

Overall Assessment of the State of the Coast in the Western Indian Ocean

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Opposite page: Will the marine resources these girls collect in the tidal flats near Ulo village, north Mozambique, be available in the future for food security or will they benefit from economic development and depend on modern amenities instead? © José Paula.

INTRODUCTION

This chapter offers an overall view of the state of the coast in the western Indian Ocean (WIO), by integrating the four sectorial assessments and following the Drivers – Pressures – State – Impact – Response (DPSIR) methodology. It analyses the current condition of ecosystems, resources, services and human activities and their expected evolution (*state and trends*) in response to root causes that drive change (*drivers*), further highlighting the ways these factors act on the environment and human related dependencies (*pressures*) and their expected outcome on the environment and livelihoods (*impacts*). Human societies adapt by acting on the drivers and pressures (*responses*) to mitigate impacts, aiming to maintain state of the environment or reverse negative trends. This chapter further condenses and provides sectorial recommendations.

The WIO region main features

The WIO spans a large latitudinal range, from the Somalia region, influenced by the strong monsoon regime of the northern Indian Ocean, to the sub-tropical regime of the Kwa-Zulu Natal Province in South Africa. It thus encompasses tropical and subtropical regions of diverse nature, rich stretches of coast along the mainland countries of Somalia, Kenya, Tanzania, Mozambique and South Africa, and vast oceanic areas with the island states of Madagascar, Seychelles, Comoros, Mauritius and French Territories. The WIO region is essentially within the Western Indo-

Pacific biogeographic realm, but its southwest limit enters the Temperate Southern Africa biogeographic realm (Spalding and others, 2007). The WIO region presents such uniqueness of features that render it a structural and functional unity within the world global ocean (Obura and others, 2012). The main portion of WIO region is also referred to as the Eastern African Marine Ecoregion (WWF 2001).

Geomorphological and oceanographic features define the character of the WIO (see detailed description in Chapter 1). The bathymetric structure influences water flows (Parson and Evans 2005), modulating the ecosystems' large-scale mosaics and associated biodiversity (Obura and others, 2012). The main oceanographic features are the monsoonal regime in the northern WIO and the equatorial current that diverges close to the mainland and produces the southern moving complex eddy system of Mozambique Channel, the south-flowing East Madagascar Current, meeting the mainland south of Mozambique and merging with the Agulhas Current that transports heat to the south before retroreflecting eastwards at the southern end of the African continent (Lutjeharms 2006, see Figure 36.1).

The social fabric of the WIO, where much of the population lives at the coast, is an amalgam of diverse populations with different origins, a product of the rich and varied political history, where networks of trade interactions generated a high ethnic and cultural diversity (see Chapter 1). The cultural heritage is important and matches the natural richness. Most countries in the WIO have high population

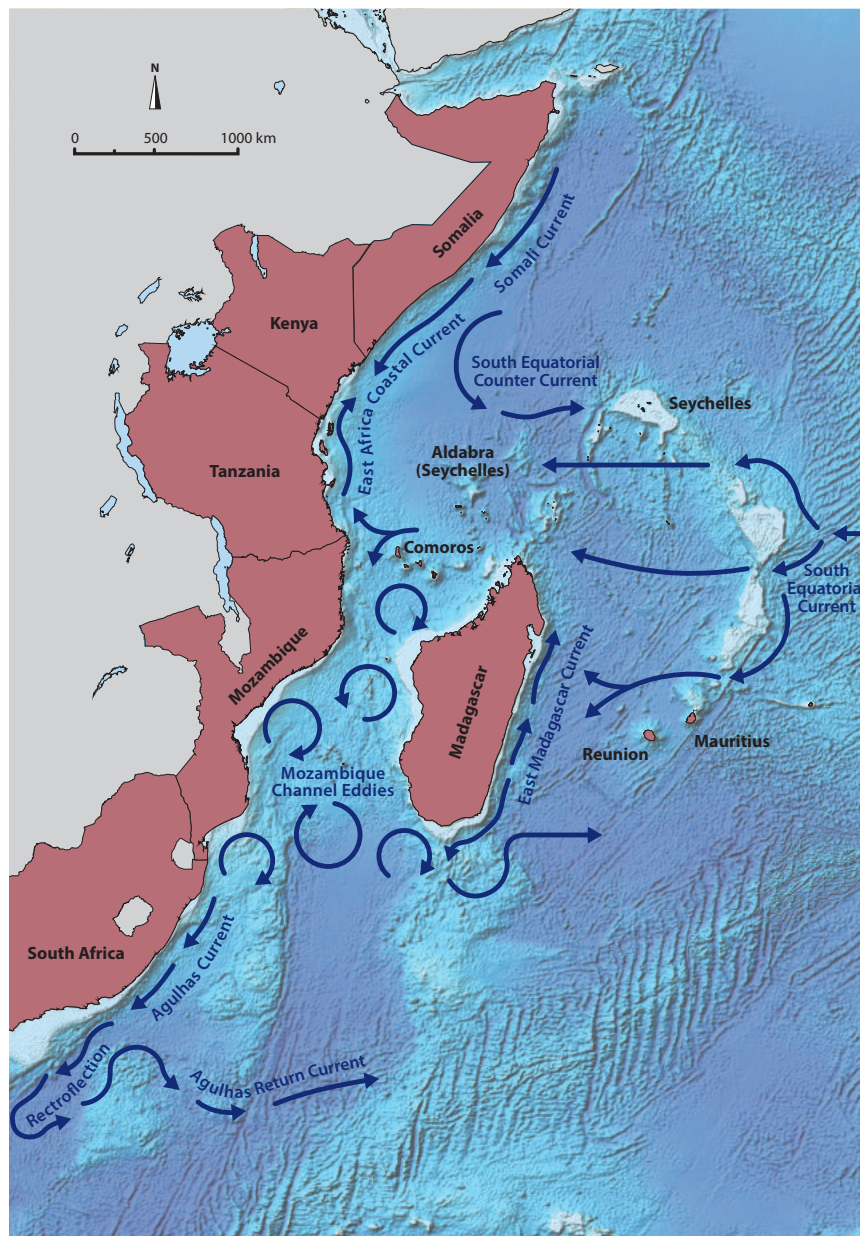


Figure 36.1. The WIO region, showing the countries, the bathymetric profile (adapted from Amante and Eakins 2009) and main current patterns (adapted from Lutjeharms and Bornman 2010).

growth rates (UNFPA 2002, UN 2012), and coastal development is expected to grow accordingly (UN-Habitat 2014).

The main drivers of growth rely on the extractive, construction and services sectors, and the latter also including the tourist industry. Foreign direct investments (FDIs) have supported growth but focus particularly on the extractive industry. However, for most WIO countries, GDP is low with widespread financial constraints and poverty. Economic development and poverty alleviation are therefore main targets within the policies of most WIO governments.

The vast resources of the region are driving economic development, with many countries presenting annual eco-

nommic growth rates over 7 per cent. With the Blue Economy adoption (see Box 36.1), defensive precautionary policies give rise to sustainable exploitation of resources for economic development and poverty alleviation. For a few countries in the region, the oil and gas industry has the potential to take a leading role in driving national economies. Other emerging industries, such as those derived from the exploration of genetic resources and bio-prospecting, are developing. Although economies of most WIO countries are essentially still extraction-dominated, most have enormous potential for development, especially if they increase their capacity by moving into product transformation through adding value.

The mandate and methodology of the RSOCR for the WIO

The RSOCR derives from requirements of the Nairobi Convention and contributes towards the United Nations-led production of the World Ocean Assessment (WOA) reports, and to other global and regional processes, such as the Environment Outlooks, coordinated by UNEP. The background methodology is based on the Opportunities Framework and the DPSIR approach (see Chapter 2), adopting and adapting the WOA framework. While the political agenda included the Contracting Parties and National Focal Points of the Nairobi Convention, the RSOCR technical process was guided by WIOMSA (Western Indian Ocean Marine Science Association) and involved a representative set of scientists with broad experience in the region.

The general aim of the RSOCR is to integrate the socio-economic and ecological knowledge of the WIO region. Its main objectives are to: i) provide a comprehensive baseline, ii) highlight main opportunities, iii) describe successes and challenges, iv) identify capacity building needs, v) identify knowledge gaps, and vi) propose policy options.

ASSESSMENT OF BIODIVERSITY

The WIO countries have, in general, low income, and consequently a large portion of the population is dependent on coastal and marine resources and ecosystem services. The biodiversity of these systems is thus under direct and indirect pressures from resource exploitation and anthropogenically-driven habitat degradation. The effects and impacts of global climate change add further pressures to local-acting sources of disturbance.

The assessment of biodiversity addressed the main ecosystems that constitute the major support for biodiversity and living resources, such as the nearshore habitats (see Chapter 4), mangroves, salt marshes and seagrass beds (see Chapter 5), coral reefs (see Chapter 6), rocky reefs (see Chapter 7), sediments (see Chapter 8) and pelagic and deep sea environments (see Chapter 9). The assessment further included a summary of threatened marine species (see Chapter 10), as well as the significant social and economic aspects of biodiversity conservation (see Chapter 11). For detailed descriptions, refer to these chapters and references therein. The overall assessment merges the biodiversity components (ecosystems, threatened species and

socioeconomic aspects) into a single analysis. Figure 36.2 attempts to provide a summary of the RSOCR biodiversity assessments under a framework of DPSIR methodology. The term “biodiversity” is used here in its holistic scientific meaning, ie, including all levels of organization of life, from genes and populations to species, habitats, ecosystems and ecoregions.

Drivers of change

Drivers of change include those that affect oceans at a planetary scale, namely global change driven by climatic alterations due mainly anthropogenic forcing, but also local drivers related to human development and emerging activities. Global change main effects include (see Chapters 14, 15 and 17):

- **Increased extreme events**, such as storms and cyclones, affecting physically the coastal zone by erosion, sedimentation and destruction of habitats, but also through alteration of precipitation patterns leading to flood and drought events. Behaviour of river catchments in relation to these pressures will produce changes in sediment loads and estuarine discharges to the ocean.

- **Sea level rise** is considered to affect the WIO region in the mid term, with consequences to habitats by submerision and erosion, especially in low lying intertidal areas like tidal flats, mangrove forests and salt marshes. Additionally, sea level puts at risk the integrity of human settlements at the coast.

- **Temperature rise**, mainly SST, affects directly the biology of key organisms such as corals that are prone to bleaching. On the longer term, ocean warming will alter the distribution of organisms and will impact of species local extinctions and replacement, with unforeseen consequences for ecological patterns and resource availability.

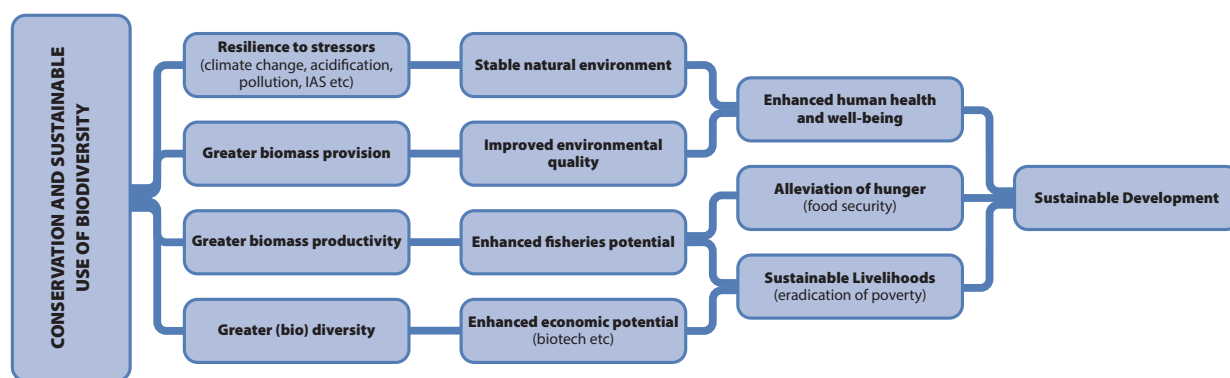
- **Ocean circulation** may be altered, namely patterns of currents at mesoscales. This will affect dispersal of organisms and distribution of primary productivity, affecting biomass and biological communities. These shifts may not necessarily decrease productivity and biodiversity at a WIO region scale, but will certainly displace resources and affect the geography of traditional living resource extraction activities.

- **Changes in sediment dynamics** can occur via extreme events, as well as changes to coastal currents and sediment loads from river basins, affecting patterns of sedimentation and erosion in the coastal zone.

- **Acidification** is a consequence of the increasing

BOX 36.1.

THE OCEAN OR BLUE ECONOMY by Louis Celliers



Integrated holist approach underlining ecosystem approaches for developing countries with economies directly related to environmental exploitation, Source: UNEP Blue Economy Concept Paper.

UNEP defines a green economy as one that results in “improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities” (UNEP 2010b). In its simplest expression, a green economy is low-carbon, resource efficient, and socially inclusive. In a green economy, growth in income and employment are driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services (UNEP 2011).

In providing food, oxygen and livelihoods, the world’s oceans and coasts have the potential to perform a critical role in the move towards a green economy. In this coastal context, what can be called the ‘Blue-Green Economy’, results in a reduction in ecological impacts, while promoting the economic and

social sustainability of traditional and emerging ocean-oriented economies (UNEP and others, 2012). The blue-green economy is related to a number of interrelated sectors, including, for example fisheries, tourism, maritime transport, energy generation, aquaculture, mining and nutrient Economy.

More recently, WWF International estimated the economic value of the oceans, measured as “gross marine product” (GMP) – equivalent to a country’s annual gross domestic product, to be at least US\$ 2.5 trillion. They estimated the total “asset” base of the ocean to be at least US\$ 24 trillion (Hoegh-Guldberg and others, 2015). These values are underpinned by direct outputs (fishing, aquaculture), services enabled (tourism, education), trade and transportation (coastal and oceanic shipping) and adjacent benefits (carbon sequestration, biotechnology).

load of CO₂ in the oceans, albeit their effects more pronounced in cold and deep waters. It affects the calcification processes of organisms such as corals and certain phytoplankton. Scenarios predict that by 2100 all coral reefs will live in marginal conditions for survival under this threat.

At the WIO region level, demography, including population growth, is a major driver of change. The major components of human development drivers are (see Chapters 29 and 32-34):

- **Population growth** within the coastal zone, by either migration or high growth rates, impacts on urbanization and land reclamation, but also on pollution dis-

charges and pressure over natural resources.

- **Poverty and inequality**, leading to widespread uncontrolled resource extraction.

- **Inadequate governance**, such as limited efforts for regulating and especially enforcing measures to avoid and mitigate impacts from human activities.

- **Lack of education and awareness** on coastal and marine issues is a widespread problem in the region, leading to a low appreciation of the natural environment, as well as low levels of community participatory actions and weak demand for civil rights.

Land based activities are a major source of pressure on species and ecosystems, and affect in particular the

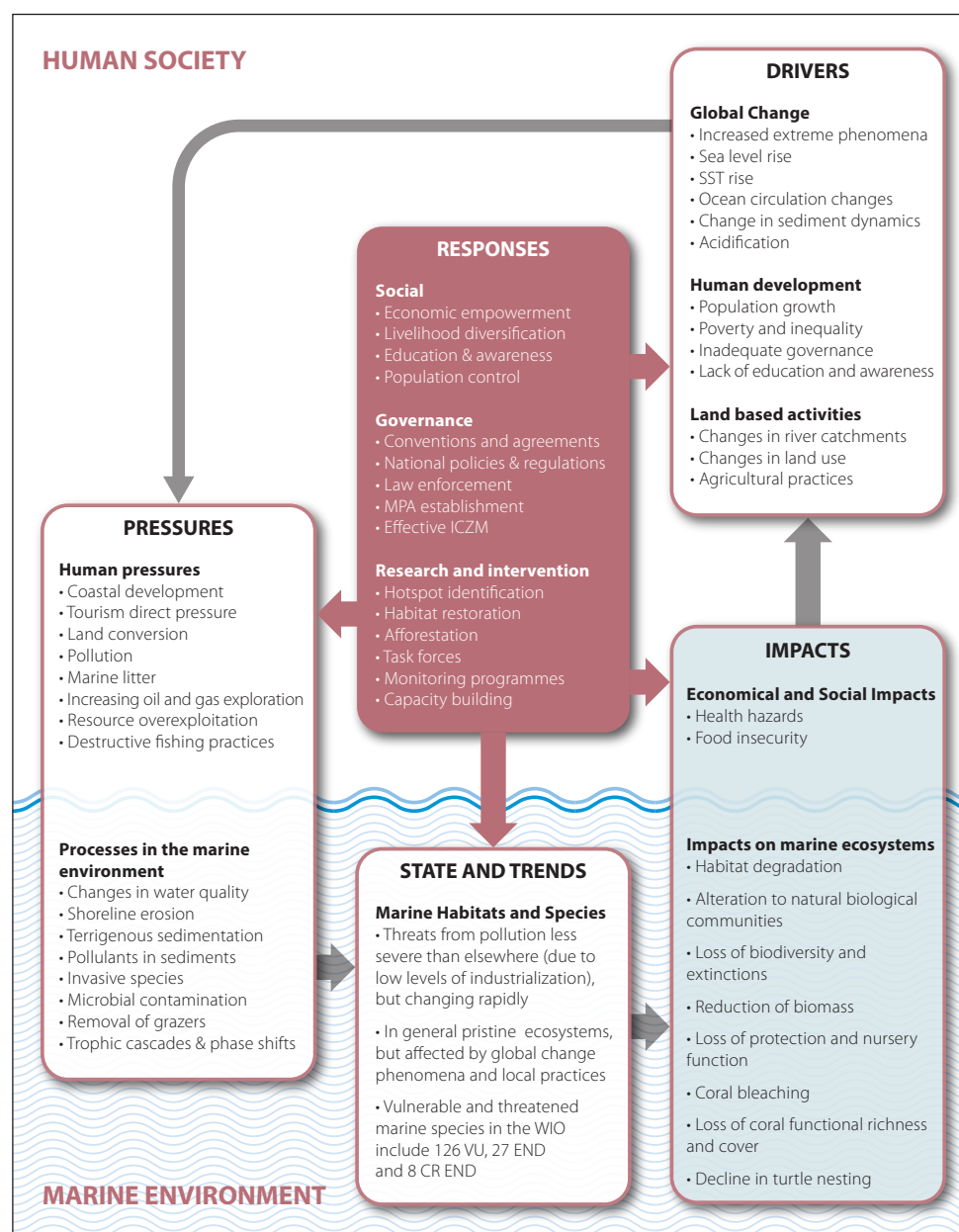


Fig 36.2. Diagrammatic summary of DPSIR analysis for marine biodiversity in the WIO.

aquatic interfaces of estuarine and lagoon character that are dependent on river basins. In particular (see Chapter 29):

- **Changes in river catchments** are increasing with economic development, namely damming for clean energy source and water subtraction for consumption and agriculture, with consequences for normal flood regimes and sediment transport, and potentially leading to salt intrusion processes near the coast.
- **Changes in land use**, namely reclamation of large portions of ecosystems such as mangroves and salt marshes for construction, aquaculture and salt ponds.
- **Agricultural practices** enhance nutrient load in rivers and estuaries, and provoke increased soil erosion.

Pressures on marine ecosystems and species

Direct pressures on marine ecosystems and species arise from human activities and include a wide range of sources that affect the environment in multiple and synergistic ways. These include:

- **Land conversion** diminishes the available ecosystem cover and associated biodiversity and resources (see Chapters 27-29).
- **Coastal development** leading to land reclamation and increasing overall impacts (see Chapter 29).
- **Pollution** arises from multiple sources and can be derived from industrialization, domestic load and other sources, such as aquaculture and agriculture, affecting biological and ecological processes (see chapters 25-29).

- **Marine litter** poses additional problems to many species by clogging feeding and respiratory biological systems, and by secondarily contaminating water (see Chapter 25).

- **Tourism pressure**, dependent on pristine ecosystems, has frequently a negative feedback by decreasing conditions that lead to tourism development in the first place (see Chapter 28).

- **Increasing oil and gas exploration** constitutes a developing threat to marine ecosystems. While creating significant economic opportunities it poses high risks for environmental contamination during both regular operations and in case of accidental spills (see Chapter 26).

- **Resource overexploitation** is evident for some resources in the WIO region (see Chapters 20 and 21).

- **Destructive fishing practices** impact on species and ecosystems, such as beach seining with destruction of seagrass beds, small-mesh seine nets affecting juvenile stages of resources, poison and dynamite used in coral reefs, and by-catch and incidental catches in semi-industrial and industrial fisheries (see Chapters 20 and 21).

The drivers of change will give rise to structural and functional anomalies within natural systems, creating situations that increase stress on the quality of ecosystems and bio-ecological patterns. In particular, the following processes may occur:

- **Changes in water quality**, affecting natural biogeochemical processes, primary productivity and tolerance of species.

- **Shoreline erosion** and sedimentation will alter natural patterns, creating artificial dynamics of sedimentary ecological processes.

- **Terrigenous sedimentation** affects different types of organisms, especially corals and filter-feeding species.

- **Pollutants** are trapped in seabed sediments, such as organic pesticides from agriculture and heavy metals from industrial waste, and can be released and contaminate trophic networks.

- **Invasive species**, via transport in ballast water or via immigration due to global climate change, pose additional threats to local species and ecological processes.

- **Microbial contamination** is a further threat to the health of ecosystems and their species, but also a risk to human health.

- **Removal of grazers** can provoke ecological disruptions and induce the overgrowth of opportunistic species.

- **Trophic cascades** are processes that affect whole trophic networks, reaching their top organisms, frequently

those that represent food security resources. An example being nutrient enhancement leading to red tides that impact filter-feeders consumed by humans.

- **Phase shifts** are states of ecosystems in which the dominant structuring species change, with long-term effects, such as the case of substitution of corals by opportunistic algae following extreme bleaching, with concomitant erosion and decrease of habitat complexity that supports high biodiversity levels.

State and trends of the marine environment

In general, the WIO region has relatively pristine coastal and marine ecosystems, mainly due to the current low levels of industrialization and economic development. However, these conditions may be rapidly changing, as GDP is increasing and emergent activities will likely induce the much-needed economic development for the region. The benefits of development and adoption of Blue Economies will pose additional threats to ecosystems and species, and risk negative feedbacks on environmental quality and traditional living resources. It can be summarized that:

- Threats from pollution and other direct anthropogenic pressures are less severe than in other parts of the world, but this current state is changing rapidly with development trends.

- Overall the marine ecosystems present high levels of quality and associated biodiversity.

- Nevertheless the WIO region has several species listed as vulnerable and threatened by CITES, namely 126 Vulnerable, 27 Endangered and 8 Critically Endangered.

Impacts on the marine environment and related livelihoods

Impacts on the marine environment in the WIO region can be categorized as environmental impacts (affecting species and ecosystems) and human impacts (affecting economic and social features). The main environmental impacts may be summarized as follows:

- A degree of **habitat degradation** is evident at the global scale, the best example being the bleaching phenomena in coral reefs, albeit of worldwide character. At local scales, severe habitat degradation is mainly found in peri-urban ecosystems and affecting their highly utilized natural resources.

- **Alteration of natural biological community** structure is expected from multiple impacts that affect abundance and diversity.

- **Loss of biodiversity** results from multiple causes, global and local, and **extinctions** can be related to climate change or local degradation pressures.

- **Loss of protection** is evident at the coastal zone, where ecosystems like mangrove forests protect coastal land from storm surges or tsunamis, and contribute to coastal stability. Seagrass beds and dune vegetation also contribute to the latter. The loss of habitats such as mangroves and seagrasses reduces **nursery function** areas for resources like fish and shrimp.

- Degradation will ultimately lead to **reduction of resource biomass**, and, together with overexploitation, can disrupt traditional artisanal and industrial fisheries.

- In particular **coral bleaching** is a strong impact that puts at risk the highly diverse and productive reef ecosystems.

- Degradation of coral reefs, also driven by other non-global pressures such as trampling and overexploitation, leads to **loss of coral functional richness and cover**.

- Pressures on the neritic waters (from marine litter and incidental fishing) and coastal urbanization provoke **decline in turtle nesting** on sandy shores, putting at risk these vulnerable animals.

Society responses

Adaptation to global change and mitigation of its effects is of major importance for the years to come. The effects of the global drivers act synergistically with the local drivers of change, which society must minimize and mitigate. Responses to these increasing challenges must be addressed in multiple actions that cross sectors and specific activities. First, social approaches must be targeted through society responses. Secondly, governance structures must fulfil their role and develop adequate political and regulatory mechanisms. Thirdly, research must be strengthened and adequate communication with interested parties established, to transmit messages in the appropriate formats for each group of stakeholders. Civil society must be engaged in actions that will promote awareness. Regarding social responses, expected targets are:

- **Economic empowerment** of society at all levels that leads to human well-being, as a fundamental step for awareness and positive environmental attitudes.

- The alleviation of pressure on resources and the ecosystems where they thrive are related to **livelihood diversification**.

- **Education and awareness** are the basic frame-

works for civil engagement on environmental issues, namely conservation and sustainable exploitation of resources.

- **Population control** is also considered as a target for sustainable development, by better regulation of human migrations and social interventions.

Managing environmental issues involves strong governance at all levels, from policies to enforcement. The following actions are necessary:

- Ratification of **global conventions and regional agreements**, to engage in worldwide efforts and promote transboundary management mechanisms.

- Establishment of strong national **environmental policies and sectorial regulations** to tackle marine issues.

- Create appropriate and effective **law enforcement** for regulations and practices.

- Establish adequate **networks of conservation** that comply with the targets of CBD by 2020 (10 per cent of protection), and this way protect sensitive systems and establish potential spill over areas.

- Strengthen **Integrated Coastal Zone Management**.

There is a consistent view that research in the coastal and marine environment has to be increased in the WIO region. Fundamental research creates the basis for the development of applied knowledge, that can address current challenges but also build up new opportunities in the framework of Blue Economy. Some of the actions that could be promoted include:

- Identification of sensitive and ecologically important areas that should be viewed and protected as **hotspots** for biodiversity at all levels.

- Promote knowledge for the **restoration of degraded habitats** to enhance ecological functions and maintain or decrease trends of biodiversity loss.

- **Afforestation** is a good example where community engagement in conservation efforts is producing promising results, such as mangrove forest plantations.

- Establishment of **task forces** within the scientific and civil society to address specific challenges, such as the existing Coral Reef Task Force and the WIO Mangrove Network.

- Create and maintain **monitoring programmes** for observing trends and link to research and management.

- Increase efficiency by making **capacity building** in necessary fields such as research, management, law enforcement and awareness promotion.

General recommendations regarding biodiversity

(these recommendations derive from the assessment under Part III, and are detailed in the summary Chapter 12).

- Promote **awareness** at various levels (resource users and managers, the public, politicians and authorities) regarding the value and vulnerability of the WIO's natural marine capital.
- Increase **funding for research**, to create the knowledge needed for a greater understanding of WIO coastal and marine ecosystems and resources and consequently their improved management.
- Increase investigation of **shelf sediments and deep sea phenomena**, the major gaps in the WIO region.
- Increased funding for **marine resource management**.
- Increase **capacity building** to promote regional skills and expertise on threatened species and their protection.
- Establish **WIO Threatened Species Task Forces** as a means to mobilise capacity to deal with threatened or declining marine species and habitats, or those in need of special attention or protection.

- Promote **National and Regional integration** and **cross-sectorial linkages** to facilitate and provide a more coherent approach to the management of trans-boundary resources.

- Promote **alternative livelihoods**.
- Search for **alternative food sources/equivalents** to alleviate overfishing.
- Promote **value-adding** and **technological transfer** regarding new products.
- **Monitor the harvest** of vulnerable species.
- **Establish MPAs and closure mechanisms**, promoting community participation.
- Prioritize **areas for protection**, in terms of suitability, size and spacing.
- Identification of **areas of resilience**, where special protection should be granted.
- Promote community-based **habitat restoration and rehabilitation**.
- Promote **sustainable use** of coastal and marine resources.
- Strive for compliance with CBD biodiversity protection **targets by 2020**.

ASSESSMENT OF SERVICES FROM THE MARINE ENVIRONMENT OTHER THAN PROVISIONING

An assessment of services from the marine environment, other than provisioning, is developed under Part IV of the RSOCR. The concept of services provided by the WIO is presented in Chapter 13, and these may be categorized into regulating, supporting and cultural services. The assessment included the role of oceans in the hydrological cycle (see Chapter 14), sea/air interaction (see Chapter 15), phytoplankton primary production (see Chapter 16), ocean-sourced carbonate production (see Chapter 17) and cultural and derived services from the marine environment (see Chapter 18). Figure 36.3 provides a summary of the RSOCR assessment of services from the marine environment, other than provisioning, under the DPSIR methodology framework.

Climate regulation in the WIO

The exchange of mass and energy at the interface between the sea surface and the atmosphere results in a complex coupling (see Chapters 14 and 15 for details on biogeo-

chemical processes, weather and climate regulation in the WIO region). The WIO region shows strong inter-annual climatic variability, due phenomena such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), as well as seasonal climatic variability derived from the monsoon circulation (Manyilizu and others, 2014). Main climatic *pressures* are:

- Increase in sea surface temperature (SST) (Roxy and others, 2014),
- Increase in surface air temperature (Vincent and others, 2011), and
- Increase in wind speed (eg Mahongo and others, 2012).

Evidence shows that basin-scale decadal warming trends in the upper ocean heat content, for the period 1955 to 2008 may lead to rising sea levels and significant stress to some coastal and marine ecosystems (Levitus and others, 2009). Zinke and others (2005) reported evidence of strengthening of the South Equatorial Current (SEC). This ocean current affects biological productivity and the capacity of the ocean to store heat and carbon. In the upper thermocline, subtropical, subsurface waters of the Indian

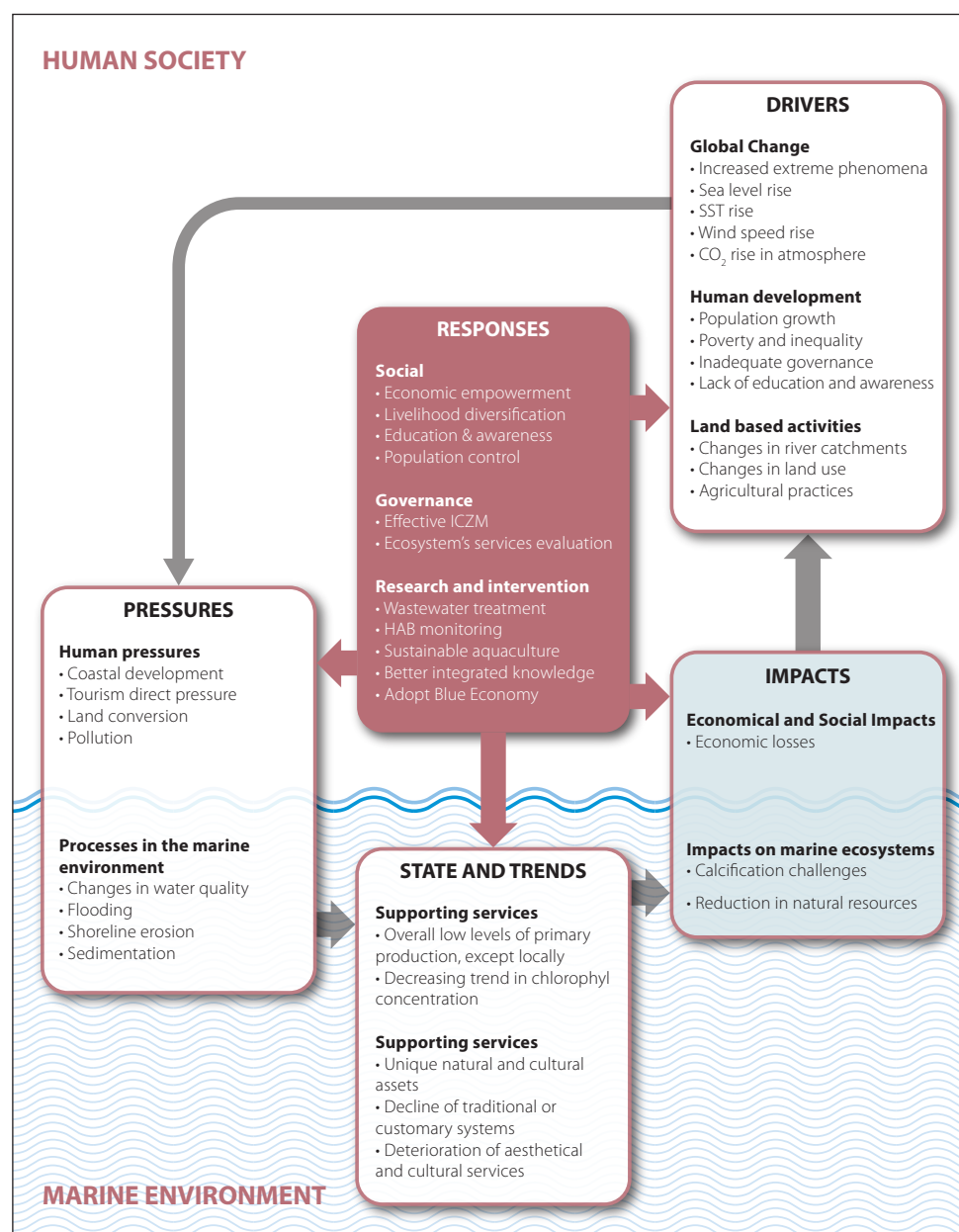


Fig 36.3. Diagrammatic summary of DPSIR analysis for services from the WIO marine environment other than provisioning.

Ocean along 20°S (which includes the southwestern Indian Ocean), anthropogenic CO₂ storage over an 8-year period (between 1995–2003/2004) is reported to have increased at an average rate of 7.1 mol m⁻² (Murata and others, 2010), almost two times higher than that reported during the previous decade (Sabine and others, 1999).

Over the last three decades, both the mean and maximum speeds of the monsoon winds have generally strengthened in some parts of the region such as in Tanzania (Mahongo and others, 2012), however it is not excluded that these changes could be derived from natural climatic cycles. Webster and others (2005) observed an increase in the annual frequency of cyclones in the South Indian

Ocean within the period 1970 and 2004. The number of intense tropical cyclones also increased from 36 during the 1980-1993 period, to 56 during 1994-2007, comparable to a simultaneous but smaller decrease in the number of tropical storms (Mavume and others, 2009). Globally however, there is no sound indication that tropical cyclone frequency has increased over the past century (Christensen and others, 2013). According to Christensen and others (2013), tropical cyclone numbers are unlikely to increase, but cyclone maximum intensity is likely to increase on the global average, meaning increased maximum precipitation and winds. Mauritius, Reunion, Madagascar and Mozambique are the regional countries that are more prone to

intense cyclone activity and landfall. Acidification is not well studied in the region, but is a global pressure affecting all oceans.

Impacts from extreme climatic events are flooding, coastal destructions by storm surges, wave action and erosion. An increase in ocean acidity will affect calcification processes in a wide range of organisms, as reported in next section.

Responses to the threats posed by climate trends cannot be addressed at local scales, and thus countries of the WIO region should join international efforts for decreasing drivers of change and adopt mitigation measures.

Support to primary production by the WIO

Status and trends: The general trend of chlorophyll-a concentration for the WIO region has been seen to decrease with time, although showing a significant inter-annual variability. The general decrease is in agreement with the global trend in primary production, which appears to be decreasing and impacting fisheries catches (Chassot and others, 2010). Although the general trend for primary production in the WIO region is a decrease, some exceptional areas have high productivity resulting from influence of nutrient input via land-based sources (eg Sofala Bank in Mozambique) and natural upwellings (off the Somalia coast).

Pressures and impacts: Ocean acidification derived from climate change *drivers* (Cooley and others, 2009) will impact phytoplankton, especially those with calcareous shells as well as calcareous macroalgae. Besides climate change, anthropogenic activities, such as increased coastal development to accommodate increased tourism (Sadally and others, in press), as well as destruction of habitats and damming of the rivers, increases sedimentation in coastal waters thereby reducing light availability for photosynthesis. So far in the WIO region, eutrophication at a large scale has not occurred. However, harmful (or nuisance) algal blooms (HABs) have been identified in pollution hotspots of the WIO countries (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009). HABs may reduce water clarity, effect aesthetics and biodiversity, increase pH, smother benthic communities, modify species composition and create anoxic conditions due to the decomposition of organic matter, resulting in mortalities of marine species from hypoxia (UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA, 2009, ASCLME/ SWIOFP 2012, Chislock and others, 2013).

Responses:

- Reduction of inputs of raw domestic and industrial wastewater into the ocean, by treating the water at source to reduce contaminants and nutrients.
- Initiation of HAB monitoring programmes.
- Conduct sustainable aquaculture in which the effluent water is treated before being released.

Conduct research to understand better the impact of variation in primary production on the wellbeing of coastal communities. There is inadequate literature relating to the variation or trends of primary production to the environmental, social and economic implications to the societies of the WIO region.

Support to ocean-sourced carbonate production by the WIO

Drivers and pressures: The most significant pressure on carbonate producers is the increase in atmospheric carbon dioxide. Worldwide, it has been postulated that carbon dioxide levels are due to increase up to 450 ppm by 2040, if the current rate of increase persists, which is believed will cause rapid decline of coral reefs due to acidification, mass bleaching and other environmental impacts (Veron and others, 2009). The spatial variability of impact responses by coral reef habitats to climate warming have varied over geographical scales (Graham and others, 2008). For the WIO region it can be implied that similar variations may occur as a result of ocean acidification. In addition to this, some calcifying organisms may shift their distribution ranges to more carbonate rich environments (Doney and others, 2009).

There is an expanding pool of knowledge about carbonate producers in WIO waters and the few studies available provide a glimpse into the critical role that these organisms play in a world of increasing carbon (Kangwe and others, 2012, Semesi 2009). Inferences can be made from the experimental work by Doney and others (2009), that show that due to the highly diverse marine flora and fauna that characterizes the WIO region, the responses to increased acidification and eutrophication of the ocean will vary, with some species expected to be resilient to these changes.

Responses: Regional land-use management is frequently more important than mediating climate change (Maina and others, 2013). There is a need for focused studies that track impacts through food webs, to understand the specific responses of the carbonate producers. As described by

Doney and others (2009), programmes that provide for systematic, cost-effective monitoring of surface water chemistry and long-term laboratory manipulative experiments are critical in understanding the responses of carbonate producers in a fast changing world.

Cultural services of the WIO

The interaction between human culture and the coastal and marine environment in the WIO region has over time produced unique cultural products, practices and cultural influences (see Chapter 18 for detailed description). Landscapes have also attracted significant tourism due to their aesthetic and historical value. Equally important are traditional knowledge systems and institutions, which illustrate the existence of customary systems of resource management and local people's understanding as well as appreciation of ecosystem functioning (Cinner and Aswani 2007, Masalu and others, 2010). Marine resources are also part of the cultural heritage associated with the ecosystem, providing a range of benefits for the sustenance of coastal livelihoods. Certain historical sites and landscapes have however suffered from poor management (Duarte 2012), owing to factors that include changing value systems and physical intrusion, calling for concerted management efforts. At the same time, while some of the intangible heritage in the WIO region remains quite vibrant and dynamic, others are declining in cultural significance (Cinner 2007, Sunde 2013). Twenty-nine of 1 007 World Heritage Sites are found among the ten states of WIO region, with twelve of these located within the coastal zone (UNESCO 2014). The aesthetic and patrimonial value of some of these sites is a source of tourist attraction (Bakker and Odendaal 2008, Obura and others, 2012).

Pressures and trends: Traditional or customary systems are largely in decline, and their current effectiveness in

coastal and marine resource management is complicated to establish without further careful ethnographic documentation. Modernization and intensification of the cash economy has led to fishing pressure both in terms of needs by the coastal populations, and (destructive) technologies. Meanwhile, market pressures have weakened or eroded customary management systems (Cinner and Aswani 2007, Masalu and others, 2010, Shalli 2011). The decline in these management systems has also partly resulted from the deterioration in quality of aesthetic and spiritual services offered by the coastal and marine environment. The WIO region is increasingly witnessing a decline in the quality of cultural heritage due to both natural and anthropogenic factors. The cultural value of many of the traditionally revered landscapes and seascapes, or customary practices, are deteriorating or eroding.

Responses: The role of science, in terms of providing a multi-disciplinary research approach (combining biological, sociological and cultural approaches) that will inform the policy making process on the value of cultural services in sustaining ecosystem health, needs to be emphasised (eg Tengberg and others, 2012). Management of coastal land- and seascapes should include customary systems into the evolving policy and legal frameworks for management. It is therefore important to identify and harmonise perceptions on cultural ecosystem services from different stakeholders for management. Likewise, it is recommended that the significance of various levels of practices, belief systems or faiths that are used to uphold ethical relationships with nature, need to be identified, for possible integration in ecosystem management (Cinner and Aswani 2007). It is also important to scale-up local capacity building for management planning and monitoring of natural and cultural heritage, among both heritage managers and local committees assigned to monitor the conservation of archaeological sites.

General recommendations regarding ecosystem services other than provisioning

(these recommendations derive from the assessment under Part IV, and are detailed in the summary Chapter 19).

- Promote holistic **ecosystem services valuation**, as these are often ignored in management planning.
- Adopt **Blue Economy** approach principles, to minimize environmental impacts of new developments.

- Adopt **knowledge integration**, namely traditional management systems with modern approaches, and its recognition in Law.

- Invest in research to address **knowledge gaps**, namely valuation of services, trends, status of traditional management, and drivers of change and vulnerability and mitigation.

- Promote **environmental awareness**.

ASSESSMENT OF FOOD SECURITY FROM MARINE RESOURCES

Around 60 million people inhabit the coastal zone in the wider WIO region (van der Elst and others, 2005), and many of them rely on the sea for their economic, social and cultural security (eg FAO 2010). The WIO region is characterised by high marine biodiversity, but contrastingly the biomass of individual species is generally low, with marine productivity depending more on nutrient input from rivers along the coasts of eastern Africa and Madagascar, than on upwelling systems (Caddy and Bakun 1994). The rapid population growth and global economic expansion over the past 50 years have exponentially increased the pressure on coastal resources (eg Jackson and others, 2001), and the resulting overfishing and demand from coastal development have increased pressure on both the abundance of fish stocks and coastal biodiversity. Compared to fishing, mariculture is a recent practice in the WIO region, where it appears to have positive future prospects, particularly in Madagascar, Mozambique, Tanzania and Kenya (Troell and others, 2011).

The assessment of food security from marine resources is dealt with in Part V of the RSOCR. Its most significant contributions are capture fisheries (see Chapter 21), the emergent and growing mariculture activities (see Chapter 22) and their socio-economic impacts (see Chapter 23). Figure 36.4 attempts to provide a summary of the RSOCR assessment of food security from marine resources under a framework of DPSIR methodology.

Capture fisheries

Status and trends: Artisanal fisheries comprise fishing households with small amounts of capital and access to simple gears, albeit diverse, that can be used from the shore or small boats. These are usually performed in inshore areas, and usually up to 3 nautical miles (around 5.5 km) from the coast and islands. Industrial fisheries of the WIO target migratory species such as tuna and tuna-like species (Cochrane and Japp 2015), penaeid prawns on shallow shelf sediments and mudbanks (Fennessy and Everett 2015) and deep-water mixed crustaceans (eg Everett and others, 2015). These industrial fisheries are dominated by fleets external to the WIO region countries.

Statistics on landings, that highlight contrasting figures, are considered as gross under-estimations, due widespread lack of reporting by the artisanal fisheries sector.

Nevertheless, it is clear that landings have continued to increase over the past decade, showing growth of the fishing sector, as is the case of Mozambique and Madagascar (Benbow and Harris 2011). However, prawn landings have declined throughout the WIO. Seychelles experienced an increase in large pelagic fish landings after 1997 reflecting the development of its fishing port as a hub for the international tuna industry.

Pressures and impacts: The influence of environmental fluctuations on fish stocks and ecosystem functioning are weakly understood – a factor exacerbated by global climate change and predicted temperature, pH, sea level and acidity changes among other factors. Nevertheless, it is expected that distribution of species, including many that are important living resources, will suffer alterations and latitudinal shifts due to sea temperature changes and movements due to possible unpredictable changes in current patterns. The open access fisheries, in which the numbers of fishers, methods used, and harvest quantities are not controlled, inevitably lead to overexploitation and habitat degradation, particularly when the numbers of fishers and their needs continue to grow. Illegal, Unreported and Unregulated fishing is common in the SW Indian Ocean, where it is responsible for considerable economic, social and ecological losses in developing countries (MRAG 2005). To offset declining catches in nearshore fisheries, states are increasingly looking further offshore to increase catches. However, sustainable exploitation appears to be feasible for only very few deep-sea species under prevailing economic conditions and governance arrangements (Norse and others, 2012), mainly because these species are often slow-growing and have low productivity. Capture fisheries affect also the environment in which they operate in different ways. Apart from removals of the harvested resource, by-catches of non-targeted species can be substantial when non-selective gears, such as trawl nets, are used.

Responses: The lack of adequate infrastructure, trained manpower and scientific skills to fully assess marine resources, reflects a need for capacity building at various levels. Similarly, more information is required to describe bio-ecological processes, distribution patterns, fishing pressure and status of important fish stocks. Single-species approaches to fisheries management do not consider broader social, economic or ecological consequences. There is need of managing whole ecosystems, such as suggested by the 1992 Rio Declaration on Environment and Devel-

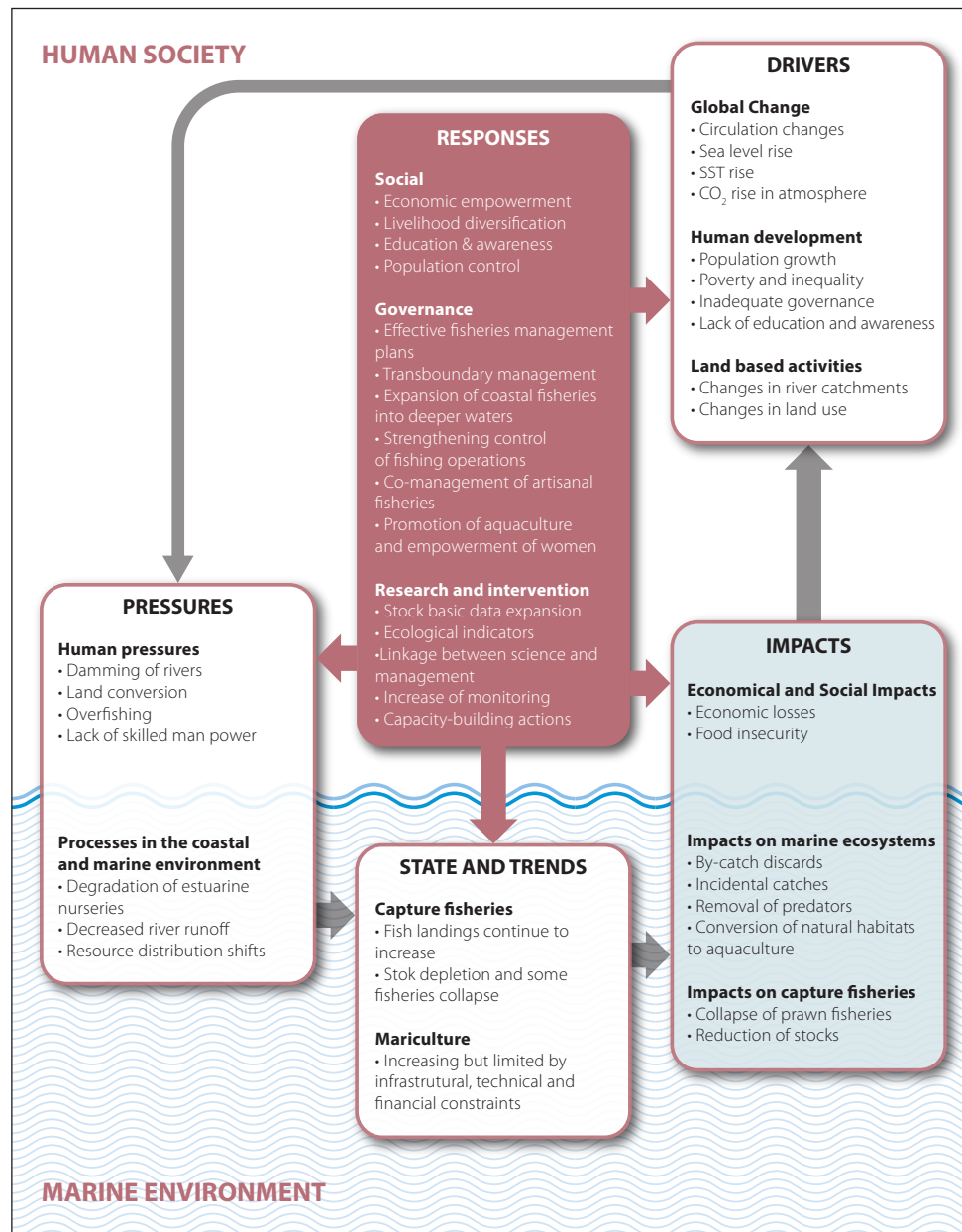


Fig 36.4. Diagrammatic summary of DPSIR analysis for food security from marine resources in the WIO.

opment (United Nations Code of Conduct for Responsible Fisheries; FAO 1995). Cooperative management of shared fish stocks among neighbouring countries may confer many ecological and economic advantages, but it is also a complex political process. New legislation in some countries (eg Kenya, Tanzania) allow for the establishment of Beach Management Units (BMUs) to co-manage fisheries jointly with officials of fisheries departments. BMU objectives are to strengthen the management of fish landing stations, involve all stakeholders in decisions, and prevent or reduce user conflicts.

Mariculture

Status and trends: Mariculture in the SW Indian Ocean is

still in an early developmental phase, with the exception of seaweed culture in Tanzania (especially Zanzibar), where production and farming methods have grown substantially over the past two decades. Kenya has made some progress over the past decades, through development of simple innovative technologies, such as construction of inexpensive ponds, pens and cages. Culture species that need limited water management and feed low in the food chain (milkfish, mullets, mud crabs, penaeid prawns) have been studied (eg Mwaluma 2002). The Mozambique action plan for the Reduction of Absolute Poverty (2001-2005) promoted small-scale mariculture (or coastal aquaculture) as a means to contribute to food and nutritional security and socio-economic development. However, small-scale mari-

culture has not really been successful, and is presently limited to scattered prawn, fish and seaweed farming operations (Ribeiro 2007). Commercial prawn farming for *Penaeus monodon* commenced in the early 1990s, and has received regular financial, technical and infrastructure support from NGOs, especially Blue Ventures, plus foreign investors (Robinson 2011).

Pressures and impacts: Pond farming in Madagascar takes place behind mangrove areas along the northwest coasts where mangroves have come under threat through erosion,

siltation and related effects from ponds constructed on salt flats. Limited success of mariculture is due economic isolation, insufficient training, and degraded road infrastructure, as is the case of Madagascar, but also Mozambique.

Responses: Mariculture is a good option for compensating for decreasing returns from capture fisheries, however it should be developed with adequate management plans, integrating governance vision, and co-management by private sector investment and NGO support, including the local communities.

General recommendations regarding food security from marine resources

(these recommendations derive from the assessment under Part V, and are detailed in the summary Chapter 24).

- Appropriate control should be acquired by authorities throughout the WIO region to address **overfishing of marine resources**; especially numbers of fishers, methods used, and harvest quantities.
- Governance and economic conditions should be developed to **expand coastal fisheries into deeper waters**, frequently tabled as an option to increase harvests from the sea.
- **Effective management plans** should be developed to include the majority of species and fisheries.
- **More basic data is required** to describe distribution patterns, biological characteristics and reference points, stock status, and the effects of fishing.
- **Strengthen the linkage between science and management** to pass messages from stock status, or to provide solutions to recent or longstanding management issues often not prioritized.
- **Increase monitoring, control and surveillance** (MCS) capacity, making enforcement of national and

international laws and regulations more effective in most WIO countries.

- **Promote co-management of artisanal fisheries**, through Beach Management Units (BMUs) empowered to manage fisheries in specific areas on behalf of fisheries departments.
- Promote awareness and implementation of an **ecosystem approach to fisheries management (EAF)**.
- Promote the use of **ecological indicators** for evaluating and comparing the status of exploited marine ecosystems.
- Promote cooperative **transboundary fish stock management** in the WIO.
- Promote **capacity-development initiatives** for the scarcity of skilled manpower (namely fisheries researchers, scientific observers, fisheries managers, surveillance technologists, hatchery and grow-out system operators) in the region.
- **Encourage mariculture** as an alternative activity to generate fish protein and wealth.
- A more **integrated approach** to mariculture is required.
- Promote **empowerment of women** in culture and business aspects of mariculture.

ASSESSMENT OF OTHER HUMAN ACTIVITIES

Assessment of other human activities in the marine environment is developed under Part VI of the RSOCR. It includes a number of important sectorial issues such as maritime activities (see Chapter 25), oil, gas and renewable energy (see Chapter 26), coastal mining and coastline stability (see Chapter 27), tourism and recreation (see Chapter 28), urbanization, coastal development and vulnerability and catchments (see Chapter 29) and marine genetic

resources and bio-prospecting (see Chapter 30). The adoption of Blue Economy agenda should drive development of human activities that promote economic development and poverty alleviation, at the same time ensuring sustainable use of resources and environmental quality maintenance. Some of the analysed emergent activities can turn into opportunities for human development in the WIO region. Figure 36.5 provides a summary of the RSOCR assessment of other human activities in the coastal and marine environment under a framework of DPSIR methodology.

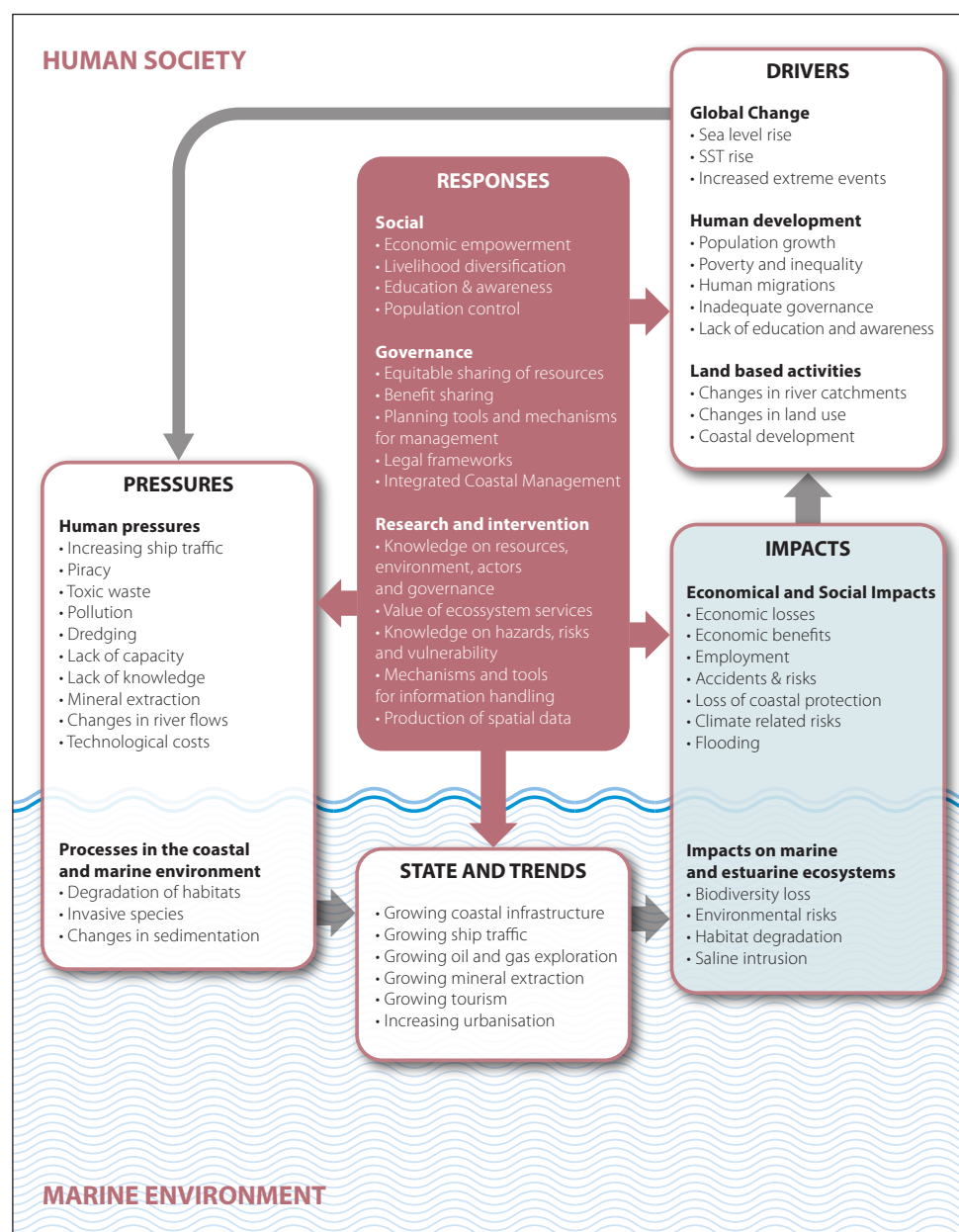


Figure 36.5. Diagrammatic summary of DPSIR analysis for other human activities in the coastal and marine environment in the WIO.

Status and trends: Oil tankers have now increased to represent 80 per cent of the WIO fleet, and around 6 per cent of the world trading fleet travels to ports in the Indian Ocean (UNCTAD 2006). Other *pressures* in the region include piracy, the illegal dumping of toxic waste and potential impacts of climate change as a result of more frequent storm events and rising sea levels. While ships are essential to the global economy, they have a variety of negative *environmental impacts*. These include pollution resulting from the ship's operations and as a result of accidents, and impacts related to ship recycling and translocation of invasive alien species primarily via ballast water and hull fouling.

Moreover, the growth of global maritime activities has

led to congestion of shipping lanes, increasing the risks of accidents, in particular around ports. While there has been a general increase in both imports and exports over the years, the most significant change has been in the African export of crude oil since 2006, but mainly from West African countries, which are likely to grow due to the recent discovery of methane gas in some WIO countries. There are 13 existing commercial ports in the region with several others either in the planning phase or under construction. In addition, there are a number of smaller ports and harbours.

Impacts of operational pollution from ships: No data is available for operational pollution from ships in the region.

WIOLaB (De Mora 2006) reported that none of the countries in the region has a comprehensive national marine pollution monitoring programme. Similarly, there has been no specific assessment of litter discharged from vessels. UNEP and others (2008) concluded that marine-based sources of litter do not appear to be as significant as land-based sources. Apart from impacts on human health and tourism, marine litter affects biodiversity as a result of ingestion, entanglement (especially of turtles, seabirds and mammals) and smothering.

Regarding *impacts from shipping accidents*, databases on shipping casualties are very limited for the WIO countries. The majority of invasive alien species (IAS) that have been recorded in the WIO region are thought to have been introduced either via bio-fouling on ships, or as deliberate introductions for mariculture purposes. Their *impacts* are presently difficult to quantify. Assessment of environmental *impacts of port activities* is limited, but the majority of the pollution hotspots identified were in or adjacent to ports. Dredging for both port construction and operational phases and concomitant disposal of the dredged material are pressures on the adjacent marine environment. Examples are evident from Mombasa, Port Louis, Maputo, Matola, Beira and Nacala.

In addition to potential *environmental impacts*, there are a number of other challenges, including piracy, the illegal dumping of toxic waste and potential impacts of climate change on shipping and port infrastructure. Climate change *drivers* and *pressures* may impact increasingly maritime activities, for example, increased frequency of storm events and rising sea level. *Impacts* may include more frequent shipping accidents, increased costs of port maintenance and disruption of port operations from both the seaward-side and hinterland supply chains. Plans to maintain and expand maritime activities in the WIO region should take these concerns into account, as responses to these *impacts*.

Improved capacities are needed to address fundamental issues in maritime activities, such as port and Flag State control, surveillance of shipping lanes and provision of navigational aids. These include surveys of shipping routes, updated nautical charts, training on hydrography, marine cartography and electronic navigational charting, repairs, and training on aids to navigation and maintenance. Another challenge is responses to oil and other spills, namely compliance to the protocol of the Nairobi Convention.

Responses to these challenges can include the imple-

mentation of Flag and Port state controls, regional co-operation around maritime surveillance, scientific monitoring and reporting of pollution levels and incidents, prevention and control of alien and invasive species introduced by ships, provision of adequate waste reception facilities at ports, increasing awareness of the impacts of marine litter, inclusion of climate change concerns into risk assessments and the development of Climate Adaptation Plans for ports and financial mechanisms to provide for the required management activities.

Oil, gas and renewable energy

Status and trends: The countries in the WIO region rely on the importation of oil to fuel power stations to generate electricity, although countries like Mozambique have a significant generation of energy from hydropower. The main driving force for generating energy is to supply electricity to industry, commerce and citizens, which is further required to account for population growth and need to reduce the dependence on imported fuel. Off the coasts of Tanzania and Mozambique, combined estimates indicate the presence of at least 150 trillion cubic feet (tcf) of natural gas (Wood Mackenzie 2014). Four main geological provinces in the WIO region are prone to discover technically recoverable conventional oil and gas resources, and estimates show potential for more gas (and oil) to be found in the WIO such as in mainland Africa, western Madagascar and the Seychelles Plateau (Brownfield and others, 2012). The East Africa discoveries have fuelled interest in the EEZs of neighbouring islands in the Mozambique Channel, and seismic surveys are starting soon (Spectrum 2014). For most countries in the WIO region, local investors are unable to match the costs of exploration and unprepared to take the risks, hence the need for participation of the large independent and major companies in the oil and gas industry. But most countries in the WIO region assume that energy diversification is fundamental to address the growing needs of the expanding populations and industries, and alternative energy sources can be deep ocean cold water, tidal energy, ocean currents and wave energy. So far only Mauritius has started the production of energy with deep ocean cold water.

Pressures and impacts: The impacts from exploration, development and production of energy from the sea include those associated to the placement of structures in the marine environment, fossil fuel exploration and production. Structures including seismic survey and drillships,

floating LNG plants, offshore oil and gas production platforms and seabed feed pipelines can physically obstruct and interfere with access for navigation or fishing activities, similarly affecting the movement of marine mammals and fish. Regarding fossil fuel exploration, the noise levels that impacts on migrating species such as whales, turtles, tuna and whale sharks, the amounts of discharged drilling muds and fluids at the well locations, on the seabed and into the water column, and the resulting degraded seawater quality around drilling platforms constitute pressures that are *state indicators*. *Impact indicators* include any reduction in migrating marine species because of the disturbance. Impacts from fossil fuel production include those derived from transportation, which is vulnerable to poor maintenance, infrastructures and accidents that result in threats to the coastal and marine environment. Social impacts can be positive (employment, benefits from corporate social obligations, skilled training) or negative (incidents due lack of adequate communication and awareness, inflation). Pollution is a concern in fossil fuel production.

Responses can include raise awareness and capacity building including the environmental regulators and negotiators with energy sector; promotion of effective management and governance of the extractive sector, encouraging participation of civil society organisations; protect the marine environment and ensure oil pollution preparedness and insurance for compensation for eventual loss of livelihoods; sign and ratify all International Maritime Organisation (IMO) conventions relevant to oil and gas exploration; review legal mandates to ensure compensation for damages caused by marine-based energy companies; adhere to the conditions of the Nairobi Convention; develop and promote renewable energy alternatives; promote regional coordination on planning of transboundary issues such as oil spill contingency, piracy and security, as well as cross-border developments to minimize negative impacts and maximize benefits from marine based energy sources.

Coastal mining and stability

Status and trends: The coastal regions of Sub-Saharan Africa are witnessing increasing non-renewable mineral resources extraction (UNEP/ Nairobi Convention Secretariat 2009a). Human development results in heavy dependence on natural resources, namely as building materials such as cement, sand and coarse aggregate (stones) for concrete and mortar, and clay for bricks (eg ASCLME 2012). The major types of materials and environments used are coral rock and lime-

stone for cement manufacturing and coarse aggregates for concrete and road building by quarrying, artisanal sand mining from catchments, flood plains, river banks, estuaries and lagoons, informal removal of sand from beaches and fore dunes, and production of sea salt from saltpans located on estuary flood plains.

Pressures and impacts: Overexploitation, modification and loss of habitats and uncontrolled development or encroachment have resulted in environmental degradation including a reduction of the natural protection effect against sea surges during storms (Roger 2002). These factors have a negative impact on coastal communities and often on the countries at large (Masalu 2002). Impacts include catchment degradation due to uncontrolled mining activities such as sand excavation from rivers and the destruction of riverine habitat for salt production (DHI and Samaki 2014). This can result in increased sediment and silt load in rivers, causing coastal accretion and in places and smothering of sensitive marine communities such as coral reefs. On the other hand, coastal erosion is enhanced due the decrease of sources of sand. Activities acting synergistically include the construction of dams in rivers courses (which trap sediments) and mining (Tinley 1985). The construction of harbours including breakwaters and/or the dredging of shipping entrance channels changes the natural alongshore sand transport, erosion and deposition patterns. According to DHI and Samaki (2014) sand and stone quarrying along beaches, coastal water-courses and other areas are important livelihood activities, in places developing into significant local industries. These informal activities create a range of jobs and local income with resultant socio-economic opportunities and challenges (Masalu 2002). Negative feedbacks however can lead to decreased economic activities, job losses and extensive long-term costs to the local economies.

Responses: Policies that relate to coastal mining activities do exist in most of the WIO countries and should be strengthened, as should local capacity regarding control of mining activities, especially where informal mining prevails. Research should be increased and a higher degree of awareness promoted, related to the importance of coastal stability and role in protecting the coast from climate change enhanced hazards from the sea. Policies to ensure the direct participation of current artisanal (informal) sand miners in the whole value chain of this activity would also enhance socio-economic benefits, whilst ensuring the integrity of the coastal sedimentary system.

Tourism and recreation

Coastal areas display high aesthetical value and offer numerous opportunities for generalised tourism and recreation (Beatley and others, 1994), while the open ocean also offers many opportunities for more specialised tourism and recreational activities (sports fishing, whale and dolphin watching and cruises). Tourism also pressures the natural marine environment, nevertheless, the economic benefits of tourism and recreation in generating employment, local income and foreign exchange is of major importance to economies, specially for those with restricted export goods or low sources of income. The WIO region has a variety of high quality physical, environmental and cultural features that serve to attract the tourism industry which should be a viable option for contributing to socio-economic development. The development of this sector is, however, directly and indirectly linked to the state of the coast and the marine environment, in myriad ways.

State and trends: The WIO countries are increasingly attracting international tourists, and the growth rate, measured as tourism income for all the countries, has been showing an encouraging trend. Coastal tourism is very popular among local populations, particularly in the Small Island Developing States (SIDS) and coastal region of the mainland states of the WIO region. Sport fishing clubs and services attracting tourists exist in all WIO countries, lead by South Africa, where recreational fishing attracts increasingly activities focused on sustainability. The expansion of cruise tourism is also on many national growth and development agendas (eg Government of Mauritius 2013), and is increasing in many South Africa and East African ports.

Impacts and pressures: The tourism and recreation sector is a major driver for socio-economic development, promotion of economic growth and alleviation of poverty (eg Richardson 2010) with direct and indirect economic impacts, promoting infrastructure development such as roads, airports and amenities in the coastal zone (eg Seet-anah and others, 2011). The tourism industry is an important source of direct and indirect employment, creating multiple opportunities. Tourism often supports conservation through the promotion of private, communal and public conservation (Buckley 2008). Ecotourism is becoming popular among environmentally-conscious tourists, presenting opportunities for sustainable tourism development. Although tourism has great potential to contribute to socioeconomic development and to envi-

ronmental rehabilitation, it also has a wide range of negative social and environmental impacts (Gössling 2006). The health status of the marine environment in the WIO is increasingly under threat and the additional pressure of tourism and recreation is a growing environmental concern.

Responses: In order to promote sustainable coastal development, there is a need to adopt long-term planning and management (eg May 1991), in order to maintain environmental and cultural integrity (Puppim de Oliveira 2005). This will help generate income, employment and conserve the local ecosystems and cultural heritage (UNEP 2003). Specific responses can include promotion of mutually beneficial tourism and conservation, whale and dolphin watching, cruise tourism, research and monitoring. Also relevant are the establishment of Marine Protected Areas, addressing piracy menaces, coastal and shoreline management, beach awards systems and efforts to increase domestic tourism.

Coastal development and vulnerability

The growth of coastal cities places an increasing demand on coastal extractive and non-extractive resources. As elsewhere, coastal cities of the WIO region attract populations that migrate from rural areas, thereby increasing pressure on the coastal zone. Urbanisation reflects the share of the national population in towns and the extent to which this change is accompanied by shifts in the economy and employment (UN-Habitat 2014).

Status and trends: Eastern Africa is a relatively low urbanized region, but this is changing rapidly. The region continues to experience massive urban poverty and other social problems (UN-Habitat 2014). The recent urban growth and projections for the short- up to long-term are cause for concern (UN-Habitat 2014), especially given the existing unemployment levels amongst the urban population and the extent and condition of degraded urban areas. Although urban growth shows a decelerating trend, the absolute urban population is projected to increase and will remain an enormous challenge. Small island states like Seychelles, Mauritius and, to some extent French Reunion, are exceptions to this generalisation since urban population growth is small, in absolute terms, or even declining (UN-Habitat 2014).

Pressures and impacts: The expansion of the built environment is among the most irreversible human impacts on the global biosphere and urban land-use

change remains one of the primary drivers of habitat loss and species extinction (Hahs and others, 2009). The transboundary diagnostic analysis by UNEP/Nairobi Convention Secretariat and WIOMSA (2009b) identified several direct causal links between urbanisation and water quality degradation, habitat modification and a decline in living marine resources. Furthermore, coastal urban areas on the mainland countries of the WIO are mostly located in the vicinity of critical habitats such as estuaries, mangrove swamps and coastal lagoons. The coastal WIO cities are mostly located in low-lying coastal and estuarine and deltaic areas, and as such prone to natural disasters derived from climate factors. In addition, the high incidence of poverty, low capacity to build and maintain infrastructural defences and soft erodible coasts contribute to the risks. A number of regional assessments have identified East Africa as one of the most threatened coastal regions in Africa and globally (eg Boko and others, 2007). Climate change drivers pose numerous threats to coastal zones where major cities are located: sea level rise, storm swells and risk of coastal flooding. Other climate change impacts, such as flooding of river catchments will also continue to affect coastal zones (IPCC 2014). Socio-economic vulnerability is expected to increase over the next decades.

Responses: Policy responses to mitigate negative environmental, social and economic consequences can include disaster risk reduction and climate change adaptation, promotion of research devoted to exploring ways to address climate issues, robust urban planning processes, reduction of the high levels of vulnerability and low adaptive capacity in local governments. Response may also address better land-use plans, establishing environmental baselines, mainstreaming adaptation options into integrated coastal management and sustainable development plans, socio-political reforms and changes for improving planning regimes, improvement of the capacity of municipal and central governments to govern urban areas, and development of effective adaptation strategies for port cities of the WIO region.

Catchments

River catchments, which connect terrestrial and freshwater ecosystems to oceans, enable and modulate essential ecological processes in coastal and marine environments. Rivers transport freshwater, sediments, nutrients, biota and chemicals, which, along with oceanic forces, shape the

coast and establish the availability of natural resources in estuaries and coastal environments (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a)

Status and trends: The WIO region has twelve major river catchments and a myriad of smaller river basins. Three of these catchments, namely the Juba-Shabelle, Limpopo River and Zambezi River Catchments, are among Africa's major transboundary river catchments (UNEP 2010a). The central Mozambican coast is called the 'swamp coast', due its many estuaries and extensive mangrove swamps; the combined discharge of these estuaries and the wide shelf make this area highly productive and important for fisheries. Many of the catchment systems in the WIO region are still in relatively good conditions, however increasing human pressures pose a variety of challenges and these ultimately impact the lower basins and their associated resources and livelihoods.

Pressures and impacts: Several major issues concerning river-coast interaction in the WIO region arise from both direct anthropogenic pressure and global climate change. These include the modification of river flows (water quantity), water quality and sediment loads (primarily because of abstraction and damming) and inappropriate land-use practices. Most large river catchments experience pressures that generate high water stress in the lower basins, due to dams constructed for hydropower and water abstraction for agriculture and consumption. The abstraction and regulation of water flows decrease the frequency of natural floods on which coastal resources like shrimp depend, and in some lower catchments like the Zambezi delta, salt intrusion is evident. Other impacts emanate from industries, poor sanitation and bad agricultural practices that contaminate freshwater bodies. In some instances, sediment transport is altered, and the pressure on lower systems is further aggravated by river sand harvesting.

Responses: Some suggestions for regional policy interventions include development of coordinated legal frameworks for the management of transboundary catchments, effective implementation of inter-governmental management instruments for river catchment management, development of protocols for inter-sectorial water governance, improvement in the collection of data and information, monitoring and assessment, improved financial investment in the development of human capital, and the development of integrated holistic regional policies for water resource management.

Genetic resources and bio-prospecting

There is global interest in exploring the commercial potential of marine genetic and associated natural product resources. Potential applications exist in a wide range of industries including pharmaceuticals, food and beverage, cosmetics, agriculture and industrial biotechnology (eg Arrieta and others, 2010, Global Ocean Commission 2013). Scientific and technological developments in various fields, such as molecular biology, genomics, and bioinformatics, together with technological advances for the exploration of the deep ocean have raised capacities for bio-prospecting the oceans (Global Ocean Commission 2013).

Status and trends: The countries of the WIO region have limited scientific and technical capabilities and consequently most research, development and commercialisation of marine genetic resources and their property rights are conducted outside the region. South Africa and, to a lesser extent, Kenya, are the only WIO countries engaged actively in international collaborative projects. Several areas in the WIO are however of major interest for the exploration of natural products. There is an increased interest in the WIO islands and East African coastline, and the presence of biodiversity hotspots in the region also suggests that the area is likely to be of increasing interest for

marine natural products. Only a small fraction of this biodiversity has been explored for its commercial potential (Davies-Coleman and Sunassee 2012).

Pressures and impacts: Currently the impacts of bio-prospecting are negligible, and the main limitations for the development of these activities are the costs of research and technologies that remains prohibitively high, the low scientific capacity, and the significant gaps in regional taxonomic and ecological knowledge.

Responses: Promotion of the exploration of marine genetic resources and bio-prospecting implies strengthening of national and regional laws relating to access and benefit sharing (ABS) from marine biodiversity in the EEZ. Promotion of research that contributes to the conservation and sustainable use of biodiversity, the building of scientific capacity and transfer of appropriate technology and access to technology from developed countries and institutions, thus improving scientific knowledge about the marine biodiversity of the WIO region are priority responses. Developing a regional ABS approach for marine genetic resources, and supporting improved disclosure of the origin of material in patent applications to ensure greater transparency and improved tracking of the source of the material.

General recommendations regarding other human activities

(these recommendations derive from the assessment under Part VI, and are detailed in the integrative Chapter 31).

- Increase the **knowledge** about the resources, the environment, the people using and exploiting such resources, and the way in which they are governed.
- Understanding the **value of ecosystem services** and how it is influenced by environmental change.
- Promote **equitable access** to and **benefit sharing** of coastal and marine resources, preferably entrenched in all national policy and legislation.
- Promote the understanding and management of **hazards, vulnerability and risk**.
- Develop **mechanisms and tools** for the capture,

exploration and archiving of data, information and knowledge.

- Develop **planning tools and mechanisms** for the management of coastal land-use and conversion at all scales (regional, national and sub-national) and human activities and their usage and exploitation of resources.
- Emphasize the production of **spatial data** that enables usage of scientific products for marine planning and other similar mechanisms.
- Establish relevant **legal frameworks** that enable rather than frustrate efforts to develop environmental management solutions for sustainable development.
- Prioritize **integrated coastal management (ICM)** for the management of coastal areas and associated human activities.

SCENARIOS, POLICIES AND CAPACITY BUILDING NEEDS

Future scenarios for the WIO region

Scenarios are fundamental tools for understanding the use

of natural goods and services with respect to sustainable development. Addressing gaps and policy failures in the governance of the ocean and coasts requires holistic approaches to manage the complexity of the natural environment. Long-range planning, informed by scenarios,

enables decision-makers to predict and explore a range of possible alternative futures in order to identify possible adaptation of governance and its effects on change trends. This way, scenario analysis can be effective in supporting policies for resource-use management and conservation. Scenario analysis goes beyond simple contingency planning, sensitivity analysis and computer simulations by presenting comprehensive exploration of alternative futures.

The scenario approach adopted the DPSIR framework (see Chapter 32) and was integrated based on variables, links, and feedbacks relevant to dynamic modelling of marine social–ecological systems, including drivers that influence human behavioural change, such as society, knowledge systems, political and institutional setting and the economy (UNEP, IOC-UNESCO 2009). The assessment used two main scenarios (or opposite worlds): the Conventional World Scenario (CWS) representing a business as usual pathway (BAU), and the Challenge Scenario or Sustainable World Scenario (SWS) representing the Western Indian Ocean Strategic Action Programme (WIO-SAP) aspirations (UNEP/Nairobi Convention Secretariat 2009b) and the Sustainable Development Goals (SDGs).

The CWS scenario

Under this scenario, governance frameworks remain neglected due to inadequate action, and, consequently, degradation trends related to the coastal and marine environment of the WIO remain. Inevitably, the decline in capture fish production and biodiversity loss is expected to continue. Damage to habitats such as coral reefs will extend to fish resources, and further affect ecotourism and associated livelihoods, while the reduction in critical coastal habitats may reduce coastal protection from storms with potential associated erosion and coastal damage risks. The diversity of nearshore habitats (including beaches, rocky shores, muddy shores and mangroves, coral reefs and sea-grass beds) will continue to diminish due to impacts from climate change, alteration of nearshore geomorphology and unsustainable coastal land-use. Non-compliance with regulations and inappropriate fisheries methods continue to be major causes of habitat degradation accompanied by the decrease in stocks of living resources. In addition to other human activities, such as continued mining and exploration, sand harvesting, trawl fishing and infrastructure developments, such as cities, ports and oil rigs, the projected exponential increase in population will challenge biodiversity conservation from species to ecosystem levels. Con-

comitantly, the risks of pollution, resulting from operational activities and accidents, as well as translocation of invasive alien species through ballast water and hull-fouling, will remain.

The SWS scenario

The value of healthy, critical, coastal and marine habitats is secured through the development of tools and methodologies to support their sustainable management, and restoration of critical coastal and marine habitats is achieved. Adequate development and implementation of management plans, scheduled for completion by 2025, such as National Plans of Action (NPAs), Integrated Coastal Zone Management (ICZM) plans or National Environmental Management (NEM) plans should be developed throughout the WIO region. The development of tools and capacity-building actions for sectorial skills will contribute as mechanisms towards management improvement, as will transboundary collaboration and integrated regional management, addressing maritime and industrial risks. Further efforts should target the development of regional approaches to the management of alien and invasive species, as well as mainstreaming climate change adaptation.

The way forward

The use of the scenario framework must be adaptive and respond accordingly to new challenges, opportunities or threats that undoubtedly will emerge. The Nairobi Convention, through its management and policy platforms, can promote the scenario frameworks for engagement between actors, as a basis for decision-making and as tools for planning and environmental monitoring. Scenarios can be used for the creation of options for policy and management, for effectively managing the coasts and oceans, for promoting adaptive management, but also for monitoring programmes to assist in refining scenarios to respond to observed change in trends.

Governance and policy options

The governments of the WIO region are Parties to the Nairobi Convention, which offers a regional legal platform for the protection, management and development of the marine and coastal environment, constituting a framework of governance in the WIO region. There are national, regional and global institutions that deal with environmental issues. Legal and institutional frameworks for addressing the marine and coastal environment include

constitutional provisions, framework environmental laws and sector-based laws. Chapters 33 and 34 provide detailed analyses of governance and policies concerning the marine and coastal environment in the WIO region.

Major governance weaknesses related to oceans and the coastal environment of the WIO region have been identified, and include policy and legislative inadequacies, limited institutional capacities, inadequate awareness, inadequate financial resources and mechanisms, as well as poor knowledge management (UNEP/Nairobi Convention Secretariat 2009a). There is also inadequate translation of relevant international commitments and obligations into national laws, and an apparent lack of mechanisms for effective coordination and inter-sectorial governance among institutions involved in the management of coastal and marine environment. A root cause is the limited capacity of human and technical resources. Governance challenges include inadequate technical capacity, lack of sufficient financial resources, overlapping or uncoordinated institutional mandates, multiple sectors affecting coastal and marine issues, lack of political will and prioritization, language and legal system constraints, multiple regional affiliations and political instability.

Governance responses and interventions are constrained by overlapping mandates of different level institutions, giving rise to inefficient use of governance instruments and resources. Nevertheless, legal, institutional and policy responses appear to converge, acknowledging that anthropogenic activities do create pressure on coastal and marine zones with resulting environmental impacts that need to be regulated. All WIO countries apply environmental impact assessment (EIA) regulations and further develop ICZM laws and policies.

There are contrasting policy options that are open to the countries of the WIO region concerning the sustainability of the coastal and marine environment, both at the national and regional level. These include: i) overarching policy instruments with sector players taking primary responsibility, ii) maintenance of sectorial policies and providing a coordinating mechanism, and iii) maintenance of sector policies as well as sectorial implementation of the policies without having a coordinating mechanism.

Research and capacity-building

Coastal and marine research in the WIO is limited when compared to more developed regions of the world, however the past twenty years have witnessed a significant

increase in regional capacities and scientific output. This has created not only more, but also better, knowledge that progressively improves management of the coastal and marine environment. Data generated by local capacity is more likely to provide adequate data for adapted management to regional and local socio-ecological needs. Nevertheless, research agendas from United Nations agencies and international NGOs (such as WWF) are contributing to the establishment of regional research targets and promoting capacity-building in key sectors and disciplines that are relevant for a sound understanding of the marine and coastal environment in the region.

Among the many socioeconomic and institutional factors that constrain capacity in the WIO region are limited financial and human resources, low investment in education and training, inadequate knowledge and awareness and lack of legal expertise. Investment and innovative approaches to building human capacity development remains a top priority for countries in the WIO. Communicating scientific results to government remains a challenge. There is a widespread perception that decision-makers often do not understand the limits of scientific data, nor how to use it to address practical applicability for management and governance framework agendas.

OVERALL CONCLUSIONS

The WIO region has unique characteristics of high biodiversity, both in terms of species and ecosystems, which place it as one of the most rich and interesting ocean regions of the world. Its geomorphological features and the complex current patterns, together with its location in relation to global biogeographic units and centres of endemism, modulate the complex distribution and richness of ecosystem mosaics. Overall biological productivity is not high but with significant production in estuarine dominated mainland coasts and upwelling systems. Most countries in the WIO are developing countries with strong socioeconomic limitations and their economies, at least in the coastal zone where most of the population is concentrated, is highly dependent on marine and coastal resources. The biodiversity of these systems is thus under direct and indirect pressures from resource exploitation and anthropogenically-driven habitat degradation. The effects and impacts of global climate change add further pressures to local-acting sources of disturbance.

The Regional State of the Coast Report for the West-

ern Indian Ocean has used a DPSIR framework for the assessment of the relevant components pertaining to the marine and coastal environment. The analysis has highlighted the main drivers of change and the consequential pressures that are exerted on the environment and human livelihoods, described current status and trends of natural and societal processes, and identified impacts. Responses to these challenges were summarized and further translated into recommendations under main sectors, providing linkages and integrative mechanisms for addressing them.

Regarding biodiversity assessment, it is apparent that marine ecosystems in the WIO region are in a fairly good condition, but the pressures from global climate change acting synergistically with the local anthropogenically-induced drivers are increasingly challenging the natural processes. Ecosystems service assessments, both related to food security from marine resources as well as those other than provisioning, also revealed similar challenges and increasing pressures from a variety of human activities on the marine and coastal environment.

Other human activities are increasing in the region, such as maritime trade and mineral extraction from the coast, oil and gas exploration, coastal tourism and bio-pro-

specting. While these sectors present enormous potential opportunities to contribute towards economic development, the potential impacts associated with each may challenge sustainability. Their development should be addressed and monitored with integrated sound management strategies.

Long-term planning enables decision-makers to evaluate predictions and explore a range of possible alternative futures in order to identify possible options for policy and management. The WIO governance frameworks are in place and the continued development of efficient institutions and regulatory mechanisms will provide the region with mechanisms for progress towards a sustainable use of the enormous potential of marine and coastal resources. But while capacities are limited in the WIO region, both economic and human, investment and innovative approaches to developing human capacity should remain at the top of priorities for all the countries in the region, at all levels.

The adoption of a Blue Economy and the will to address socioeconomic development in the region, with emphasis on poverty alleviation, gives hope for the future of the marine and coastal environment of the WIO region and the associated human wellbeing and livelihoods.

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