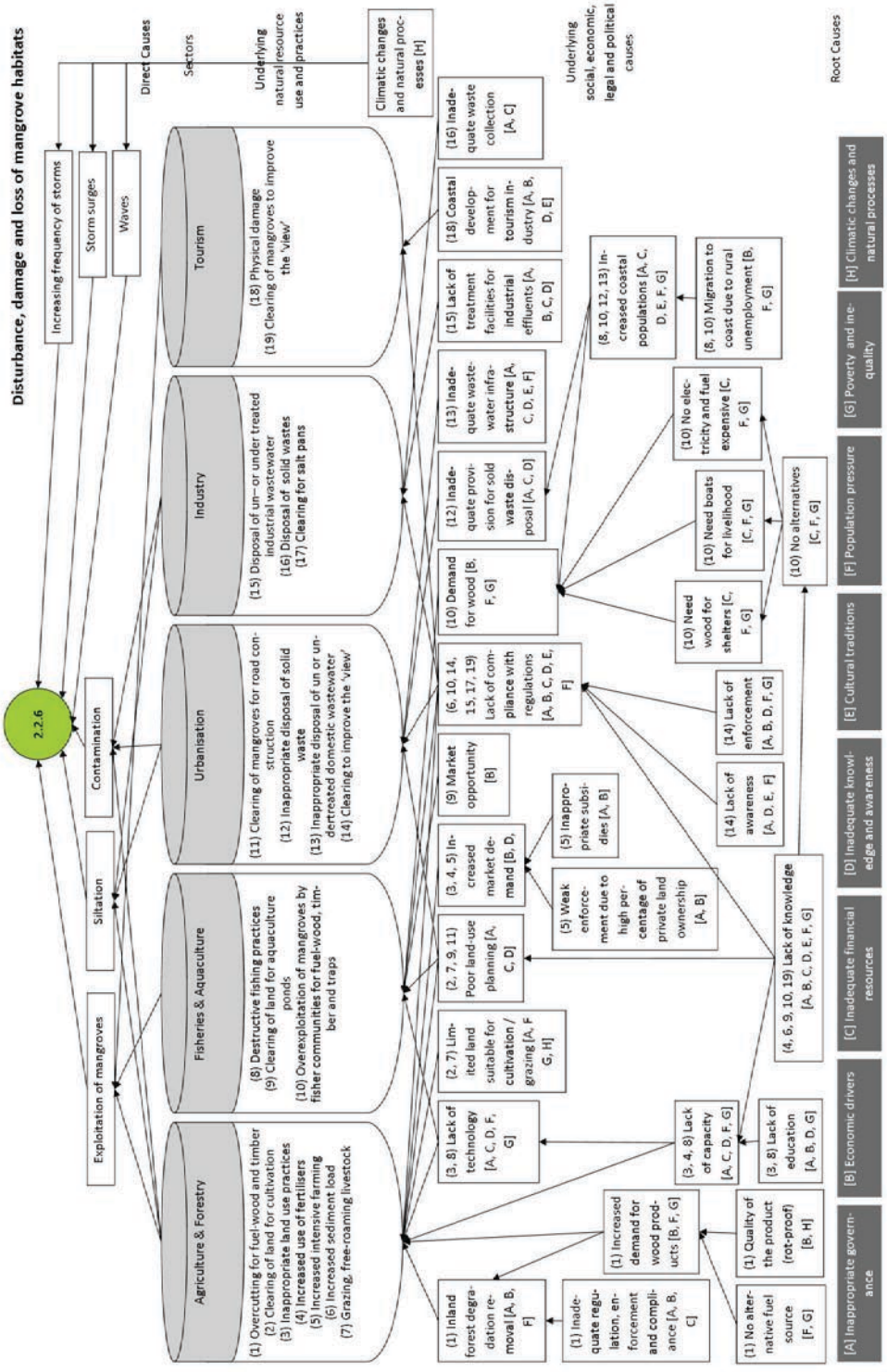

Figure 37: Causal Chain Analysis for the issue (2.2.6) Disturbance, damage and loss of mangrove habitats

2.3.1. Disturbance, damage and loss of coral reef habitats

Impact Chain Analysis

The most severe **environmental impacts** caused by disturbance, damage and loss of coral reef habitats are: loss of biodiversity; increased risk of extinction of vulnerable / focal 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 / siltation); 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 (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; 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.

Causal Chain Analysis

The most important **direct causes** of disturbance, damage and loss of coral reef 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:

Tourism: (1) Trampling damage and anchor damage by boats occur due to ignorance and lack of awareness. This results from personal attitude as well as lack of education and training due to the lack of capital investment in education and awareness. (2) The collection of ornamental products takes place due to the local demand to supply the tourist trade, as this is a money making livelihood. Tourists purchasing these products also lack awareness. (3) Anchor damage results from the increased demand for tourist activities and a lack of awareness of tourists and operators, caused by the lack of trained tour guides, due to no capital investment in education and awareness and the lack of capacity in Government (e.g. ministry responsible for tourism). In addition, there is a lack of zoning plans and a lack of moorings due to a lack of capacity to manage areas outside of MPAs, technical difficulties installing the mooring buoys and due to gaps in regulations. (4) Poor wastewater management has similar underlying causes as for urbanisation above. All of the above activities also occur due outdated legislation as a result of a lack of legal expertise, or a lack of enforcement of existing regulations, caused by a lack of capacity institutional conflicts within and between various Government departments (e.g. ministry responsible for the environment and marine protected areas and the ministry responsible for tourism).

Transportation and Shipping: (5) Ship groundings occur due to navigational hazards and a lack of navigational aids as a result of poor planning and a lack of investment. (6) Dredging takes place as it is essential to maintain port access. There is limited planning and a lack of sensitivity maps due to a lack of resource assessments and biodiversity inventories as a result of a limited number of taxonomic experts. There are inadequate human or financial resources due to other political priorities. (7) Introduction of exotic species and the (8) accidental release of contaminants, oil and oil spills occur due to the lack of information and training for staff and as a result of poor planning and ICZM. There are also limited waste disposal facilities in ports due to a lack of investment in infrastructure as a result of other political priorities. (8) Impacts arise for salvaging for scrap metal as this is an open access resource and there are no guidelines for salvage operations.

Fisheries: (10) Overfishing and (11) illegal fishing takes place due to an increasing local demand for fish, and a decline in catches results in increased use of illegal methods. The decline in catches occurs due to overcapacity within the fishery and 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. Illegal fishing methods often include those that cause (12) physical damage to habitats, which exacerbate the decline in fisheries. These practices often occur as it is often a low cost fishing method, and there is easy access to the materials to make dynamite. Overfishing (13) of keystone predators can cause a shift in the dominance of certain species groups (e.g. removal trigger fishes and increased abundance of sea urchins). Overfishing of these species is usually because they are preferred food fishes and hence fetch a higher price. There is ignorance and lack of awareness amongst the fishing community and a lack of willingness to change, due in part to limited education and awareness, which occurs as a result of no capital investment in awareness and education. (14) There are certain methods used in this fishery that involve pollution (e.g. use of oil). (15) Aquarium fisheries take place due to the international demand for fish and corals for the aquarium trade. This is a money making livelihood and is increasing in popularity as a result of a higher premium than subsistence fishing. There are no limits on the number of permits and the price of fish is not regulated which increases competition. There are no standards or guidelines for collection and no management plan due to the lack of technical capacity to prepare guidelines and there is a lack of capacity for management or enforcement.

All of the above is underpinned by low compliance with existing regulations and weak enforcement as a result of lack of capacity for monitoring and surveillance. The lack of monitoring and surveillance often occurs due to an insufficient budget allocation. This can occur as a result of resources and a lack of political understanding of the importance of the fisheries. The latter can arise from a lack of coordination between research institutions and the different Government ministries, whereby the research institutes fail to present sufficient evidence (from targeted research) to the Government to convince them of the need to increase the budget allocation. The majority of these fisheries also do not have management plans, and there is weak enforcement of MPAs and ICZM.

Agriculture and Forestry: (16) Poor land use practices take place due to limited land available for agriculture. There has also been a loss of traditional practices, due to population pressure (immigration and migration to the coast), and due to the 'Tragedy of the Commons' (river banks are open access). There is low compliance

with existing regulations, and no enforcement of illegal practices resulting from a lack of human resources (lack of extension officers). There is also a lack of awareness as a result of a lack of education about best practices. (17) Deforestation takes place due to a high demand for wood caused by the reliance on wood for fuel and a lack of affordable alternative fuel sources as well as inadequate infrastructure for a growing population caused by a lack of planning. (18) Increased surface run-off and sedimentation occurs as result of failure to protect the watersheds, inadequate land-use planning, due to a lack of capacity (human and financial). (19) Over-application of fertilisers and the continued use of (20) POPs takes place due to the low productivity of soils, and increased demand for agricultural produce, but also a result of a lack of knowledge, technology and best practice, and an inability to control the import and use of toxic chemical compounds.

Urbanisation: (21) Poor management of municipal wastewater arises due to an increase in coastal populations and an increased demand for modern housing. This results in un- or poorly planned developments with a lack of adequate waste disposal and treatment provision. The sewage infrastructure is outdated and under capacity as a result of lack of investment, due mainly to other political priorities and corruption. (22) Land reclamation activities take place due to a high demand for flat land. There is a lack of awareness by Government and gaps in the legislation due to a lack of legal expertise. There is also a lack of capacity to monitor for EIA compliance and EIA processes are not transparent due to corruption in planning activities. (23) Desalination occurs due to poor planning with no anticipation of the increased water demand.

Mining: (25) Sand and coral mining take place due to the local demand for building materials and the high price of imported cement and lack of affordable alternatives. There is a lack of compliance with regulations due to weak enforcement.

Energy: (26) Accidental release of oil from storage facilities arises due to limited maintenance of storage facilities.

Industry: (27) Poor wastewater management occurs due to the lack of investment in treatment for effluents as a result of weak corporate social responsibility of the company as well as a lack of compliance with regulations due to a lack of capacity to regulate actions by foreign companies.

Natural environmental variability and change: Disturbance, damage and loss of coral reef habitats occurs due to increased seawater temperatures, ocean acidification, and increasing frequency and intensity of waves.

The main **Underlying Causes** of damage and loss of coral reef habitats can be summarised as follows:
Rural poverty, increased coastal migration and urbanisation
Economic growth potential and employment opportunities
Failure to cost the environment
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
Loss of traditional management practices
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 Govt.

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
[H] Climate change and natural processes
[I] Personal attitude

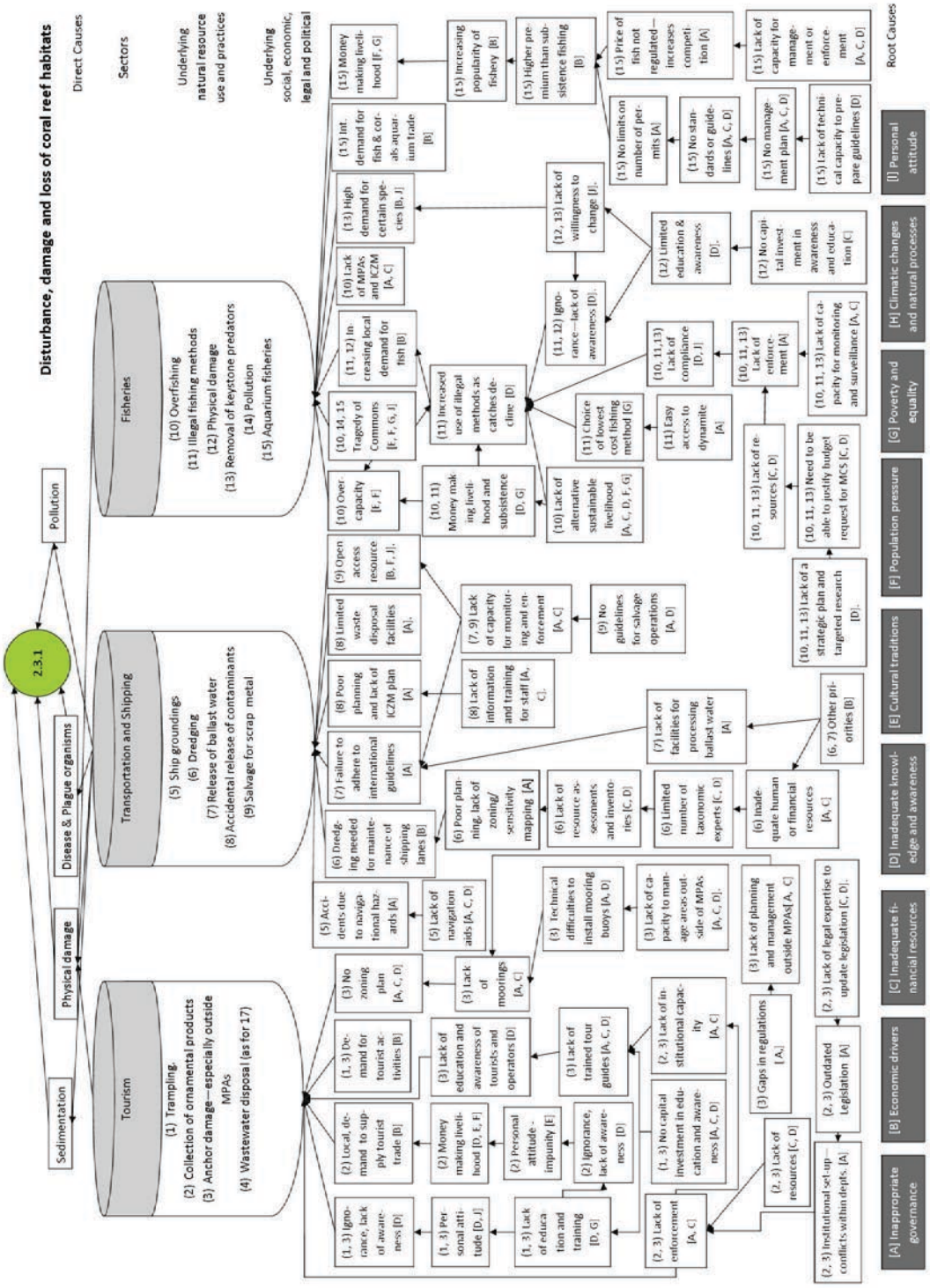

Figure 38a: Causal Chain Analysis for the issue (2.3.1) Disturbance, damage and loss of coral reef habitats (part 1 of 2)

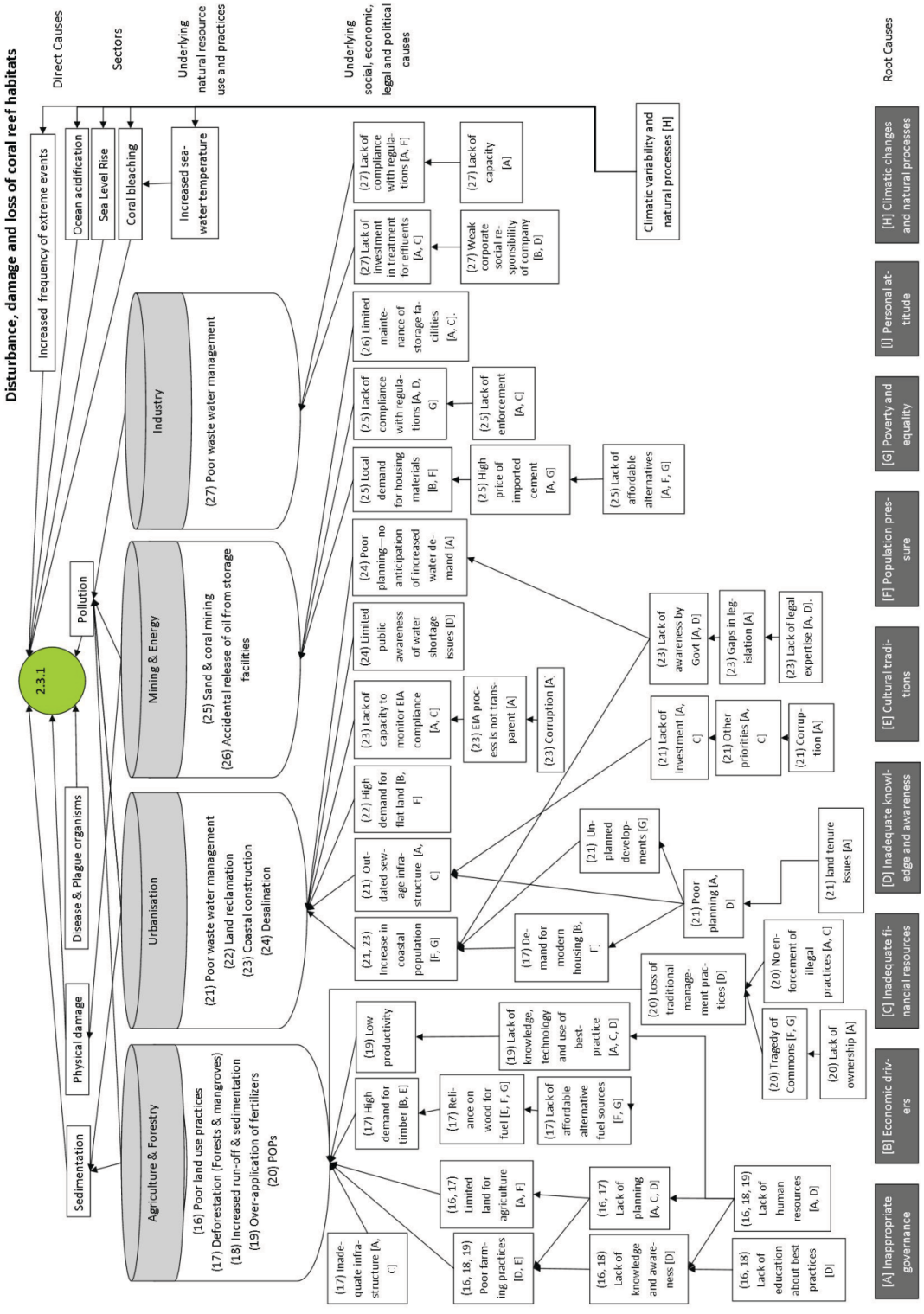

Figure 39b: Causal Chain Analysis for the issue (2.3.1) Disturbance, damage and loss of coral reef habitats (part 2 of 2)

2.3.2. Disturbance, damage and loss of seagrass habitats

Impact Chain Analysis

The most severe **environmental impacts** caused by disturbance, damage and loss of seagrass habitats are: increased coastal erosion; changes to sediment transport dynamics (accretion / siltation); 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 / focal 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 (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; 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).

Causal Chain Analysis

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 / sedimentation 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 a loss of traditional practices due to the 'tragedy of the commons' (river banks are open

access) and a lack of knowledge, technology and use of best practices resulting from a lack of awareness. There is also no enforcement of illegal practices due to a lack of resources. (2) Deforestation takes place due to a high demand for wood caused by the reliance on wood for fuel and a 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
[H] Climate change and natural processes
[I] Personal attitude

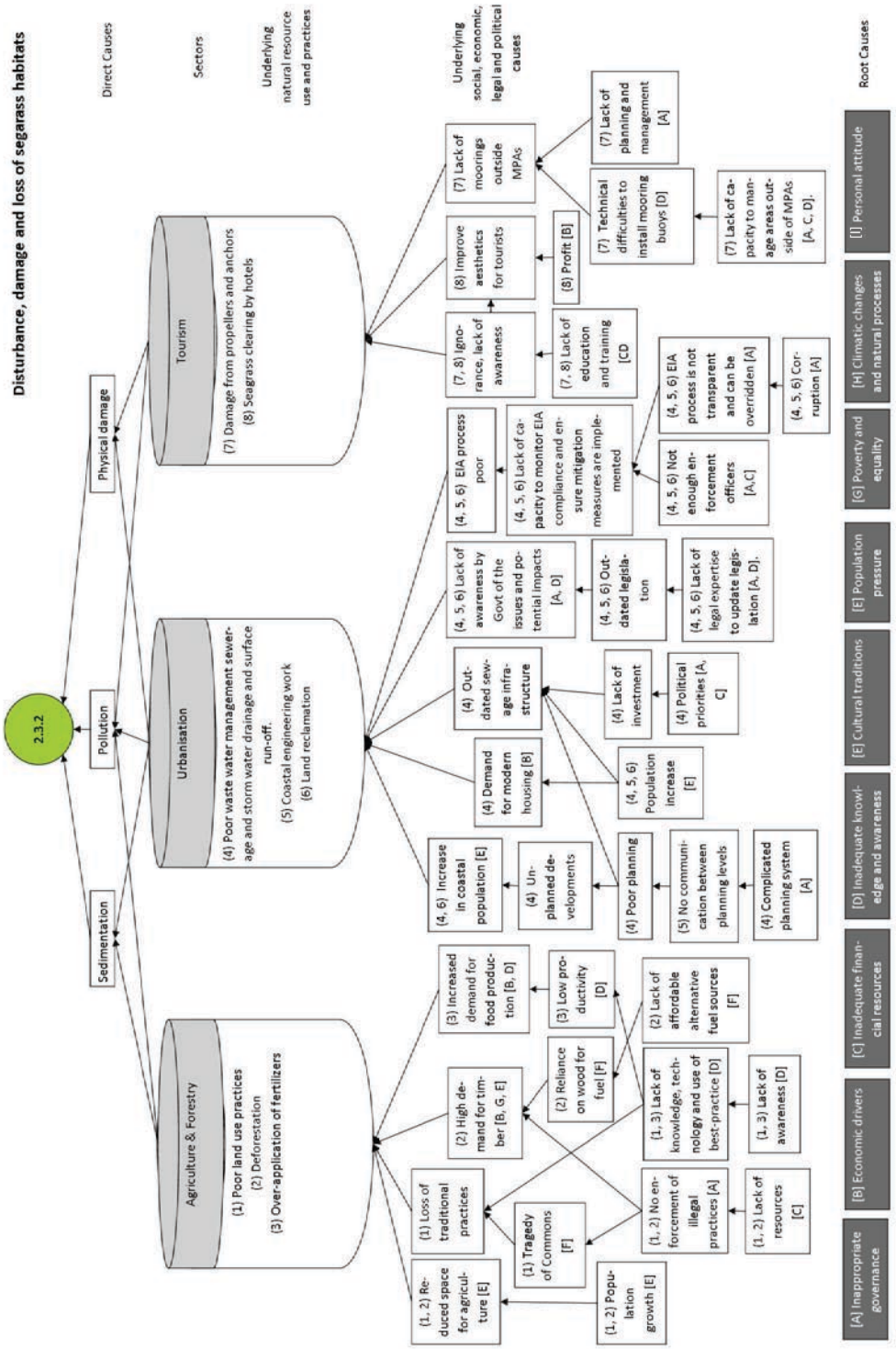

Figure 40a: Causal Chain Analysis for the issue (2.3.2) Disturbance, damage and loss of seagrass habitats (part 1 of 2)

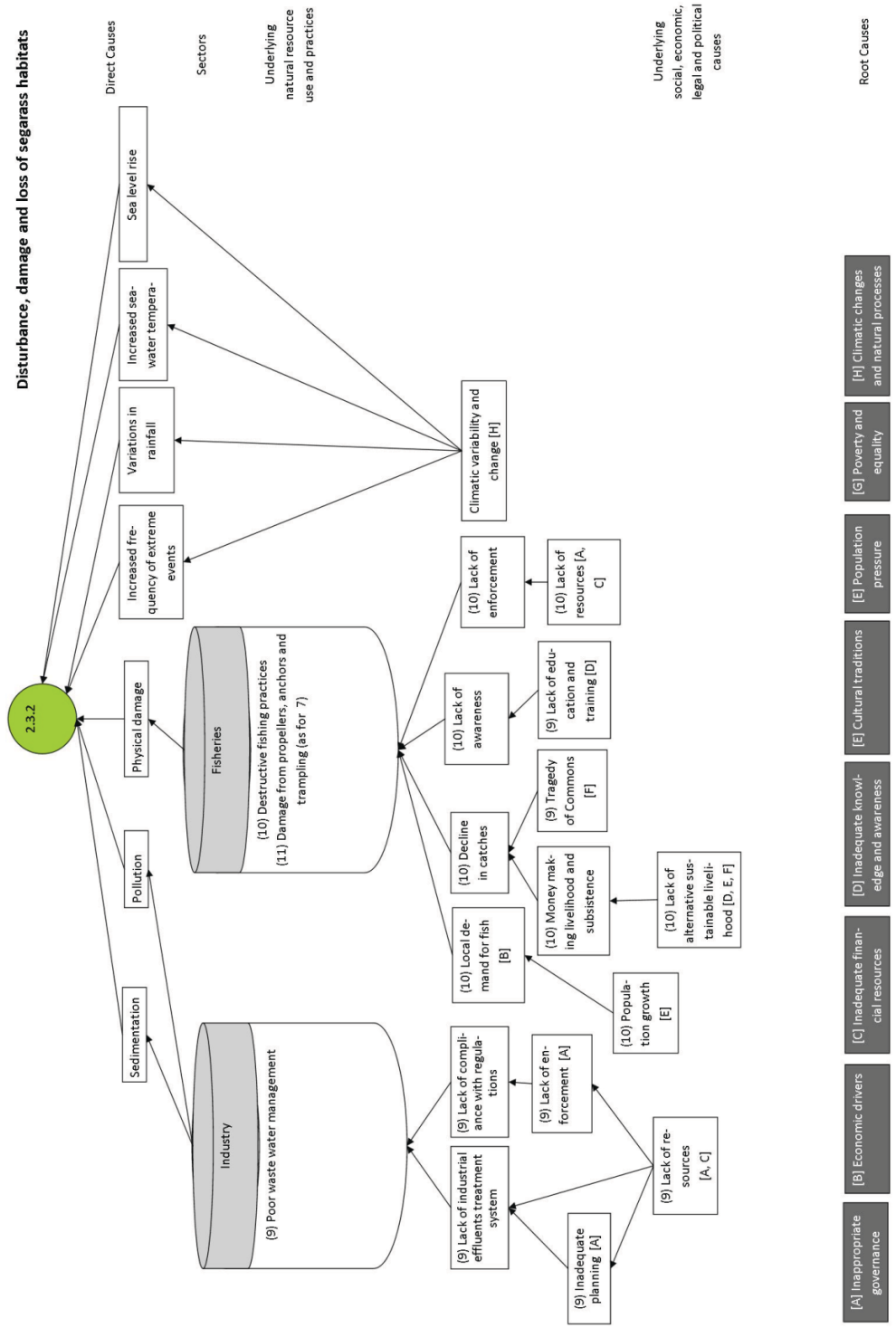

Figure 40b: Causal Chain Analysis for the issue (2.3.2) Disturbance, damage and loss of seagrass habitats (part 2 of 2).

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

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 / focal 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 (incl. 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.

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);
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 / or 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. The 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 a 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 the 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 activates and (6) exploitation activities for the oil and gas sectors in deeper water habitats has already commenced in the WIO. The expansion of this sector is driven by the declining global supplies of oil and gas in tandem with ever expanding global market demand, driving prices higher and 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 a 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 a 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, whereby nutrient supplies to the surface waters can biome depleted, while dissolved oxygen levels in the lower layers then 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 for human kind to find a new way to dispose of the carbon dioxide gas produced.

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 Govt.
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
[I] Personal attitude

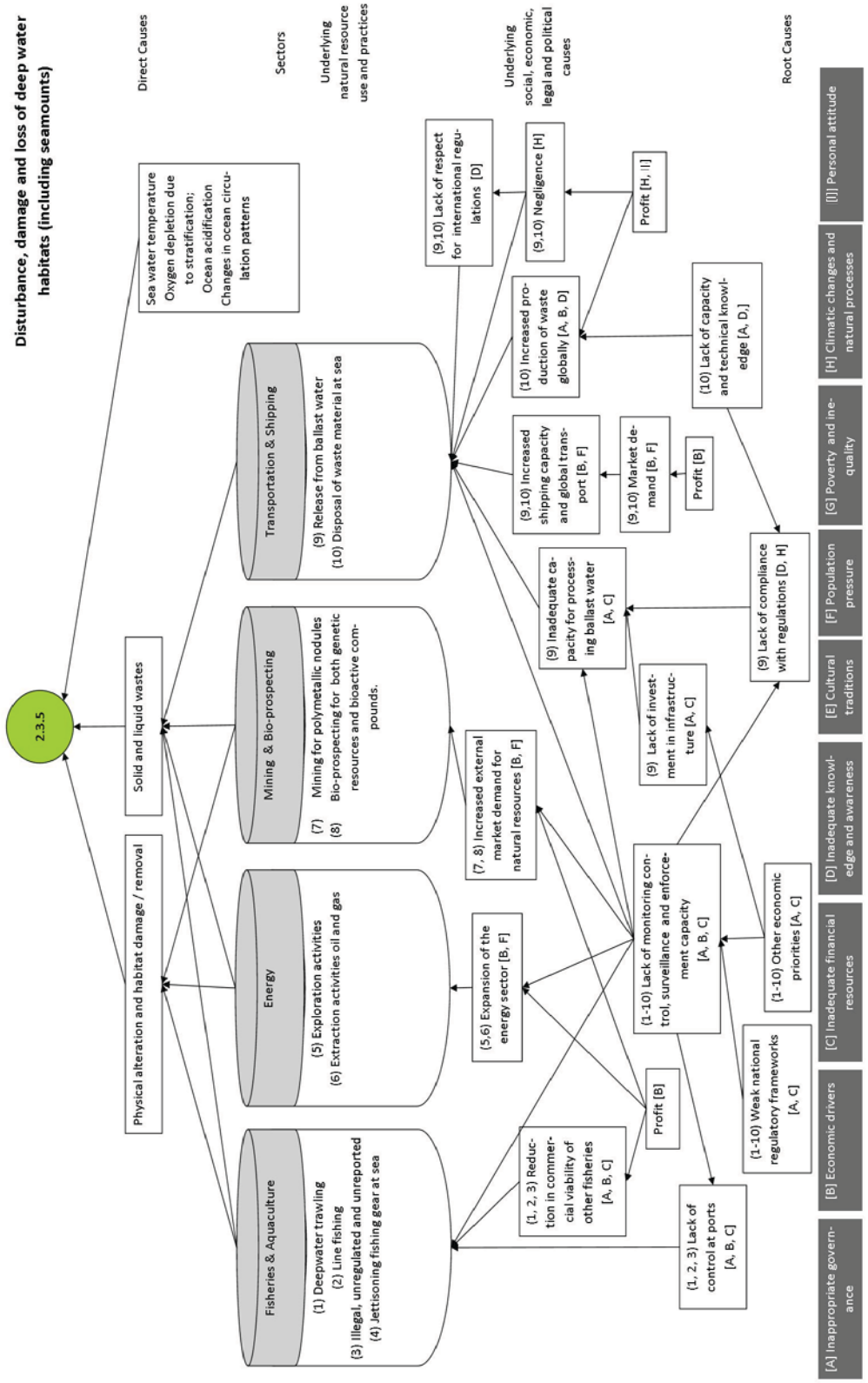

Figure 41: Causal Chain Analysis for the issue (2.3.5) Disturbance, damage and loss of deep water habitats (including sea mounts).

2.6. Introduction of exotic non-native species, invasives and nuisance species

Impact Chain Analysis

The most severe **environmental impacts** caused by the introduction of exotic non-native species, invasives and nuisance species are: reduced area of critical habitats (feeding, breeding, spawning); and phase shifts and changes in community composition. These are both likely to seriously degrade part of the ecosystem within 10 years if the issues are allowed to continue. Other medium impacts which are likely to moderately degrade part of the 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 (incl. 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 within 10 years if the issues are allowed to continue.

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
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 a 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 as a lack of control at entry points due to a 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 a lack of knowledge, a 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
[H] Climate change and natural processes

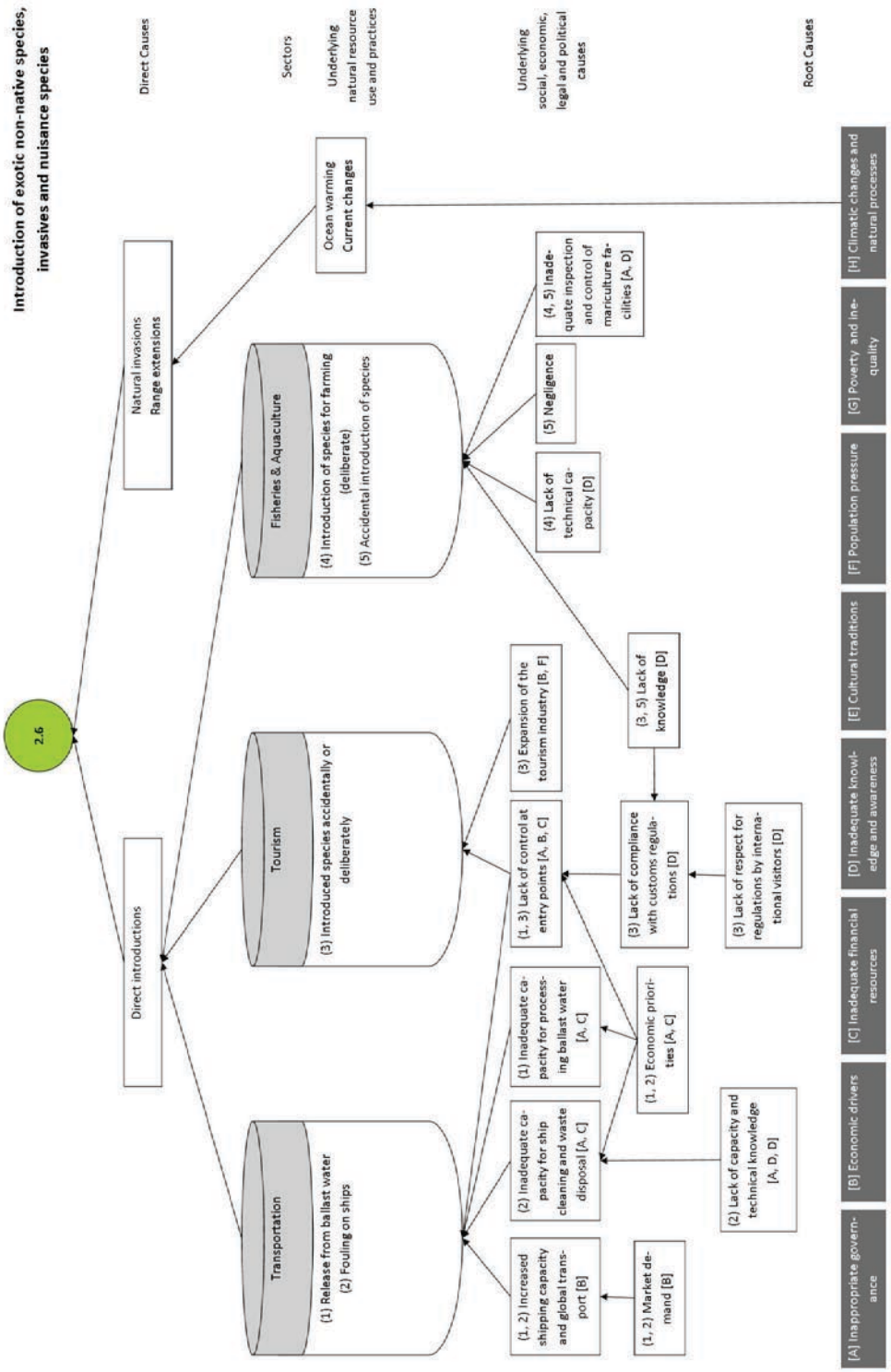

Figure 42: Causal Chain Analysis for the issue (2.6) Introduction of exotic non-native species, invasives and nuisance species.

MAC03: Declines in living marine resources

The following section presents the impact and causal chain analysis for the top priority transboundary issues related to MAC03 Declines in Living Marine Resources. The top priority issues identified by the countries within MAC03 were as follows:

3.2.1. Decline in populations of sharks and rays
3.2.2. Decline in populations of large pelagics
3.2.3. Decline in populations of small pelagics
3.2.5. Decline in populations of reef and demersal fish
3.3.3 Decline in populations of sea cucumbers
3.3.4. Decline in populations of prawns and shrimp
3.3.5 Decline in populations of lobster
3.4. 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 ad resource use practices, underlying social, legal and political causes, and root causes) is presented for each of these issue. The tabulated results for the impact and causal chain analysis for MAC03 are presented in Appendix X.

3.2.1. Decline in populations of sharks and rays

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. *Lethirinids* 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 (incl. soil formation).
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; 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.

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 and inadequate data / monitoring. 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 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. The lack of research is due to a shortage of trained scientists, which is due to the difficulty in attracting students into science, as a result of inadequate funding (low salaries) and a failure in the basic education system (maths and science).

The lack of funding (for enforcement and research) in the country concerned, occurs because there is a 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 (levies) but these are set too low to able to leverage sufficient funds to cover the costs of the 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 Govt.
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
[G] Poverty and inequality
[H] Climate change and natural processes
[I] Personal attitude

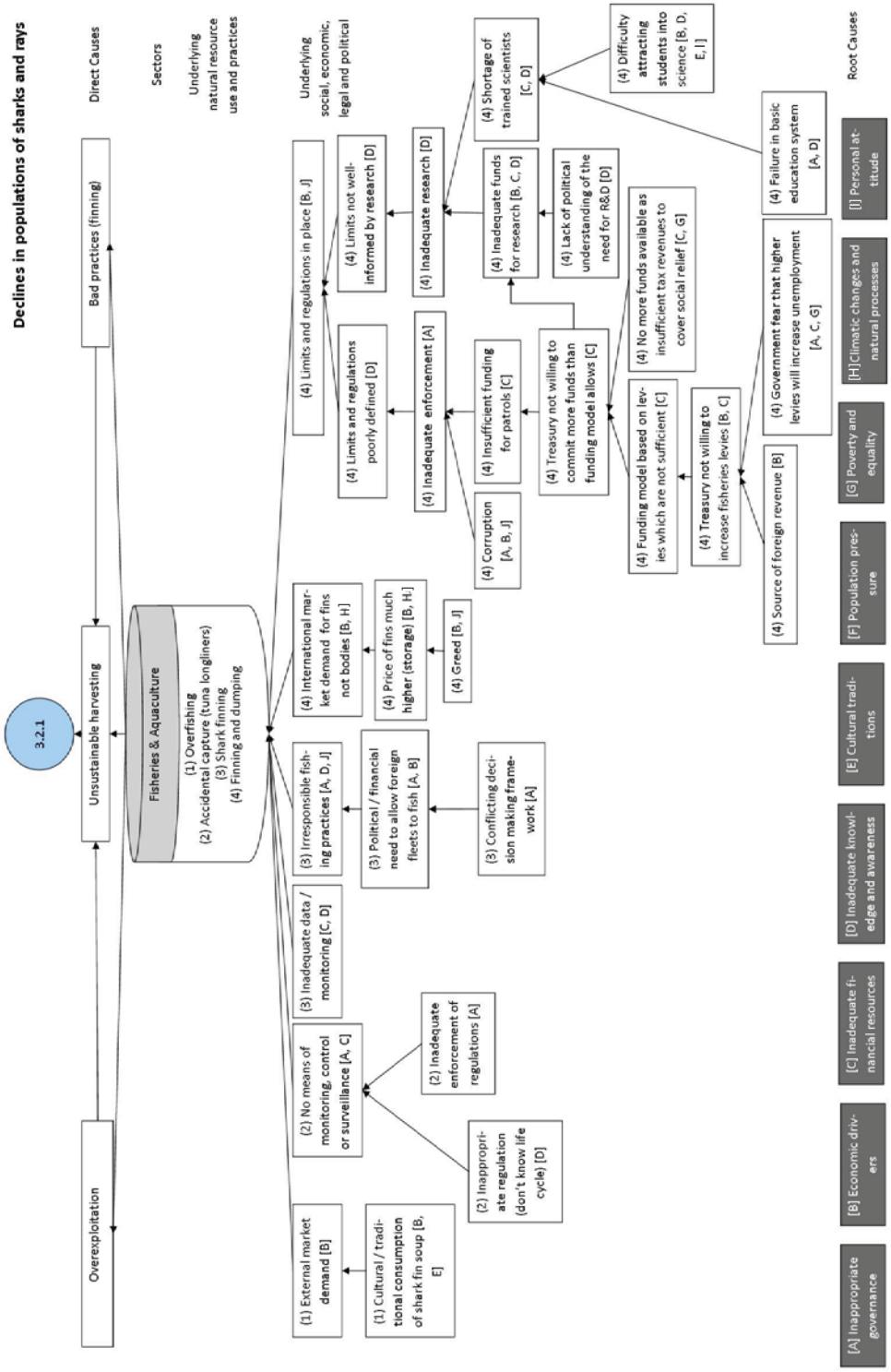

Figure 43: Causal Chain Analysis for the issue (3.2.1) Decline in populations of sharks and rays.

3.2.2 Decline in populations of large pelagics

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 (incl. soil formation).
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; 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.

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 ASCLMESs. 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 the lack of monitoring or surveillance capacity. The 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 the 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 the lack of alternative sustainable livelihoods, due to the 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 a lack of regulation of the catches.

Natural environmental variability and change: Changes in primary productivity, linked to changes in ocean circulation and sea temperatures can also contribute towards a decline in populations of large pelagics due to reduced primary.

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
[H] Climate change and natural processes.

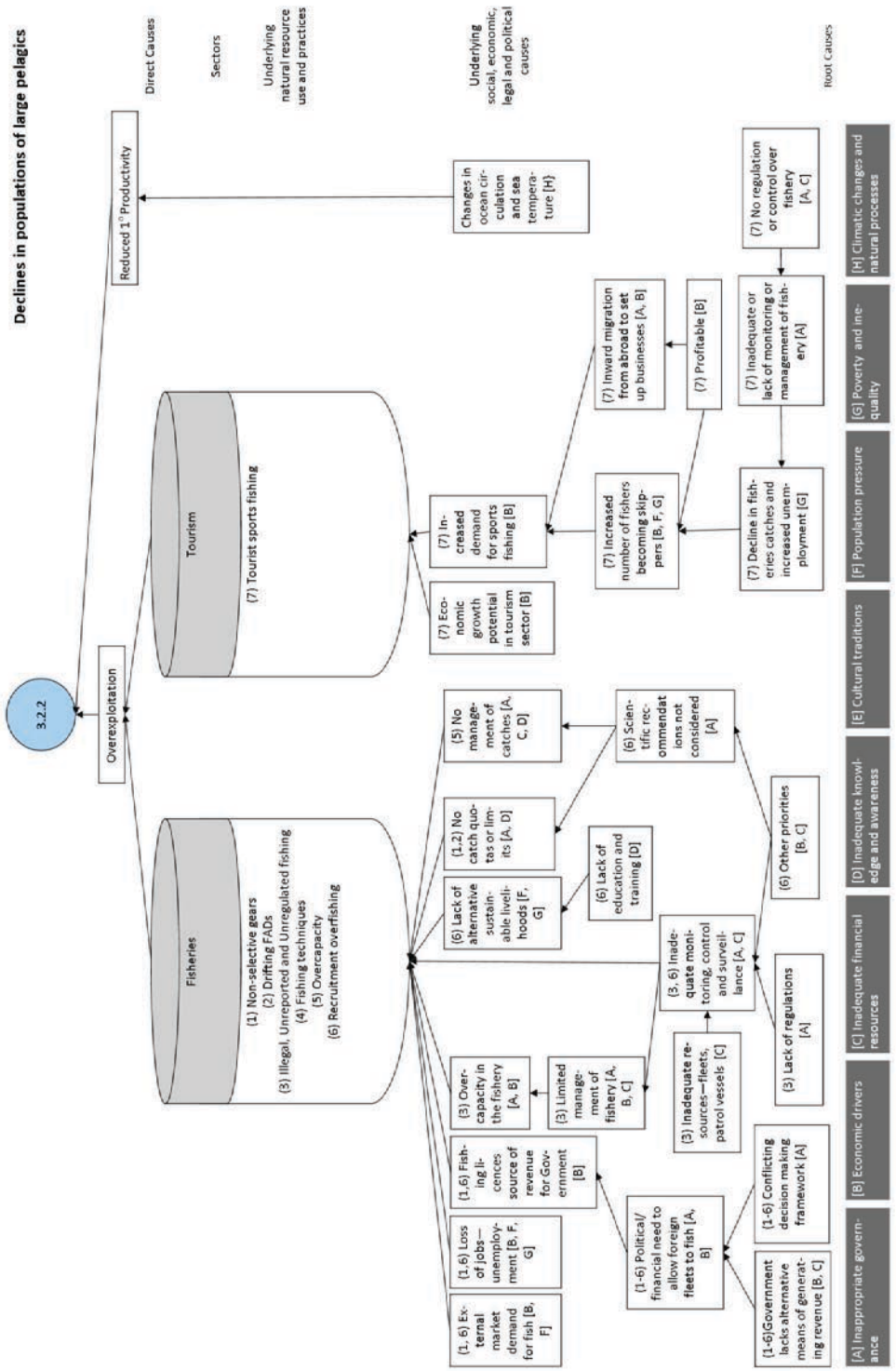

Figure 44: Causal Chain Analysis for the issue (3.2.1) Decline in populations of large pelagics.

3.2.3 Decline in populations of small pelagics

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 (incl. soil formation).
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 (people) 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 (local) 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.

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 hyrdroelectric 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 urbanisation

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
[H] Climate change and natural processes.

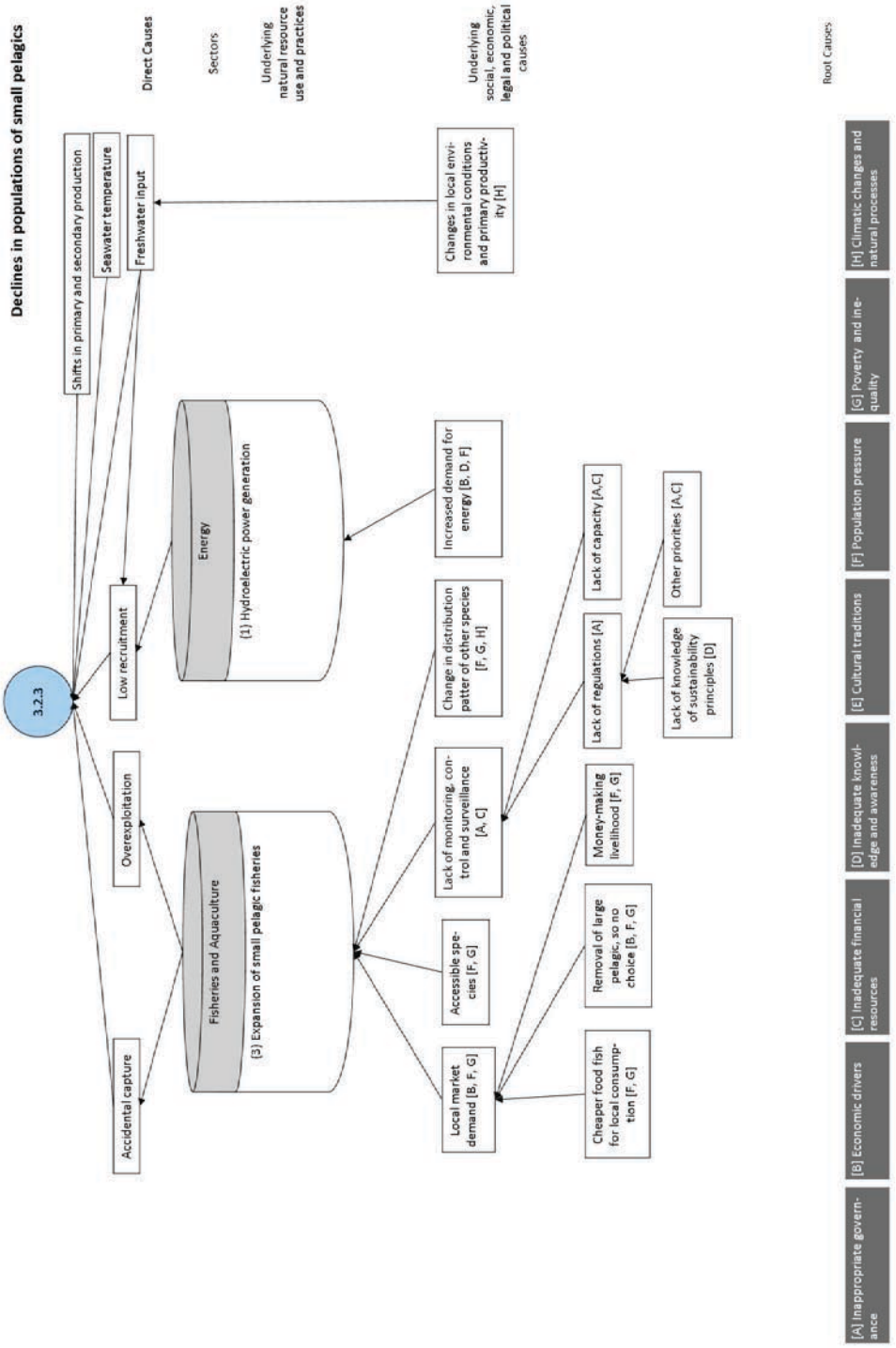

Figure 45: Causal Chain Analysis for the issue (3.2.2) Decline in populations of small pelagics.

3.2.5 Decline in populations of reef and demersal fish

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 (incl. soil formation).
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.

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 a lack of compliance with regulations as a result of inadequate knowledge and awareness and conflicts between resources users. There is a lack of monitoring, control and surveillance due to a lack of fisheries management capacity and a 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 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 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 a 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 a 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 a lack of affordable alternatives. (17) Mining in estuaries occurs due to the market demand for sand and minerals and a 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 a 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 urbanisation
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
[H] Climate change and natural processes.
[I] Personal attitude

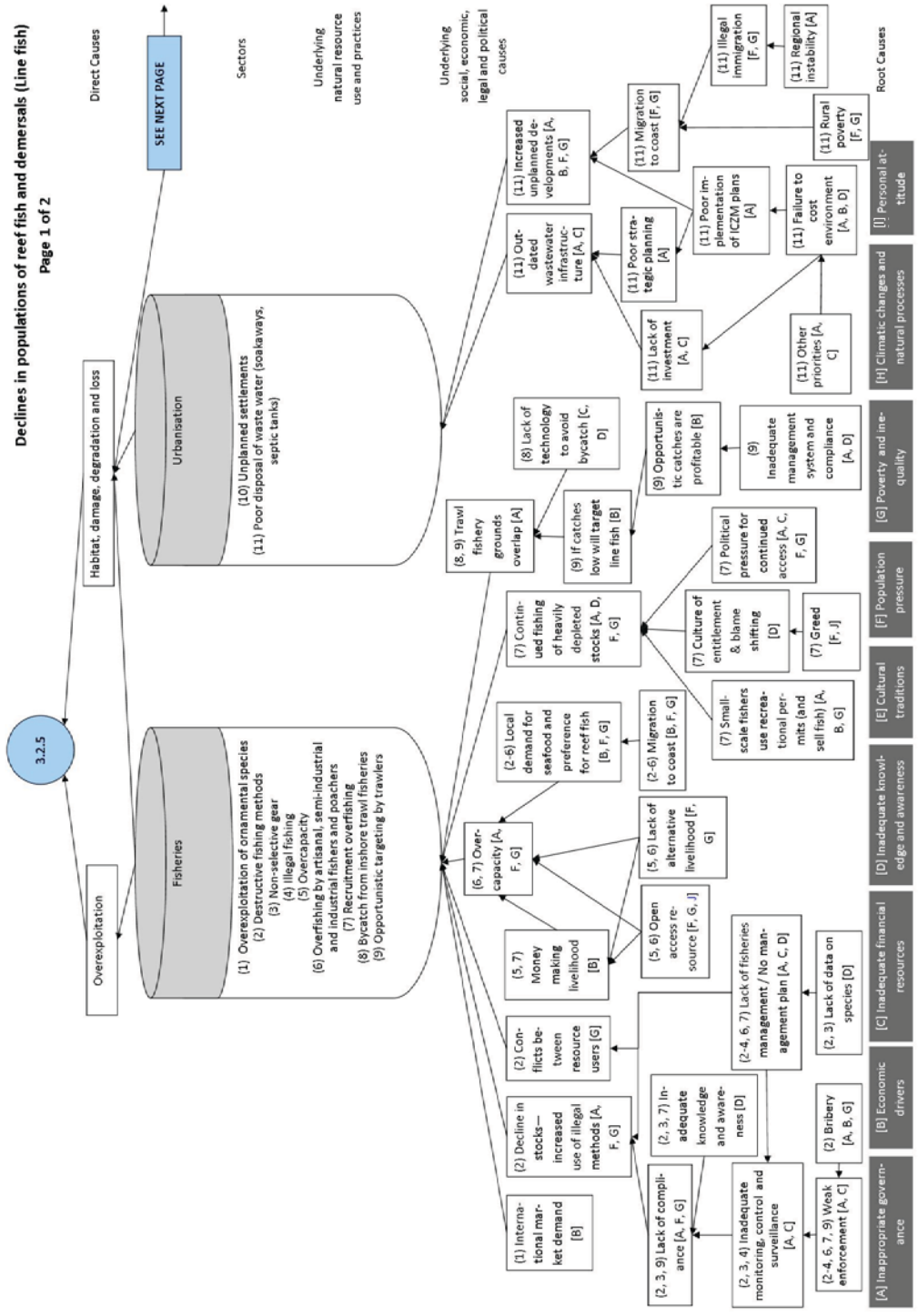

Figure 46a: Causal Chain Analysis for the issue (3.2.5) Decline in populations of reef and demersal fish (part 1 of 2)

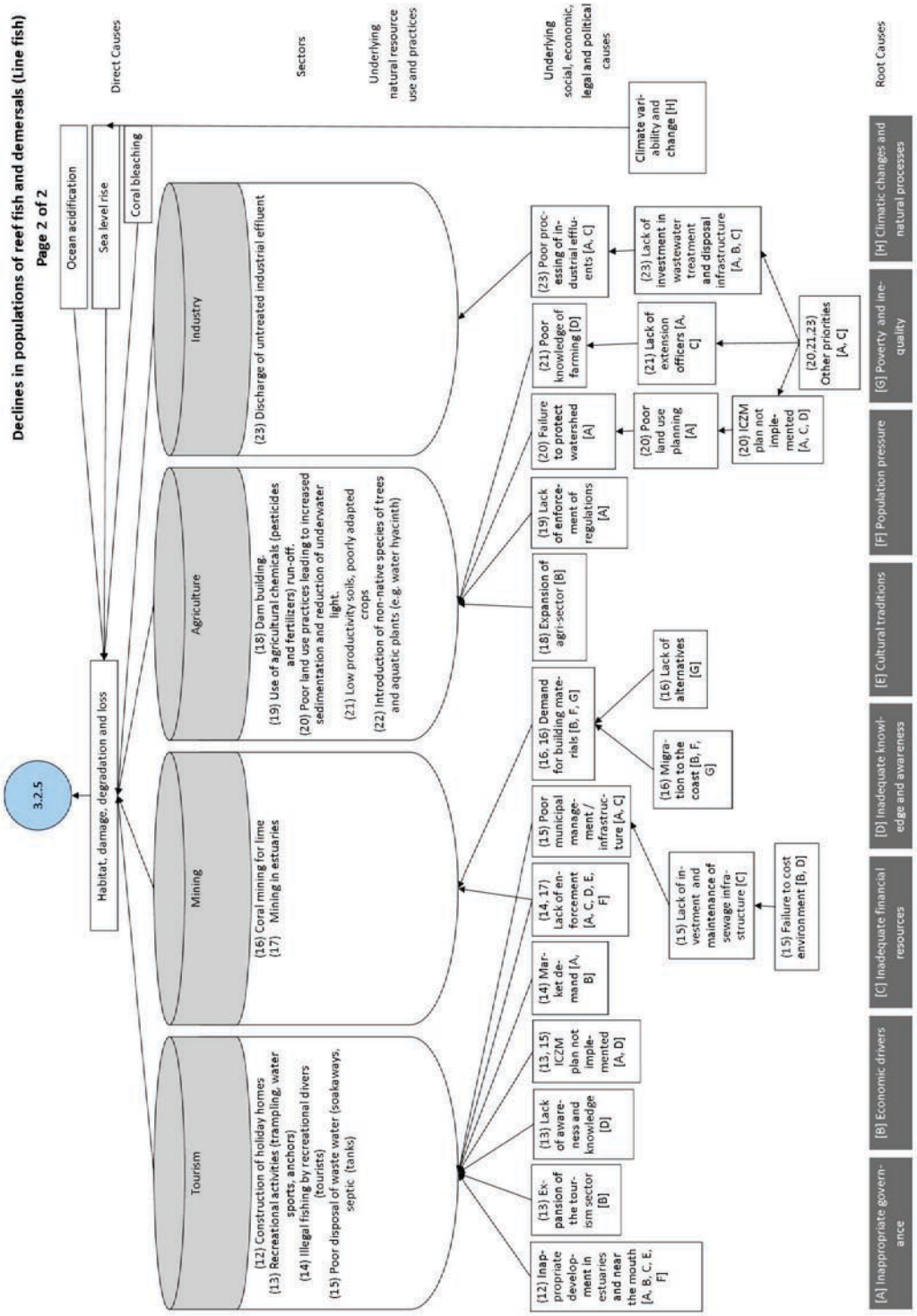

Figure 46b: Causal Chain Analysis for the issue (3.2.5) Decline in populations of reef and demersal fish (part 2 of 2).

3.3.3 Decline in populations of sea cucumbers

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 (incl. soil formation).
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.

Causal Chain Analysis

The most important **direct causes** of the 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
Physical 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 a 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 the 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 (as above). (3) Dangerous diving takes place because it has money-making potential and due to the 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

The **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
[I] Personal attitude

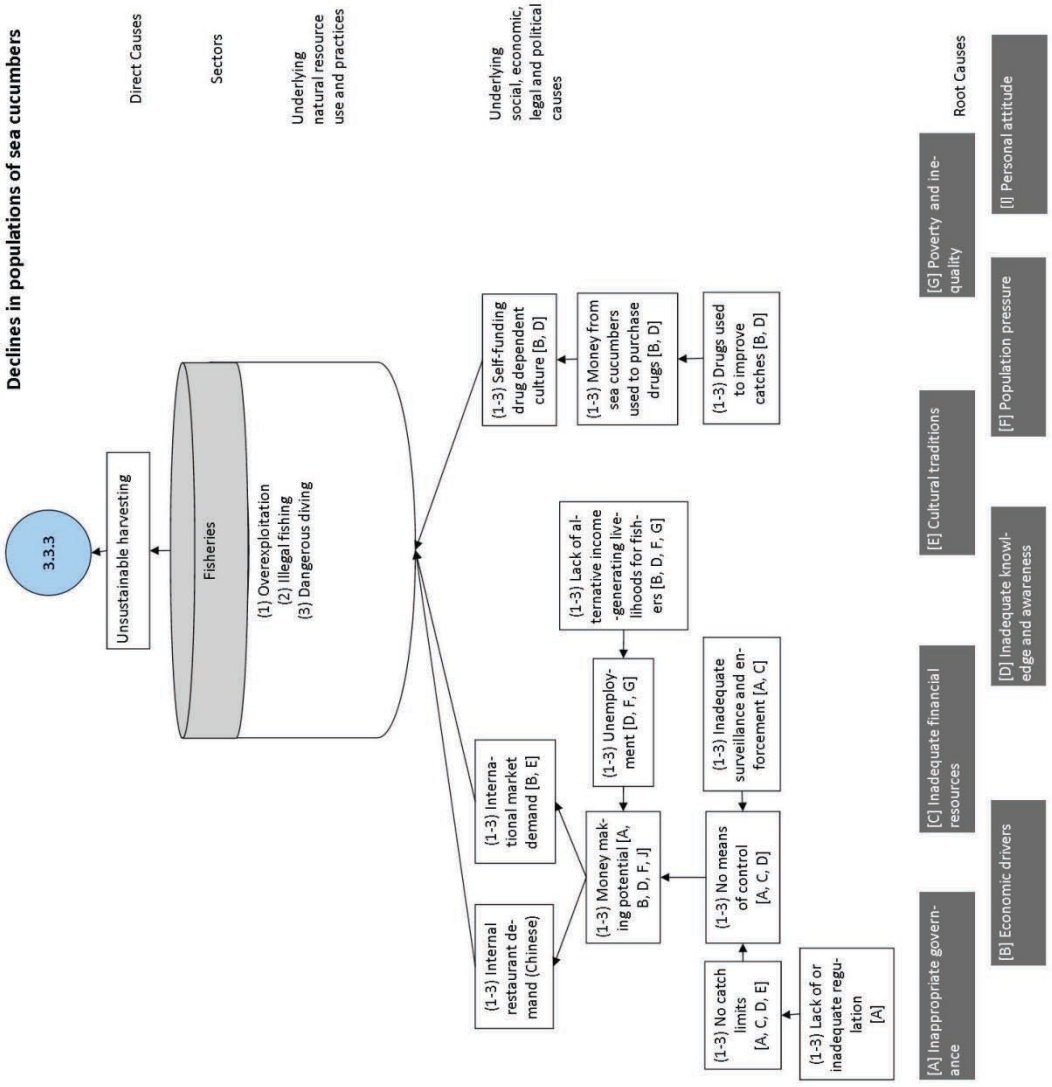

Figure 47: Causal Chain Analysis for the issue (3.2.5) Decline in populations of sea cucumber.

3.3.4 Decline in populations of prawns and shrimp

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 (incl. soil formation).
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.

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 a 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 the 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 a 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 a 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 the lack of technical and financial capacity. (5) Clearing of mangroves for timber and fuelwood occurs due to the high demand for wood products for building and fuel as a result of the 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 the lack of affordable alternatives.

Industry: (7) Clearing of mangroves for salt production occurs due to the demand for salt and commercial profits and the lack of alternative livelihoods. There is also poor planning.

Urbanisation: (8) Clearing of mangroves / deforestation takes place due to the 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

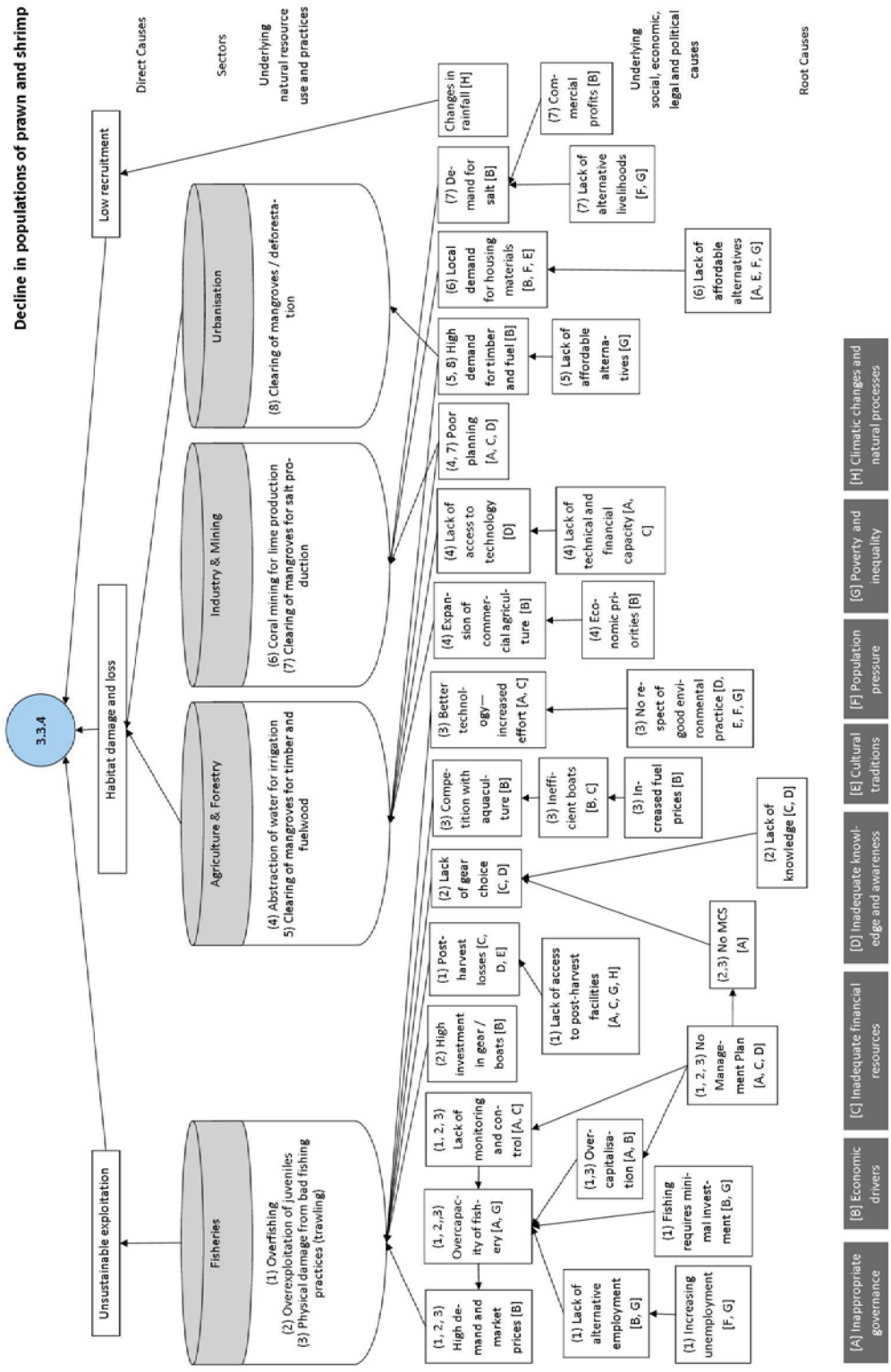

Figure 47: Causal Chain Analysis for the issue (3.2.5) Decline in populations of prawn and shrimp.

3.3.5 Decline in populations of lobster

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 (e.g. fish, game fruit) and; genetic resources (e.g. for crop improvements and medicinal purposes);
Regulating Services: nutrient cycling and maintenance of fertility (incl. soil formation).
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.

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 a 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 a lack of management (collapse of government) there is also a lack of capacity for management (financial or human) and a lack of technical training for the new generation; both of 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 should be paid for, but there is no-one to ask for the payment, as there is no administrative authority to collect the fees due to the lack of management (collapse of government) as a result of internal conflicts on boundaries (between Puntland and Somaliland). In addition, irresponsible fishing companies know that they can get away with fishing illegally as the EEZ is not declared and so there are no legal boundaries (can claim they are fishing in international waters).

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
[D] Inadequate knowledge and awareness

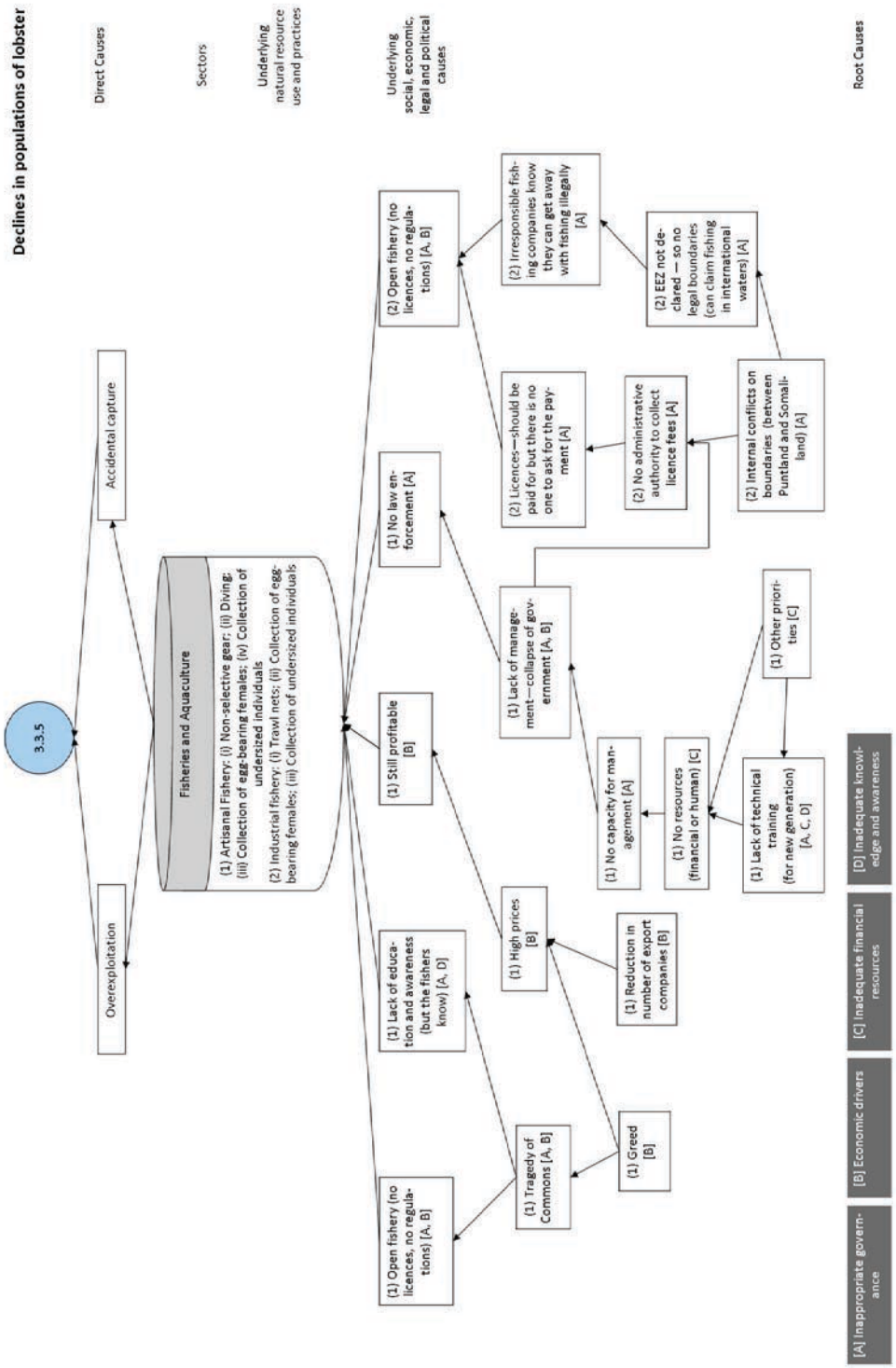

Figure 48: Causal Chain Analysis for the issue (3.2.5) Decline in populations of lobster.

3.4 Excessive bycatch and discards

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 (incl. soil formation).
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).

Causal Chain Analysis

The causes of excessive bycatch and discards are:
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 a lack of market / low price for other species as a result of selection pressure and consumer demand. There is a lack of gear regulations (for selective gear) and a lack of monitoring, control and surveillance. There is a 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
[I] Personal attitude

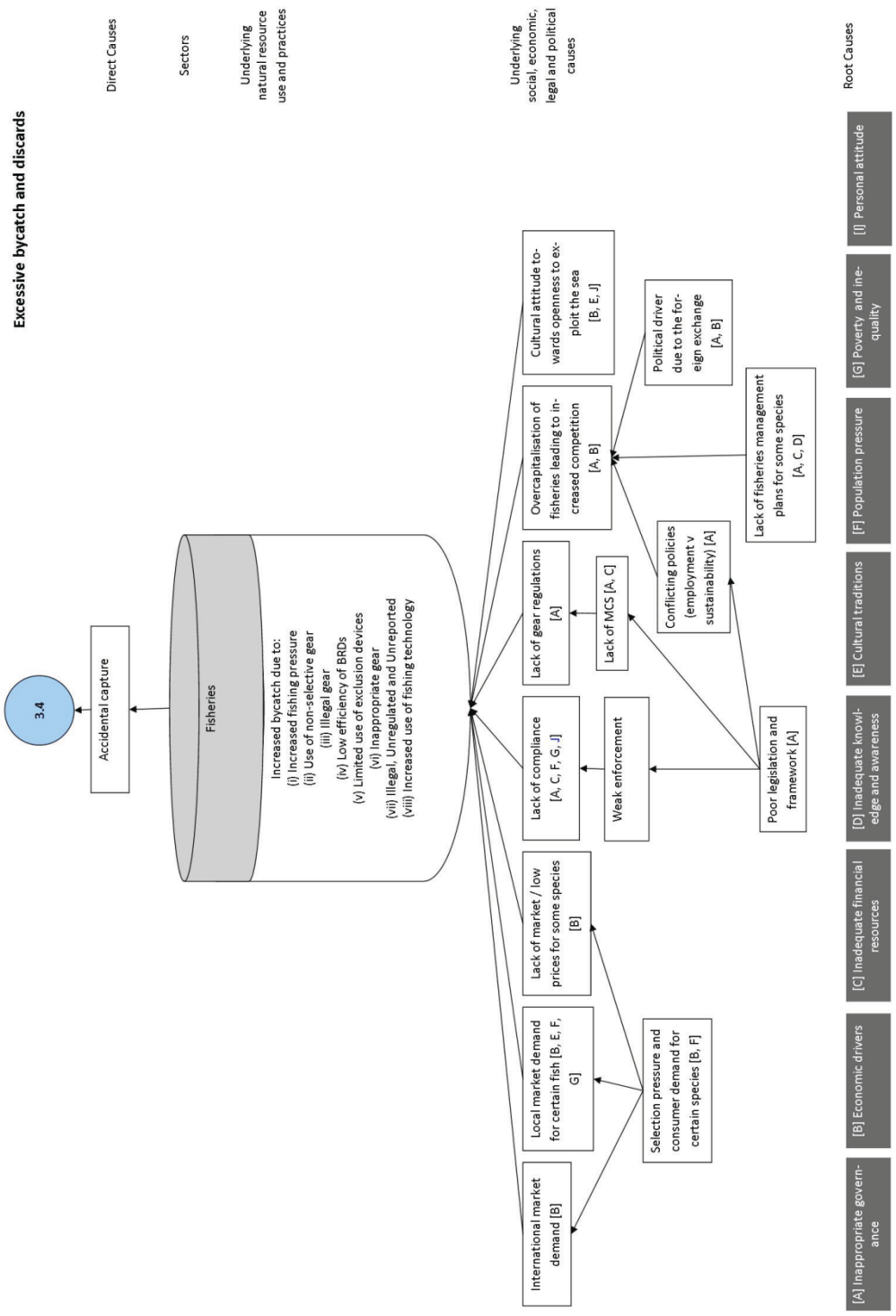

Figure 49: Causal Chain Analysis for the issue (3.2.5) Excessive bycatch and discards.

MAC04 Unpredictable Environmental Variability and Extreme Events

The following section presents the issues that were identified by the countries related to MAC04 Unpredictable Environmental Variability and Extreme Events. These are however direct causes which contribute, and indeed exacerbate, many of the other issues that were identified through the prioritisation process:

4.1. Climate hazards and extreme weather events
4.2. Sea level change
4.3. Ocean acidification
4.4. Changes in seawater temperatures
4.5. Changes to hydrodynamics and ocean circulation
4.6. Changes in productivity (shifts in primary and secondary production)
4.7. Geohazards (tsunamis, volcanic eruptions, earthquakes)

As these issues are also causes, Causal Chain Analyses were not completed. A summary of each of these causes is presented below:

4.1 Climate hazards 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.

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).

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).

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).

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).

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).

4.2 Sea level change

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.

4.3 Ocean acidification

Ocean acidification occurs as a consequence of increased dissolved CO_2 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 CO_2 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).

4.4 Changes in seawater temperatures

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 of the Somali Current has also followed the warming trend, having warmed 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.

4.5 Changes to hydrodynamics and ocean circulation

Potential changes to ocean-atmosphere interactions

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).

Potential changes to global thermohaline overturning circulation.

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

4.6 Changes in productivity (shifts 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.

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).

Changes in secondary production (zooplankton)

It is believed that evidence from climate change in marine communities will first appear in the zooplankton with respect to species range and population.

Changes to consumer populations

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).

Trophic effects

There is 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.

4.7 Geohazards (tsunamis, volcanic eruptions, earthquakes)

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).

10. Regional summary of underlying and root causes

The Causal Chain Analyses (CCA) described in Chapter 9 identified a range of root causes for the high priority transboundary issues, and common underlying causes. 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 priority transboundary issues and provides some recommendations for consideration in the SAP.

10.1 Summary of Root Causes

The 10 common root causes identified through the combined national to regional TDA process were 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
[I] Personal attitude

The influence of these root causes on the 21 issues of priority concern within the WIO is shown in Table 25 and 26. The root causes and some of the underlying (social, legal and political) causes that were common to these priority issues are described below:

[A] Inappropriate governance

There were various common deficiencies in governance that were identified as contributing towards the perpetuation of unsustainable practices in the ASCLMEs. 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 indeed conflicting mandates. Some of the underlying (social, legal and political) causes associated with this root cause are as follows: **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 c**orruption and; **poor stakeholder / community participation in governance.**

[B] Economic drivers

While there is a huge diversity in terms of the state of the economies of the countries within the ASCLMEs region, the need for continued sustained economic growth and development is common to all the WIO 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 SE Asian economies, which has opened up some new and tempting revenue sources. Many of the countries in the region have 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, the 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 / companies, especially if the companies themselves have poor internal environmental management policies, and a lack of good corporate social responsibility standards. An example of this is provided by the bilateral fishing access agreement. Some countries in the region are heavily, if not entirely dependent on, the license fees from distant water fishing fleets. In negotiating the terms of these agreements the country is often required to not disclose the terms of the access agreements. This places the host countries at a disadvantage in negotiating terms, as there is little or no information on what other countries are receiving, and has resulted in huge discrepancies between the price paid for one tonne of fish taken from the EEZ of one country versus another.

The higher the dependency of the country on foreign investments the more vulnerable the country is to exploitation, especially where there are also weaknesses in institutional and regulatory frameworks, a lack of financial resources for monitoring, control and surveillance, combined with a lack of transparency in public accounting and a risk of corruption. Permitting foreign companies to operate without sufficient regulation can contribute to the overexploitation of a resource, avoidable habitat damage and other impacts, which could otherwise be mitigated against. Furthermore, a failure to properly cost the environment, to take full account of the ecosystem services that could be lost or degraded as a result of a new development, can create future problems which are irreversible long after the target resource has been fully exploited. Some of the underlying (social, legal and political) causes associated with this root cause are as follows: 'Increased internal / external market demand for (use of) natural resources' (e.g. timber / agricultural produce/ fuel-wood / construction materials / minerals / oil and gas/ seafood / land etc.); 'Inadequate monitoring, control, surveillance and enforcement', 'Failure to cost the environment'; 'Lack of transparency'; and 'Wealth creation and corruption'.

[C] Inadequate financial and human resources

A lack of or limited access to financial resources was a common root cause, often was associated with [A] Inappropriate governance, [B] Economic Drivers, and [D] Inadequate knowledge and awareness.Most countries in the region have low GDPs, limited means or 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 the 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 which lack the capacity for Environmental and Social Impact Assessments are also particularly at risk. Indeed a lack of research funding, data collection, monitoring, control and surveillance, enforcement of existing regulations, maintainance, education and training, employment of environment or extension officers was usually due to a inadequate financial and human resources. In countries where finances were more readily available the associated underlying cause was commonly due to a 'Failure to cost the environment' i.e. inadequate priority setting. The lack of financial resources for certain activities (e.g. research or enforcement) may be due to more specific reasons. For example, in one country, the availability of research funding was dependent on fisheries licence fees which were set too low, but which the governments were reluctant to change for fear that they will deter business and lose the revenue stream. In another country, funding for enforcement was not allocated by the government because the relevant research department had not provided sufficient evidence of the need for enforcement.

[D] Inadequate knowledge and awareness

Human capacity constraints identified included 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 are as follows: 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.

[E] Cultural traditions

A common root cause, cultural traditions often was associated with [D] Inadequate knowledge and awareness, [F] Population Pressure and Demographics and [H] 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). In Madagascar for example there was traditional management of coastal and marine resources, by villages. In recent years, however, there has been a loss or erosion of some of these traditional / historical 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 as follows: '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'.

[F] 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 the 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 the number of people moving to coastal cities in search of employment. 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.

[G] Poverty and inequality

High levels of poverty and low incomes can lead 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 may 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. A lack of access of alternative energy sources can result in overuse of mangroves for fuelwood and building materials in many areas at the coast, and this is the root of increased soil erosion and sediment load to rivers.

[H] Climate change and natural processes

The WIO region has already witnesses climate related changes and extreme weather events over the past 10 to 15 years that have heightened awareness about the vulnerability of the countries in this region to climate change. Effect include; shifts in rainfall patterns and severe droughts, cyclones, extreme storm surges, coastal flooding, coral bleaching as a result of elevated sea water temperatures. 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. New studies are however revealing inter-regional variations in extent of sea level rise to date.

[I] Personal attitude

Among some fisher communities and other marine resource users 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 was associated included bribery, greed and corruption and negligence

10.2 Common Underlying Causes

Increased internal /external market demands for (use of) natural resources / materials
Pressure on coastal and marine resources has intensified in the WIO region as a result of population growth, demographics shifts, migration, 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.). 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 provide 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 was 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'.

SAP Recommendations
- 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 (CBA), and how these economic tools can help inform policy formulation and decision-making.

Rural poverty, increased coastal migration and urbanisation

As above, 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)

Weak national (strategic) planning and regulatory frameworks for sustainable development

The majority of issues, concerned with water quality degradation, habitats and community modification, made reference to weaknesses the national strategic planning systems, often associated with poor inter-ministerial and inter-sectoral coordination. Some of the causes included: (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) a lack of or failure to implement ICZM plans. There is a group of closely associated underlying causes related to this cause, as outlined below:

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'.

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 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 would be standardised and would 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.

Lack of ICZM plan / ICZM plan not implemented: Several countries identified weak capacity for integrated planning and management as a cause. While many countries in the WIO have now set-up ICZM Committees (see Chapter 7, Section 7.2), 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 the countries to identify gaps. For example, in Mauritius, ICZM strategies, policies and guidelines have been finalised and approved by the Cabinet of Ministers. Some of the gaps in ICZM capacity identified in the MEDAs included: (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).

Note: Also see MPA planning below:

SAP Recommendations

- Provide support for and facilitate the 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;

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 the international and regional agreements into national legislation, a 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 and hindering the implementation of ecosystem based management approaches. These concerns were often compounded by weaknesses in the institutional frameworks and technical capacities that prevented effective enforcement of existing regulations. There was also are recognised 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:

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 (see Chapter 7). 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. 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.

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 already are high historical levels of private land ownership, the government has limited powers to influence or control the types of activities or land use practices.

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 Somalia has 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 completed through ASCLME identify 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).

Need to harmonise 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 WIO 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 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 needed 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 SWIO countries should also consider a revision of national laws (Swan 2012).

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 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).

Gaps in legislation related to seabed:

SAP Recommendations

- 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 for, and provide assistance in the revision and harmonization of existing fisheries legislation and policies, with respect to the 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;

Low levels of compliance with existing regulations

Low levels of 'voluntary' compliance with existing national, regional or international regulations was another underlying cause common to many of the top priority issues. Low levels of compliance at the national level often occurred as a result of: poverty, low levels of education, insufficient outreach, a culture of entitlement, or a shift in demographics, due to high levels of immigration (migrants may not know or understand the laws). In South Africa, for example, the small-scale fishery sector suffers from low levels of compliance, which was believed to be due to poor information dissemination, and a 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, with particularly when the governments are perceived to be weak, 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.

SAP Recommendations

- 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.

Complex institutional framework and capacity constraints

The national MEDAs and Causal Chain Analyses frequently 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 a 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, the 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 mainly sectoral (ASCLME 2012f).

SAP Recommendations

- Provide advice to strengthen local capacity for good governance, and application of science based governance so as to improve decision-taking

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 the lack of MCS was a particularly common cause relating to fisheries related issues, 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. A 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 was 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:

Inadequate national capacity monitoring, control and surveillance capacity: Many WIO countries have limited resources (human and financial) to invest in deploying 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.

Insufficient regional coordination and cooperation in monitoring, control and surveillance: Effective implementation 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 to the combat against 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 transhipment at sea for large-scale longline vessels, could also contribute to the control and reduction of IUU fishing in the region.

SMARTFish also made recommendations to improve regional cooperation (mostly through IOTC related projects) but they also made the suggestion to: *Develop and implement a regional cooperation programme where MCS platforms can be shared as well as on-the-job training can be given. The project must facilitate planning as well as finance direct costs related to the initiative (e.g. charter costs of patrol vessels, charter cost of airplanes). This initiative should include pre-patrol planning including use of intelligence information, VMS information (from countries with operational VMS), use of IUU lists, use of research data in terms of fleet movements, AIS data etc. to maximum practical training experience.*

So an area where there appears to be an opportunity for linkages within the region is through the establishment

of regional VMS system. COI-IOC is proposing to establish a system including Mozambique, Tanzania and Kenya, but the possibility of design in coordination with other systems is apparently not taken into account. IOTC has a VMS programme, SADC is also proposing to serve as a regional VMS centre and SIOFA will also likely have VMS requirements. It will be important to have consistent tracking facilities. Notwithstanding issues of confidentiality applicable to all VMS systems, this is again an area where linkages would be useful.

***Lack of capacity (human and financial) for enforcement*:** In addition to the gaps identified in the legislation, the inadequate implementation of existing regulatory instruments was also identified as a common underlying cause. The lack of capacity to enforce existing legislation was cited as a underlying cause that was common to all priority issues. This cause was usually underpinned by a lack of resources, in terms of both insufficient budget allocation to support such activities, but also in terms of a lack of adequately trained staff, as well as an insufficient number of staff to enforce. For example, the 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. In Kenya for example, there are no offshore patrols except those carried out by the Kenyan Navy during its routine surveillance (ASCLME 2012b) and in Mozambique, none of the agencies charged with maritime surveillance and control have a significant sea-going capability (ASCLME 2012d).

While this underlying cause was commonly associated with the fact that countries had 'Failure to cost the environment', it was also associated with the underlying causes a '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). The 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 government.

SAP Recommendations

- 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 licencing fees could be allocated towards MCS and enforcement.

Failure to cost the environment

The ecosystems of the WIO are critically important to human well-being and economic prosperity. 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 a lack of awareness, understanding and appreciation of economic value of coastal and/or marine ecosystem goods and services, and knowledge is still incomplete.

Countries with weak economies and an urgent need for economic development, and dependent on sources of foreign revenue, such as licence fees for the exploitation of their natural resources (e.g. fishery access agreements, resettlement compensation schemes for oil and gas developments) are particularly vulnerable. Under these circumstances there is often a disproportionate imbalance between the short term immediate needs for economic and social development and environmental protection policies that to allow for development to occur in a sustainable manner. Such short term decisions do not always adequately account for mitigation measure, or indeed reflect the level of compensation that would be needed to offset the long term value of the ecosystem

good service lost.

The marine and coastal ecosystems of the WIO continue to deliver services, but some parts are already exhibiting signs of long-term decline, in habitat extent or status and changes in community structure or loss of biodiversity. Understanding of the exact relationship between habitats and biodiversity and the ecosystem services they provide is still incomplete. Nevertheless, the downwards trend is likely to continues as the population bordering the WIO will continue to grow, demands continue to expand, putting ecosystem services under further pressure, while climate change impacts will likely accelerate globally.

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 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). Spatial planning in combination with an improved understanding of temporal, spatial and distributional aspects of the ecosystem values, can allow for a more integrated (as opposed to sectoral approach) approach to ecosystem based management; conflicting activities are separated, allowing the overall value of the system to be maximised. Involving government officers, and representatives of the private sector, voluntary organisations and civil society in transparent processes (co-management) that encourage collaboration and participation in these processes would allow any necessary trade-offs to be understood and agreed on when making decisions.

SAP Recommendations

- Develop and implement a regional training programme in ecosystem valuation methods and cost benefit analysis tools in partnership with appropriate regional and international organisations;
- 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 (includin monitoring, control, surveillance and enforcement, as above);
- 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'.

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 education (secondary level) 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.

SAP Recommendations

- 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).

Limited knowledge, access to technology and understanding of best environmental practices

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 identified that they now simply lacked the staff needed to undertake the multitude of tasks, ranging from education and outreach to monitoring and overseeing ESIA processes and enforcing mitigation measures. The lack of government extension officers or environmental inspectors was most often associated with a 'Failure to cost the environment'. In several countries these officers have been re-entrenched 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.

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. For example, the Seychelles identified weak EIA capacity, as well as mediocre EIA compliance rates, as an underlying cause for concern, and there was a particular concern with regards this capacity in relation to tourism and new oil exploration activities (Seychelles CLA 2012). In the Seychelles, the Ministry of 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 two-week period to comment, which is too short; 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. The NGOs lack capacity, and technically prevented by the *locus standi* provisions in the EPA, which are weak (Seychelles CLA 2012). In Somalia 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.

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:

Distribution and status of critical habitats: There a need increase knowledge of the spatial distribution and extent of critical habitats within the 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. CBD global MPA targets). 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) have yet to be mapped, and the extent of the former have yet to be ground verified. For example, the WIO Atlas (Andrefouet et al. 2009) provides a description of reef habitats and an estimate of the total area of surface reef. These maps have not been ground-verified and there are often discrepancies between the habitats mapped, and between the area estimates provided and other sources for the total reef area. The maps also do not provide an indication of the status of the habitat.

***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 coordinated at present. The modality 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 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 methodological conflicts, and capacity constraints. Many countries simply lack a sufficient number of trained surveyors to be able to maintain the 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.

***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 the 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). 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.

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/).

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, the 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) is conducted. Management of deep-sea fisheries remains complicated due to the 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 and to improve collection of catch and fishing effort data for the reef demersal fisheries (Heileman 2012). In pursuing these goals, the WIO countries need to identify and implement cost-effective methods for monitoring and assessing small-scale and multispecies fisheries, such as rapid appraisal methodologies and participatory processes 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 SWIOFP countries for their small-scale and data poor fisheries.

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).

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.

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 a NPOA-Seabirds should be urged to initiate assessments of the risks of their fisheries to seabirds, and prepare a 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 a marine turtles, seabirds and sharks in the pelagic ecosystem. These binding actions need to be fully implemented by the IOTC member States.

Limited research into marine invasives: Few studies have been carried out on invasive species in marine waters of WIO. Baseline studies on invasive species are needed.

Limited research into harmful algal blooms and productivity: Few studies have been carried out on productivity in marine waters of WIO. Baseline studies on productivity and bloom species are needed.

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.

Unknown impact of agricultural run-off: The importance of agriculture as a source of persistent organic pollutants. 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.

etc.

SAP Recommendations

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-resettlement 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.

ESIA

- 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;

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;

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.

Migration and residency

- 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.

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;

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;

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);

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 (Biastoch *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 researchers interested in studying the effects of climate change on coastal and marine ecosystems (sea level rise, ocean acidifcation 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

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 interms 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.

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).

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 SWIO 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 is currently undertaking

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 towards assessing the status of these resources, and agreeing to management actions based on the scientific advice.

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 run or co-managed MPAs, such as the community led MPAs in Madagascar, and 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 a 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).

Various efforts have been put in place to support MPAs in the WIO region over the past 10 years. The protocol to the Nairobi Convention concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region was adopted in 2002, a Group of Experts on Marine Protected Areas in Eastern Africa (GEMPA-EA) was set up, hosted by UNEP and the Western Indian Ocean Marine Science Association (WIOMSA), to oversee implementation. There are a number of programmes supporting the development of MPA networks and these and the regional activities undertaken through the Nairobi Convention have increased awareness of the need for a network of MPAs. The Western Indian Ocean Marine Ecoregion (WIOMER), covering the WIO island states, promoted the development of an MPA network through the Réseau des Aires Protégées des Pays de la COI project, in collaboration with the COI, WWF, and CI, and funding from Fonds Français pour l'Environnement Mondial (FFEM). The network ceased however once the funding stopped. WIOMSA, also established a programme to certify MPA practitioners as 'professionals' (WIOCompass).

SAP Recommendations

Crustacean Fisheries

- Surveys and stock assessments for both the small-scale and industrial crustacean fisheries.
- Support the improved management of the 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.

Inadequate investment in infrastructure / poor maintenance

***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 the necessary facilities to handle liquid or sold 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).

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 the 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).

Lack of investment in solid waste collection and disposal facilities: The WIOLab Marine Litter report (UNEP and WIOMSA 2008), identified 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.

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 the 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 is estimated to be 20% (ASCLME 2012c).

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. The 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 organisations
- 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

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.

In Kenya, corruption and inefficiency in public sector affects port and transport systems, fisheries and tourism sectors (Kenya CLA 2012). For example, the collapse of the fisheries cooperative societies in the coast of Kenya between mid 1990s and early 2000s was considered to be due to mismanagement, low levels of education among the officials and claims of corruption, particularly 'rent seeking' behaviour (Kenya CLA 2012). In Mozambique, concerns were identified about the influence of theft and vandalism, as well corruption at the provincial level, in the mariculture sector, and; corruption and interference in private-sector operations of ports has also become problematic (Mozambique CLA 2012).

In Somalia, the combination of inter-clan rivalry, corruption, arms proliferation, extremism and pervasive impunity has facilitated the increase in crime in most parts of Somalia, particularly in Puntland and Central Somalia, and which has now moved from land to the sea (Somalia CLA 2012). In South Africa, political patronage, rampant corruption at all levels of government, and fiscal constraints have all been highlighted as major threats and weaknesses prevalent in the ports and transport sector; while corruption and poor policy as well as nationalisation has also been highlighted as a challenge in the mining sector (South African CLA 2012). Similarly, corruption has been identified as a challenge in the ports in Tanzania (Tanzania CLA 2012).

There are examples within the region whereby the countries are undertaking efforts to address corruption. For example, in Madagascar, a project funded by NORAD called 'Oil for Development' (since closed due to

closed due to political instability), aimed to improve Madagascar's capacity to deal with potential discoveries of oil on the Malagasy continental shelf. The programme consisted of a number of components, legislation, policy development, environment, financial management, but also anti-corruption measures (Madagascar CLA 2012).

Another important regional arena where greater transparency could bring widespread benefits, and help lower corruption, is the fisheries access agreements. Access by foreign commercial fishing boats wishing to fish within the EEZs of countries within the WIO is often governed by bilateral fisheries access agreements. The governments negotiate a contract to permit a certain number of fishing boats to operate within their waters. The majority of these agreements are with distant water fishing fleets (Europe Union, Russia, Japan, China, Taiwan, South Korea and the United States). Fisheries access agreements often include a fixed entry fee, then an additional fee which is calculated on a percentage of the value of expected fish landings. These agreements can also contain extra funds for development projects, or they can form part of broader bilateral aid package.

Most access agreements are negotiated behind closed doors, few contracts are ever published and public knowledge is this limited (Standing 2011). The value of the licence fees paid to host countries are often not disclosed or reflected in annual government accounts (Standing 2011). The terms of these agreements, such as the 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).

It should be noted however that it is often the foreign companies that enter into these agreements that require the countries to keep the agreements as confidential; this may be set as a condition by those paying for access, rather than the host country. The confidentiality clauses place the host countries at a disadvantage when negotiating terms, as they have little information on what other countries are receiving (Standing 2011). Weaker countries, or those that have a higher dependency on these licence fees as a source of income, may be paid less for the same tonnage of fish than a neighbouring country. These negotiations may also allow foreign countries to unofficially link the agreements to the availability of broader development packages, which may undermine responsible fisheries management, including the development of regulations supporting sustainable fisheries and an ecosystem approach to fisheries management (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. The task of improving accountability and public access to information in other sectors, such as mining and the oil and gas industries, has been commenced through the Extractive Industries Transparency Initiative (EITI) (http://eiti.org/). A similar process has now been commenced for fisheries by the World Bank. The Bank commenced the 'Fisheries Transparency Initiative' in collaboration with other donors, and helped encourage the government of Madagascar to publish all details of private fishing licenses in local newspapers. The initiative improved the contribution of the fishing companies to Madagascar economy. A similar commitment has been made by Seychelles in association with a loan from the IMF (Standing 2011).

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.

Lack of sustainable alternative livelihoods: Many different alternative livelihoods schemes have already been developed in the WIO which 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

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 was 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.

Table 25: Priority transboundary issues of concern and root causes.

	ASCLMEs PRIORITY TRANSBOUNDARY ISSUE	[A] Inappropriate governance	[B] Economic drivers	[C] Inadequate financial resources	[D]Inadequate knowledge and awareness	[E] Cultural traditions	[F]Population pressure & demographics	[G] Poverty and inequality	[H] Climate change and natural processes	[I] Personal Attitude
1.1	Alteration of natural river flow and changes in freshwater input and sediment load	✓	✓	✓	✓	✓	✓	✓	✓	
1.2	Degradation of ground and surface water quality	✓	✓	✓	✓	✓	✓	✓	✓	
1.3.1	Microbiological contamination from land-based and marine sources	✓	✓	✓	✓	✓	✓	✓	✓	✓
1.3.5	Solid wastes / marine debris from shipping and land-based-sources	✓	✓	✓	✓	✓	✓	✓	✓	✓
1.3.6	Oil spills (drilling, exploitation, transport, processing, storage, shipping).	✓	✓	✓	✓		✓		✓	✓
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 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	✓	✓	✓	✓	✓	✓	✓	✓	✓
2.3.5	Disturbance, damage and loss of deep water habitats (including sea mounts)	✓	✓	✓	✓					
2.6	Introduction of exotic non-native species, invasives and nuisance species	✓	✓	✓	✓		✓		✓	
3.2.1	Decline in populations of sharks and rays	✓	✓	✓	✓	✓	✓			✓
3.2.2	Decline in populations of large pelagics	✓	✓	✓	✓	✓	✓	✓	✓	
3.2.3	Decline in populations of small pelagics	✓	✓	✓	✓	✓	✓	✓	✓	
3.2.5	Decline in populations of reef and demersal fish	✓	✓	✓	✓	✓	✓	✓	✓	✓
3.3.3	Decline in populations of sea cucumbers	✓	✓	✓	✓	✓	✓	✓		✓
3.3.4	Decline in populations of prawns and shrimp	✓	✓	✓	✓	✓	✓	✓	✓	✓
3.3.5	Decline in populations of lobster	✓	✓	✓	✓					
3.4	Excessive bycatch and discards	✓	✓	✓	✓	✓	✓	✓		✓

Table 26: Priority transboundary issues of concern and underlying causes.

		Increased external market demands for (use of) natural resources / materials	Increased internal market demands for (use of) natural resources / materials	Weak national planning and regulatory frameworks	Lack of alternative sustainable livelihood opportunities	Failure to cost the environment	Weak economies and need for foreign revenues	Economic growth potential and employment	Failure to mainstream climate change into planning and decision making	Open access resource 'Tragedy of Commons'	Limited knowledge, access to technology and understanding of best environmental practices	Rural poverty, increased coastal migration and urbanisation	Lack of education, training and awareness	Lack of awareness of longer term implications in Govt.	Lack of capacity of management	Lack of adequate and reliable data to support management	Lack of capacity for monitoring, control, surveillance and enforcement	Low compliance with existing regulations	Gaps in regulations and lack of legal expertise	Unresolved legal issues related to land ownership	Lack of capacity for Environmental and Social Impact Assessment (ESIA)	Lack of extension officers / environmental inspectors	Inadequate or lack of land use plans and appropriate environmental policy	Lack of ICZM plan / ICZM plan not implemented	Lack of MPA management plans	Lack of fisheries management plans	Wealth creation and corruption / Lack of transparency	Inadequate investment in infrastructure / poor maintenance	Negligence
1.1.	…natural river flows and sediment	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓		✓	✓			✓	✓	✓				✓	✓	
1.2.	… ground and surface waters	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓		✓	✓			✓	✓	✓				✓	✓	
1.3.1	Microbiological contamination	✓	✓	✓		✓		✓			✓	✓	✓		✓		✓	✓			✓	✓	✓	✓			✓	✓	
1.3.5	Solid wastes / marine debris	✓		✓		✓		✓			✓	✓	✓		✓		✓	✓			✓	✓	✓	✓				✓	
1.3.6	Oil spills	✓	✓	✓		✓	✓	✓	✓		✓				✓		✓				✓	✓	✓	✓				✓	✓
2.1.	Shoreline change…	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	
2.2.1.	.. upland / watershed habitats	✓		✓	✓	✓		✓				✓		✓	✓	✓	✓	✓		✓	✓	✓	✓					✓	
2.2.3.	…coastal habitats (beaches, dunes)	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓			✓	✓	
2.2.6.	… mangrove habitats	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	
2.3.1.	… coral reef habitats	✓	✓	✓	✓	✓		✓	✓		✓				✓	✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	
2.3.2.	…seagrass habitats	✓	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	
2.3.5	…deep water habitats	✓		✓		✓	✓	✓						✓	✓	✓	✓	✓	✓		✓					✓	✓		
2.6.	… exotic non-native species, invasives	✓		✓		✓		✓			✓				✓	✓	✓	✓			✓						✓	✓	✓
3.2.1.	…sharks and rays	✓		✓	✓	✓		✓					✓	✓	✓	✓	✓		✓						✓	✓	✓		
3.2.2.	…large pelagics	✓		✓	✓	✓	✓	✓					✓		✓	✓	✓		✓						✓	✓	✓		
3.2.3.	…small pelagics		✓	✓	✓	✓				✓	✓	✓	✓		✓	✓	✓		✓						✓	✓			
3.2.5.	… reef and demersal fish	✓	✓	✓	✓	✓				✓	✓	✓	✓		✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓
3.3.3.	… sea cucumbers	✓		✓	✓	✓	✓			✓			✓		✓	✓	✓	✓	✓						✓	✓	✓		
3.3.5.	…prawns and shrimp	✓		✓	✓	✓	✓	✓			✓		✓		✓	✓	✓		✓		✓				✓	✓		✓	
3.3.6.	…lobsters	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓	✓		✓						✓	✓			
3.4.	Excessive bycatch and discards	✓	✓	✓		✓	✓	✓			✓				✓	✓	✓		✓							✓	✓		

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