Regional State of the Coast Report

Western Indian Ocean

A SUMMARY FOR POLICY MAKERS

UNEP

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WIOMSA

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FOREWORD

The complex archipelagic system of 115 islands, of which 41 are granitic and 74 are coralline in nature, within an exclusive economic zone of about 1.44 million km2, of the Seychelles, is representative of a truly unique Western Indian Ocean (WIO) region. A region that is world-renown for the vast array of habitats with remarkable natural beauty, spectacular biodiversity and rich natural resources. In the WIO region, we are proud of our leadership and history in the management of the marine environment. Our marine protected areas are among the oldest eg Malindi Marine Park in Kenya, established in 1968, and the Aldabra Atoll in the Seychelles, that was established in 1981 and declared as a World Heritage site in 1982. The Primeiras and Segundas Archipelago in Mozambique is among largest protected area in Africa, covering more than 4020 square miles. The region continues to explore new and innovative options for managing oceans and coasts. We also recognise the transboundary nature of shared ocean resources, and our governments have signed the Nairobi Convention and its protocols as the framework for collaboration in the management of our oceans to sustain cultural and economic opportunities that the marine resources presents to the region as a whole.

The coastal area in the WIO region is home for over 60 million people, with long and rich cultural traditions on the management of the coastal and marine resources. The Seychelles is a microcosm of our Western Indian Oceans cultural diversity. People with African, Asian and European origin, have brought with them their traditions and customs, contributing to the existing vibrant Seychellois maritime culture.

Seychelles has been in the forefront at regional and global level in promoting a Blue Economy pathway for sustainable growth. We strongly believe that we can reconcile fast economic growth with climate resilience development by harnessing the full array of ocean wealth to accelerate our countries' abilities to produce more goods including food and energy.

Our success in developing a Blue Economy is equally dependent on effective management of the coastal and marine environment. The production of this first Regional State of the Coast Report for the Western Indian Ocean Region, which describes the status of the environment and our ocean's vast array of untapped or under developed resources, is the first step in our efforts to establish a common understanding that will be used as the baseline for future reports, scenario building and forecasting.

This report is also a reflection of our collaborative efforts under the Nairobi Convention to create a link between science and policy making at the regional scale. May I commend all those who have made the production of this report possible for their worthy contribution to the body of knowledge on the coastal and marine environment of the WIO region.

It is my hope that this report will inspire our countries in our pursuit to take more concrete actions towards turning our dreams of developing Blue Economy for our countries into reality.

Didier Dogley
Minister of Environment, Energy and Climate Change
Seychelles

PREFACE

The Western Indian Ocean Region – Taking the lead!

The Regional State of Coast Report for the western Indian Ocean (WIO) is the first comprehensive regional synthesis to provide insights into the enormous economic potential around the WIO, the consequential demand for marine ecosystem goods and services to match the increasing human population, the pace and scale of environmental changes taking place in the region and the opportunities to avoid serious degradation in one of the world's unique and highly biodiverse oceans. The report goes a step further and presents exploratory scenarios and policy analysis to better inform anticipatory planning and management of coastal and marine resources.

Thirty years after the Nairobi Convention was enacted, there is no better way to mark this major milestone than launching this report in 2015 - a report which amongst others, will provide the Convention with the basis for reflection on where it is coming from and where it would wish to be in another thirty years from now. For the Convention to successfully mobilize experts from a range of disciplines, decision-makers at different levels, various UN organizations, partners and donors from within and outside the region, to contribute in meaningful and concrete ways towards the production of this report, is testimony to the recognition of the important role the Convention has played as a regional platform for cooperation in the protection, management and development of the region's marine and coastal environment. We at UNEP, as the hosts to the Convention, are very proud to be associated with this landmark document, not only since different sections of the organization have played an active role in its production, but more importantly, this region has become the first Regional Seas Programme to produce its Regional State of Coast Report, based on the format and structure of the UN-coordinated World Oceans Assessment. This is setting the standard for other Regional Seas Programmes to follow.

Further, by linking the production of this report with the Eighth Meeting of the Contracting Parties to the Nairobi Convention, a new dimension is added to the Convention's efforts to bridge the science-to-policy interface. In addition to providing the basis for some of the key decisions of the Meeting, the report will contribute to the Convention's Work Programme for 2018-2022 and follow-up interventions to be developed.

This report highlights the enormous economic potential and development needs of countries around the WIO and, at the same time, points out the growing natural and anthropogenic pressure imposed on the region coastal and marine environment, and the opportunities to avoid them. It is evident from the report that countries and the region as a whole have placed a high priority on the coastal and marine environment. Nationally and regionally, actions are being taken at different levels to sustainably manage the coastal and marine environment, however, more needs to be done. This report highlights the perils of continued delay on addressing some of the major challenges and also how critical it is to balance economic, social and environmental needs, if the countries are to continue to benefit from the diverse and life-sustaining goods and services provided by the coastal and marine environment for many years to come.

Achim Steiner
United Nations Under-Secretary-General (UN)
Executive Director of the United Nations Environment Programme (UNEP)

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It is with profound gratitude that we want to thank UNEP for the guidance, leadership and the support that was extended to the Secretariat for the Nairobi Convention in the preparation of this report. Secondly, we wish to express our sincere thanks to WIOMSA and its membership for the technical support in the production of this report.

We are grateful for the dedication, generous and thoughtful contributions by experts, policy makers and heads of institutions from all the Western Indian Ocean countries. We truly are indebted to you all for accepting our many demands with such grace and professionalism.

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We acknowledge with sincere thanks for the major role played by José Paula as the Editor of the report. He not only supervised the overall technical and style editing of the report but also, he provided professional guidance throughout the process and more importantly at the critical stage of finalization of the report. During the finalization of the report, he was assisted by Maria Luísa Ramalho and Margarida Antunes da Costa (in formal aspects such as checking references, lists of figures, tables and acronyms, glossary and compiling the index). Their contribution is acknowledged.

Support of the Lead authors is also gratefully acknowledged. They provided a link between Contributing Authors and the Editor, by overseeing the work of the Contributing authors in their respective parts. Your dedication and commitment to the process was very critical in ensuring the report is finalized in time and providing the expected quality.

We would like to specifically acknowledge the authors who have worked tirelessly to ensure that the chapters are technically sound and based on up-to-date information. Without your hard work and dedication to the process, this report would not have been completed in time. Special thanks also go to the authors of the text boxes within chapters.

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In such a comprehensive and ambitious initiative as the production of the Regional State of the Coast Report, there is a large number of individuals and institutions who provided support and technical inputs in many different ways. It is not possible to list all of them by names, but their support and inputs are much appreciated.

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Part I
Summary

José Paula

Executive Summary

The Western Indian Ocean (WIO) region spans across a large latitudinal range, from the Somalia region, influenced by the strong monsoon regime of the northern Indian Ocean, to the southern temperate regime of the tip of South Africa, where the Agulhas current diverges from the northward moving Atlantic Benguela current. It 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 surrounding the island states of Madagascar, Seychelles, Comoros, Mauritius and French Territories. Geomorphological and oceanographic features define the character of the WIO. The social tissue of the 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 have generated a high ethnic and cultural diversity. The cultural heritage is thus important and matches the natural richness of the region. Most countries in the WIO have high population growth rates, and coastal development is expected to grow accordingly.

The Regional State of the Coast Report (RSOCR) derives from requirements of the Nairobi Convention and contributes to the United Nations-led production of the World Ocean Assessment (WOA) reports as well as to other global and regional processes, such as the Environment Outlooks coordinated by UNEP. The RSOCR aims to integrate the socio-economic and ecological systems of the WIO region by using a uniform methodology based on the Opportunities Framework and the DPSIR (Drivers, Pressures, Status, Impacts, Responses) approach. The RSOCR's approach has been adapted from the WOA framework, however the content and organization of the concluding chapters are based on the distinct needs of the WIO region. While the political agenda included the Contracting Parties and their National Focal Points to the Nairobi Convention, the 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 RSOCR's 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.

The WIO region is characterised by high biodiversity, both in terms of species and ecosystems, which places it as one of the most rich and interesting ocean regions of the world. The regional countries have in general low income, and as such a large fraction 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 through 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 (developed in Part III of the report) addresses the main ecosystems that constitute the major support for biodiversity and living resources, such as the nearshore

habitats, mangroves, salt marshes and seagrass beds, coral reefs, rocky reefs, sediments and pelagic and deep sea environments. The assessment further includes a summary of threatened marine species, as well as the significant social and economic aspects of biodiversity conservation. Regarding the 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.

Sectorial and specific recommendations have arisen from the RSOCR that target the sustainable use of biodiversity resources and the maintenance of ecosystem quality and associated biodiversity, as derived from the goals of the Convention for the Biological Diversity and its 2020 targets. These relate firstly to the efforts of addressing the engagement of the civil society (such as promoting awareness on the value and vulnerability of the WIO natural marine and coastal capital at varying levels including by resource users and managers, public, politicians and authorities). Secondly, it is recommended that higher levels of funding for marine research are considered, especially targeting knowledge gaps such as the continental shelf and the deep ocean, conservation areas, resilience and habitat restoration and rehabilitation, but also aiming to increase the level of management processes. Another recommendation for the short term is the establishment of comprehensive monitoring schemes for the marine environment, while in the longer term there is a need of a progressively better integration of regional policies and the promotion of cross-sectorial linkages, allowing for more coherent approaches to ecosystem management and transboundary issues.

Over 60 million people inhabit the coastal zone in the WIO region, which has very high rate of population growth and urbanization. Invariably many of the coastal communities rely on the sea for their economic, social and cultural security. Assessment of services from the marine environment, other than provisioning services, is developed in Part IV of the report. The non-provisioning services provided by the WIO may be categorized into regulating, supporting and cultural services. The assessment includes the role of oceans' in the hydrological cycle, sea/air interaction, phytoplankton primary production, ocean-sourced carbonate production and cultural and derived services from the marine environment. The assessment of ecosystems services, other than provisioning services, emphasizes the same global challenges and the increasing pressures of the variety of human activities on the marine and coastal environment.

Ecosystem services should be addressed based on Blue Economy principles, and for this to happen appropriate holistic ecosystem services valuation should be promoted. In the short term, addressing knowledge gaps will have to involve innovative research, targeting trends of ecosystem services, their drivers of change, vulnerability and mitigation actions. A strong recommendation regards knowledge integration, namely the inclusion of traditional management systems together with modern approaches and its recognition in laws and regulations, allowing for a better engagement of communities.

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. The assessment of food security from marine resources is dealt with in Part V of the RSOCR, and its most important contributions are the capture fisheries, the growing emergent mariculture activities and their socio-economic impacts. The rapid population growth and global economic expansion over the past 50 years have exponentially increased the pressure on coastal resources, and overfishing and coastal developments have put pressure on the abundance of stocks and the biological diversity. Compared to fishing, mariculture is recent in the SW Indian Ocean and it appears to have positive future prospects, particularly in Madagascar, Mozambique, Tanzania and Kenya.

Overfishing of marine resources should be addressed by authorities by appropriately quantifying fishers, methods and harvests. Evident knowledge points to the need for research to target distribution patterns, biological characteristics and reference points, stock status and the effects of fishing. Research results should be passed to managers and thus there is a need to strengthen the linkages between science and management. This way managers can provide better plans for fisheries and the main target species, adopt holistic ecosystem approaches, and promote co-management of artisanal fisheries and cooperative management of transboundary stocks. Sound management also requires that monitoring, control and surveillance capacities be increased in most WIO countries. But opportunities for increased food production from marine resources are also

present and should be addressed, such as expansion of fisheries into deeper waters and promotion of mariculture.

Assessment of other human activities in the marine environment is developed in Part VI of the RSOCR. It includes a number of important sectorial issues such as maritime activities, oil, gas and renewable energy, coastal mining and coastline stability, tourism and recreation, urbanization, coastal development and vulnerability, marine genetic resources and bio-prospecting. The adoption of a Blue Economy agenda should drive development of human activities that promote economic development and poverty alleviation, while at the same time ensuring sustainable use of resources and maintenance of environmental quality. Some of the analysed emergent activities can turn into opportunities for human development in the WIO region. Maritime activities and mineral extraction from the coast are increasing in the region, as are emergent and fast growing socioeconomic activities such as oil and gas exploration, tourism and bio-prospecting. While these sectors offer vast opportunities for economic development, their potential impacts can challenge sustainability and should be addressed through sound, integrated management strategies.

The pressures and opportunities created by emergent human activities mean that efforts should be invested in increasing our knowledge about resources, their environment and the social aspects of their exploitation. It is desirable that, in the longer term, equitable access to and benefit sharing of coastal and marine resources be promoted. But in the short term there should be an effort to develop mechanisms and tools for handling and processing data, promotion of the production of spatial data products, as well as integrated coastal management and the necessary legal frameworks.

The scenario approach of the RSOCR adopted the DPSIR framework 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 settings and the economy. 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 and the Sustainable Development Goals (SDGs). The use of the scenario framework must be adaptive and respond to new challenges, opportunities or threats that undoubtedly emerge. The Nairobi Convention through its management and policy platforms can promote the scenario framework for engagement between actors and also 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 aimed at effectively managing the coasts and oceans, promote adaptive management, but also to monitor programmes set for the refining of scenarios in view of observed changes over time.

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 several other institutions, regulatory or policy frameworks with a mandate for governance, including national and regional institutions, regional economic integration organizations, regional and international civil society organizations, and global inter-governmental institutions. Legal and institutional frameworks for addressing the marine and coastal environment include constitutional provisions, framework environmental laws and sector based laws. 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 pressuring on coastal and marine zones have environmental impacts that need to be regulated. WIO countries apply Environmental Impact Assessment regulations and these are naturally merged into evolving Integrated Costal Zone Management laws and policies.

Contrasting policy options are open to the countries of the WIO region concerning the sustainability of the coastal and marine environment, both at the national and regional levels, including: 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. Irrespective of these options, there are scenarios that countries of the WIO region need to consider so as to mainstream coastal and marine issues for the future: policy instruments which largely or primarily provide incentives for voluntary compliance or, alterna-

tively, countries may consider strengthening the command and control approach in their policy formulation.

The overall human capacity for governance of ocean and coasts in the region is still incipient and currently does not cover the necessary array of disciplines, their up to date methodologies and the complex and multidisciplinary issues in the coastal and marine environments. The many socioeconomic and institutional factors that constrain capacity in the WIO region include 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 human capacity development remains a top priority for countries in the WIO.

The Regional State of the Coast Report for the Western 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.

The WIO region is faced with strong challenges regarding the sustainability of its marine and coastal environments, both from global trends that require wider international integration, but also from regional and local sources of disturbance that governance mechanisms need to address. The path towards meeting the natural expectations of the development of the region's societies requires socioeconomic development and the use of the region's rich natural resources. Emergent opportunities are arising and regional capacities growing, both in terms of technology and human capacity, from the civil society to decision making structures. The adoption of a Blue Economy and the will to address socioeconomic development in the region, with emphasis on poverty alleviation, gives a 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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Part II
The Context of the Assessment

José Paula

1 Planet: Oceans and Life

Shigalla Mahongo and Rosemarie Mwaipopo

UNIQUE FEATURES OF THE WESTERN INDIAN OCEAN

The Western Indian Ocean (WIO) is construed as an area with unique and age-old geological processes. The geological features play a crucial role in influencing water flow, driving all marine ecosystems and species, on evolutionary and ecological scales. These features have significant impacts on the meteorology, ocean circulation, flux of heat and nutrients as well as on the patterns of living marine resources. Among the prominent features of the WIO region, the Mozambique Channel and the Mascarene Plateau are globally unique, and constitute biodiversity hotspots.

The seasonal monsoon system dominates the climate of this region, while Madagascar and the Mascarene Plateau interact with the currents imparting meso-scale dynamics that are unique to the ocean. The oceanographic processes have a substantial impact on the ecology of the region, influencing the availability of nutrients and driving the productivity, distribution and abundance of phytoplankton and fisheries. The currents are mainly important on inshore areas, open fringing reefs and inlets, where local currents coupled with freshwater inputs, provide the major source of food and nutrients to adjacent inshore waters.

The geography of the Indian Ocean, compared to other ocean basins, is quite unique. Nowhere on earth is the monsoon as pronounced as over this region, where the seasonal reversal is uniquely strong and sustained. The meteorology of the Western Indian Ocean is strongly influenced by large-scale climatic phenomena, especially the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). Tropical cyclone activity is also an important feature of the meteorology of the WIO region.

THE HUMAN CONTEXT

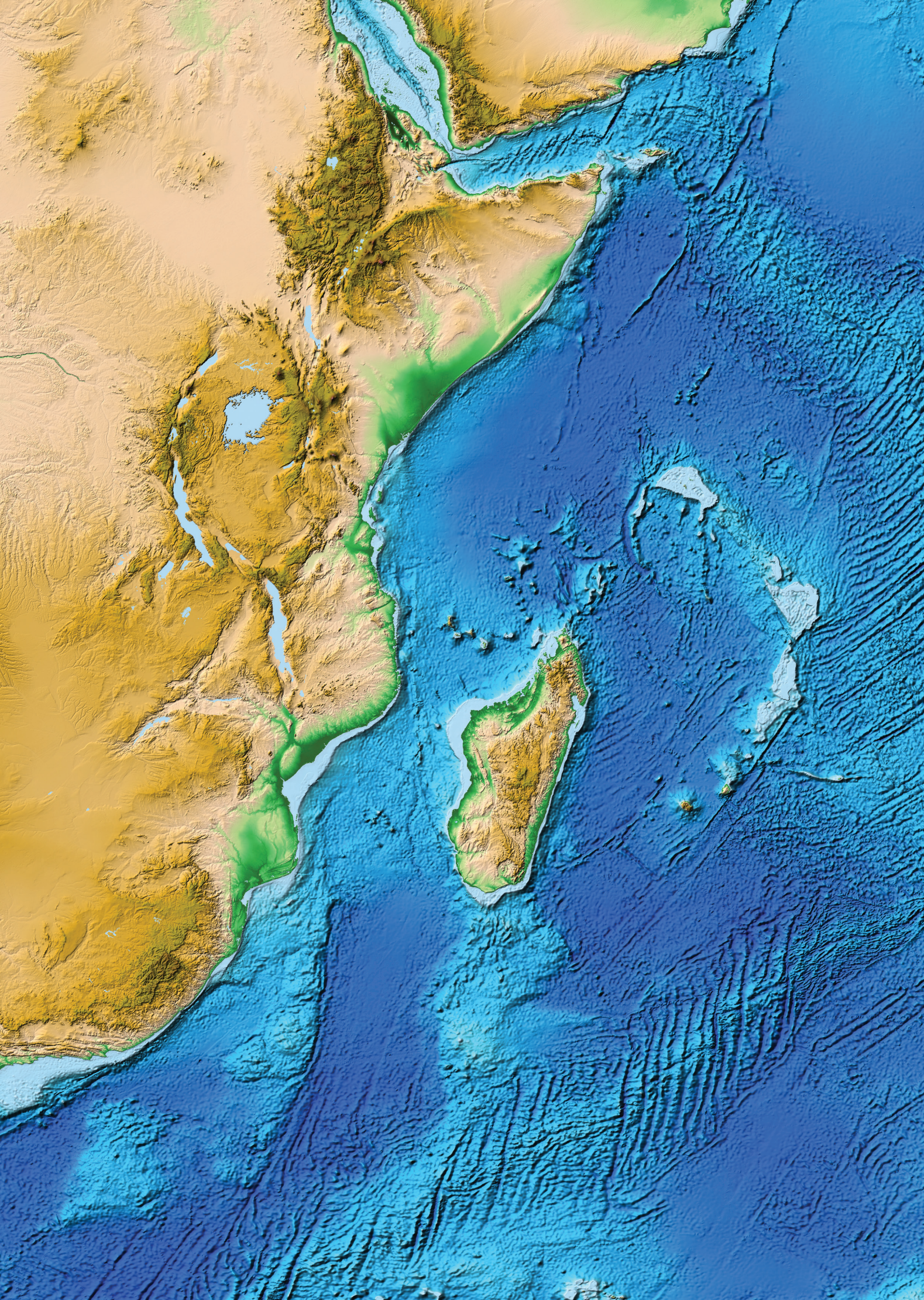
The coastal communities of the WIO region comprise a population with a rich and varied political history, cultural heritage, traditions and other social and economic features that together render the region a fascinating amalgam with a unique context for coastal and marine environmental management. The recent successful exploration of oil and gas, with potential for social and economic growth, illustrate the pressing need for maintaining the delicate balance between environmental management and economic pursuits. Pertinent issues include the region's ability to govern its resource wealth in an inclusive process to allow for poverty reduction and the achievement of the Sustainable Development Goals (SDGs).

Countries in the WIO region are characterized by high population growth rates, largely attributed to natural growth. The concentration of populations within coastal areas has increased due to rural-urban migration, with people attracted to the more urbanized and economic centres of the region. One of the major challenges that remain is the states' generally low participation in global value chains (GVCs); mainly on account of their economic structures and low competitiveness.

The Western Indian Ocean is unique

Livelihoods of coastal people in the region have been evolving and changing in nature due to population changes, cultural transformations, including opportunities for women, policy measures, global economic expansion and institutional linkages (such as to markets), resource conditions and poverty. Artisanal/small-scale fisheries is the main source of livelihood for many coastal communities. Other activities include tourism, agriculture, subsistence forestry, mariculture, small-scale mining (stone and sand quarrying, lime and salt production), petty trading, small livestock husbandry, trade in handicrafts, employment in services industry (including oil and gas production) and those associated with shipping and ports.

Opposite page: The Suomi NPP blue marble planet centered on the Western Indian Ocean. © NASA/NOAA.



2 Mandate and Methodology

Julius Francis

MANDATE

The production and submission of RSOCR to the Eighth Meeting of the Contracting Parties to the Nairobi Convention was in line with the requirements of the Convention, and providing an important link and contribution to the global processes such as the UNEP-led production of the GEO-6 and the United Nations-led production of the World Ocean Assessment reports.

The RSOCR has been based on national state of environment reports where they exist. Further, the regional status report provides a basis for cooperation among environment regulatory frameworks, responsible national institutions and departments to periodically produce a state of coast report at the national level using similar approaches to assess and to manage trans-boundary resources.

METHODOLOGY

The preparation of the RSOCR involved two parallel processes: (1) technical - selecting prominent regional scientists as the contributing authors and for the review process, and (2) political - mobilization of national support at the policy level, and regional scientific community through capacity building workshops.

The Nairobi Convention Secretariat and UNEP's Division of Early Warning and Assessment (DEWA) in collaboration with the Government of Mozambique and the Division for Ocean Affairs and the Law of the Sea of the Office of Legal Affairs of the United Nations (UN/OLA/DOALOS) launched the process in 2012, involving the National Focal Points of the Nairobi Convention and selected scientists from the region. A uniform assessment methodology ie the Opportunities Framework as well as the Drivers – Pressures – State – Impact – Response (DPSIR) methodology was adopted. The framework used in the report also followed the WOA framework (including the content and methodology). The RSOCR was prepared with full participation and support of the policy organs of the Convention. The technical process on the other hand was guided by WIOMSA as the coordinating institution, due its multidisciplinary membership, extensive network of regional scientists and broad experience and good reputation in designing and implementing large regional projects/programs.

The RSOCR reflects the commitment and interests of a wide range of stakeholders as its production of RSOCR has been widely participatory and encompassing, enriched with inputs from different meetings of the organs of the Convention, UNEP and the Convention staff, involved authors and external reviewers.

OBJECTIVES OF THE REPORT

The main objectives of the report are to (1) provide a comprehensive baseline on the status of coastal and marine environment in the WIO region; (2) highlight main opportunities of coastal and marine resources; (3) describe successes and challenges faced in management of coastal and marine resources; (4) identify main capacity building needs; (5) identify main knowledge gaps; (6) propose policy options for effective management of coastal and marine resources.

Engaging stakeholders in preparation for the Report

For the purpose of this report, its geographical coverage refers to the geographical region or area for which the Convention and its protocols apply. The Nairobi Convention Act (Amended 2010) defines the Convention area to "comprise the riparian, marine and coastal environment including the watershed of the Contracting Parties".

The main target audience for the report are policy-makers at national and regional levels, scientific community, civil society and general public. The report is expected to serve as reliable information for policy-making and environmental management, provide materials for educational and research activities, and to provide the basis for identification of new research priorities.

Opposite page: Relief model of the WIO surface that integrates land topography and ocean bathymetry. © Amante and Eakins/ National Geophysical Data Center, NOAA (2009)

Part III
Assessment of Marine Biological Diversity and Habitats

Michael H. Schleyer

3
Introduction – Biodiversity

Michael H. Schleyer

Biodiversity is most simply defined as the variety of plant and animal life in the world or in a particular habitat. Its importance is manifold. The popular concept of its importance is that it enriches our lives, provoking the sentiment that it should be preserved so that our children will also enjoy what we have. However, preservation of our biodiversity will ultimately be for our survival. Human livelihoods are also dependent on what are known as ecosystem services, or the provision of goods and services within an environment. We thus need to sustainably conserve both our environment and resources to survive.

This becomes particularly true in poorer coastal communities. By and large, communities in the tropical and subtropical regions of the western Indian Ocean (WIO) fall into this category, comprising some 156 M people. Population drift to the coast in shore-fringed countries is a global phenomenon and is prevalent in sub-Saharan Africa. Most of this population are dependent on coastal and marine resources and ecosystem services, placing direct or indirect pressures upon them through resource extraction, pollution and human-driven habitat degradation. The effects and consequences of climate change add further pressure to this challenging situation.

The major habitats in the WIO comprise estuarine and coastal systems ranging from mangroves, salt marshes and seagrass beds to beaches, rocky shores and reefs, coral reefs, nearshore sandy substrata, the offshore shelf and deep sea environments. Amongst these, coastal habitats comprise the most productive of ecosystems, and the richest in biodiversity in the world. The biodiversity of all the aforementioned environments is considered in the following chapters, giving consideration to their status and threats. Human implications are dealt with in terms of socio-economic considerations and gaps in our capacity to deal with environmental management issues.

Preservation of biodiversity will ultimately be for our survival

Opposite page: Diversity of sea star colours at Inhaca Island, Mozambique. © José Paula.

4
Beaches and the Nearshore

Joseph Maina

These constitute the land-sea interface and include rocky shores, sandy beaches, muddy shores, estuaries, mangroves, seagrass beds and coral reefs; the first four will be dealt with here and the last three separately. They are dynamic systems subject to surf and tide. They are also economically important and provide cultural, provisioning and recreational benefits to humans.

Nearshore habitats are of ecological and economical importance

Rocky shores undergo the greatest exposure and temperature gradients during low tides but nevertheless support great biodiversity. They are important nursery grounds for fish. Sandy beaches and nearshore sediments are possibly the most dynamic, being subject to sediment movement and erosion. They provide habitat for fauna adapted to their dynamic nature and are particularly important for the breeding of endangered turtles that use them as nesting sites. Estuaries are extremely productive systems subjected to fluctuations in salinity from freshwater inflow and tidal flux to which they are delicately balanced. Globally, they are amongst the most threatened ecosystems and are important nurseries for fish and Crustacea. Muddy shores occur off major river systems and provide habitat for prawns that are targeted in important fisheries.

Fish, prawns, rock lobsters, bivalves, squid, octopus and sea cucumbers are heavily exploited within these habitats and, in many cases, are dangerously depleted. In the case of sea cucumbers, the stocks have become so depleted that protective measures have been introduced in some small island states to prevent their extinction. Conflict is arising between traditional artisanal and commercial fisheries as the catches they target dwindle. Seabirds are represented mainly by widespread species but do include nine breeding endemics of which five are under threat.

Probably the most important threats affecting these habitats arise from human development (urban, agriculture, mining, industry, tourism) associated with population growth within the coastal region, as well as climate change, particularly sea level rise. The benefits of the nursery function, fisheries, biodiversity and tourism value of these habitats are thus being impaired. Even apparently insignificant issues such as light pollution emerge as problems; urban light sources disorient turtle hatchlings when they emerge from their nests! The regulation of human population growth in the coastal zone, greater community education, improved regulation of resource extraction, and greater protection of the coastal environment were thus recommended. More research is needed in the subtidal zone and greater integrated coastal zone management, treating the intertidal zone as a single management entity.

Opposite page: The beach at Ulo village near Mocímboa da Praia, North Mozambique. © José Paula

5
Mangroves, Salt Marshes and Seagrass Beds

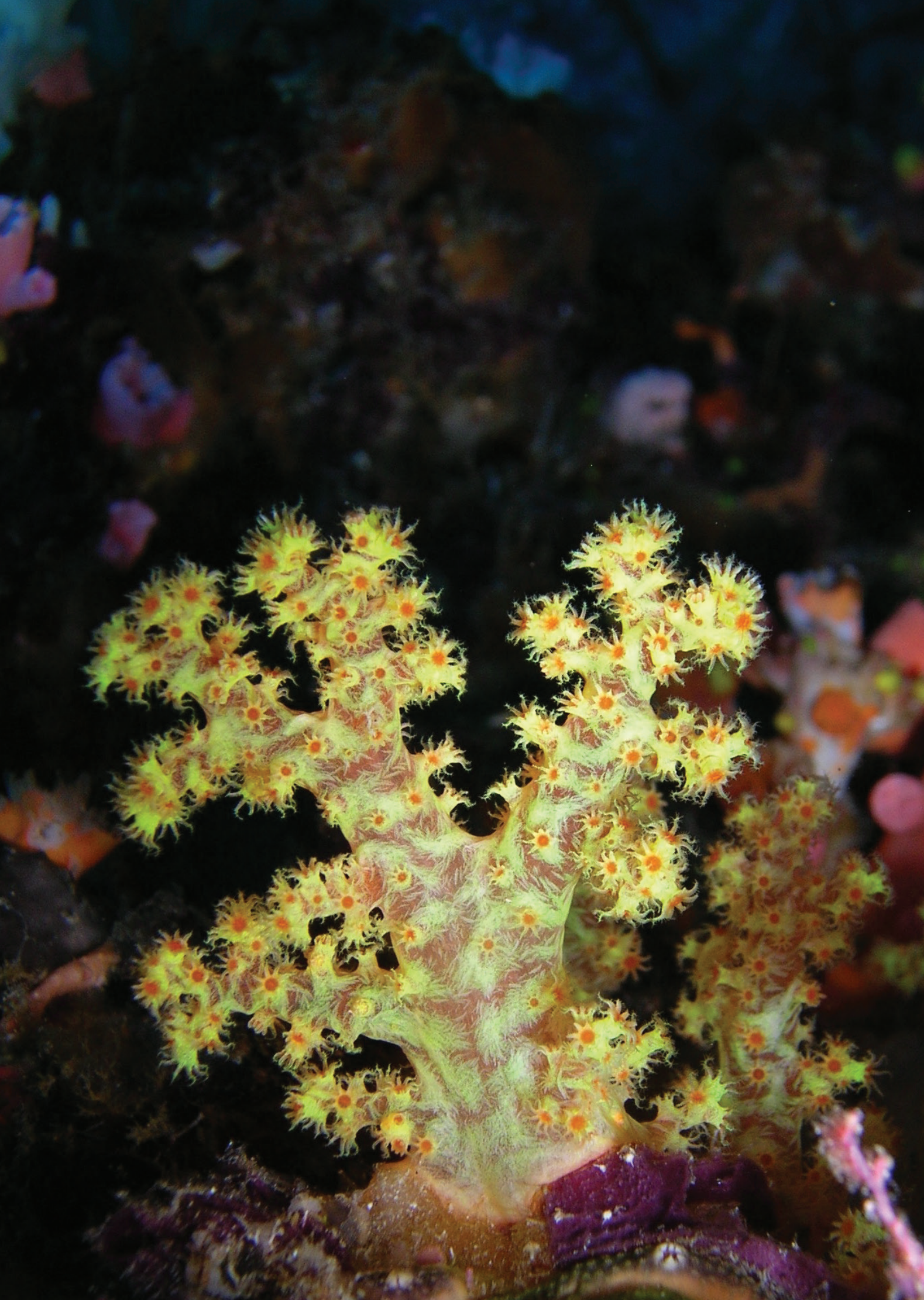
Blandina Lugendo

Mangroves and seagrass beds are widespread in the western Indian Ocean; limited salt marshes only occur in the south. All are highly productive and thus ecologically and socio-economically important but vulnerable to human activities. The area of mangroves in the WIO is extensive, totalling ~1 000 000 Ha, but this is on the decline throughout the region except Mauritius where their loss has been reversed by afforestation. Mangroves (ten species) are exploited for timber, firewood and charcoal, cleared for agriculture, aquaculture, salt extraction and urban development, and affected by pollution, sedimentation and reduced freshwater flow. They play an important but little recognised role in shoreline protection. Seagrasses (12 species) are less well documented despite their beds being often found in association with mangroves and coral reefs, extending to a depth of 40 m depending on water clarity. Together, mangroves and seagrass beds provide valuable habitat and nurseries for harvested fish and Crustacea. Seagrass beds are under threat from sedimentation and human activities such as trampling and trawling. Salt marshes, comprising few species, occur predominantly in South Africa where they are considered important, despite their limited distribution. They are poorly studied elsewhere in the WIO but small patches are believed to occur in association with some mangroves. These ecosystems are all rich in biodiversity and export organic enrichment to the sea.

The threats to these communities are numerous. They range from over-exploitation, siltation and water abstraction to urban and industrial development, fishing, agriculture and aquaculture. This results in the direct loss of these resources as well as their valuable nursery function for harvested marine and estuarine resources. The situation is exacerbated by a lack of adequate knowledge of the benefits of these ecosystems by both lay people and the authorities. Broad recommendations have thus been made for their improved management and conservation, entailing: the development of national management plans; improved mapping, monitoring and research; raised awareness and education of their importance, including the formulation of guidelines for their rehabilitation and restoration; improved law enforcement with implementation of integrated coastal zone management to reduce their disturbance and siltation; and economic studies to elucidate their true socio-economic value.

Mangroves and seagrasses feed and protect us

Opposite page: Swamp mangrove near Quionga, North Mozambique. © José Paula.



6
Coral and Biogenic Reef Habitats

David Obura

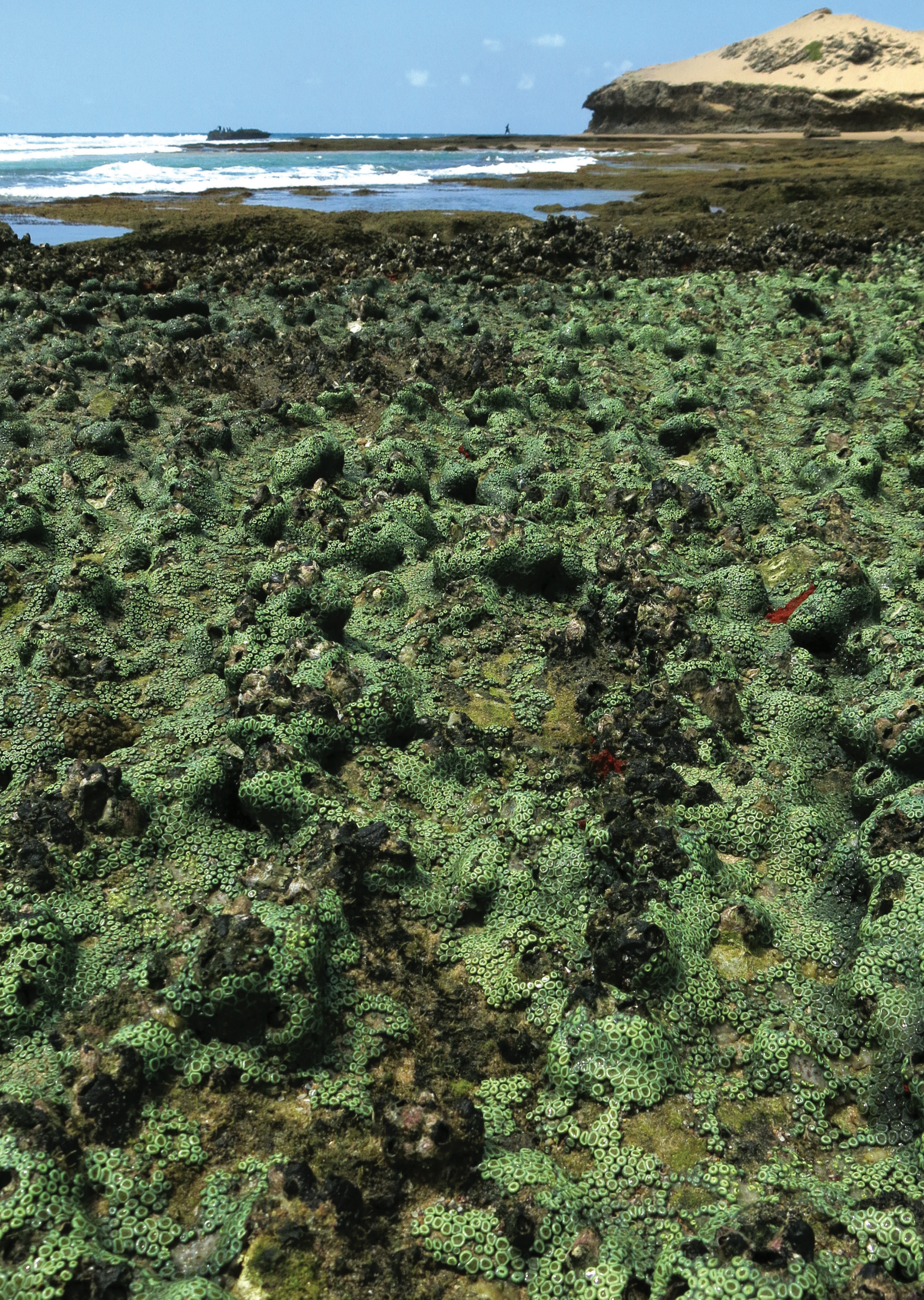
Coral reefs are amongst the best-known marine habitats in the WIO and are found to a depth of 50 m where conditions, primarily clean water, allow their development. They occur in the region as barrier, fringing, bank and patch reefs, as well as atolls. They are amongst the most biodiverse and productive of ecosystems in the world and provide goods and services that range from drug development to fishing and tourism. In terms of biodiversity, too, they provide habitat for organisms ranging from microbes to turtles and whales. Most of these resources, especially the fish stocks, are heavily exploited. Corals are not the only reef-builders in the WIO. There are also biogenic reefs which are also formed by organisms such as bivalves and coralline algae in more temperate waters.

The pressures and threats which coral reefs face are manifold. Climate change probably constitutes the single biggest threat as heating events cause coral bleaching which results in mass mortality. Some reefs in the WIO lost 50-90% of their coral cover during the El Niño event of 1998. Outbreaks of crown-of-thorns starfish which prey on corals also occur periodically and pose an additional threat. Damaging fishing practices, particularly dynamite fishing, destroy corals and often cause irremediable damage on reefs. Overfishing, pollution and sedimentation add further to these problems. In consequence, coral reefs are probably the most threatened marine environment in the WIO.

The benefits of coral reefs in terms of the goods and services that they provide are better recognised, as well as their deteriorating condition, than many other marine environments. In consequence, a number of initiatives have resulted in the protection of representative reef systems in MPAs, ranging in status from marine reserves to World Heritage Sites. Improved regulation of resource extraction, often through co-management, and the seasonal closure of reefs, are being used to improve reef conservation. A regional Coral Reef Task Force has also been formed under the auspices of the Nairobi Convention. Despite these efforts, the prognosis for coral reefs is not good as drivers such as climate change and human pressures on reef resources are not diminishing. Increased commitment to their conservation by the state and non-state bodies is thus recommended to ensure their survival and continued use by coastal communities dependent on their resources.

Coral reefs are probably the most threatened marine environment in the WIO

Opposite page: A soft coral of the genus *Scleronephthya*, found occasionally under ledges and overhangs on reefs in the WIO.



7

Intertidal and Nearshore Rocky Reefs

Daudi J. Msangameno

Intertidal and nearshore rocky reefs offer diverse habitats to organisms able to tolerate the variable environmental extremes they experience during surf and tidal exposure. They support an intricate food web of a wide variety of marine plants and animals, with different forms occurring within distinct tidal zones depending on their degree of exposure and wave action. While many of the predators and grazers are mobile, most of the animals are attached filter feeders such as barnacles and mussels. Rocky shores on the East African coast consist of sandstone, limestone and basalt and are more limited in extent than the intervening stretches of sandy shore. Resources on rocky shores are subject to subsistence, recreational and commercial harvesting of seaweeds, molluscs, sea urchins, Crustacea and fish.

As rocky shores constitute one of the harshest of marine environments, they are resilient to many of the threats with which they are confronted. Nevertheless, they have been subjected to serious trampling and resource overexploitation, in some cases entailing the loss of what are known as habitat-forming organisms, i.e. biota that create habitat for other forms of life. Since they occur on the shoreline, they have also been affected by coastal development, many forms of pollution and invasive alien species. A number of effects of climate change will affect them, particularly for example the increased frequency and intensity of storms and ocean acidification. A lack of knowledge of the rocky shores in most of the region poses a challenge that needs to be addressed. More research is thus recommended, as well as improved education on their importance, legislation for their conservation, their inclusion in MPAs, effective coastal zone management, the identification of biodiversity hotspots and improved monitoring.

Rocky shores are resilient but under great pressure

Opposite page: Zoanthids at the rocky shore of Ponta Mazondúe, Inhaca Island, Mozambique. © José Paula.

8

Shelf Sediments and Biodiversity

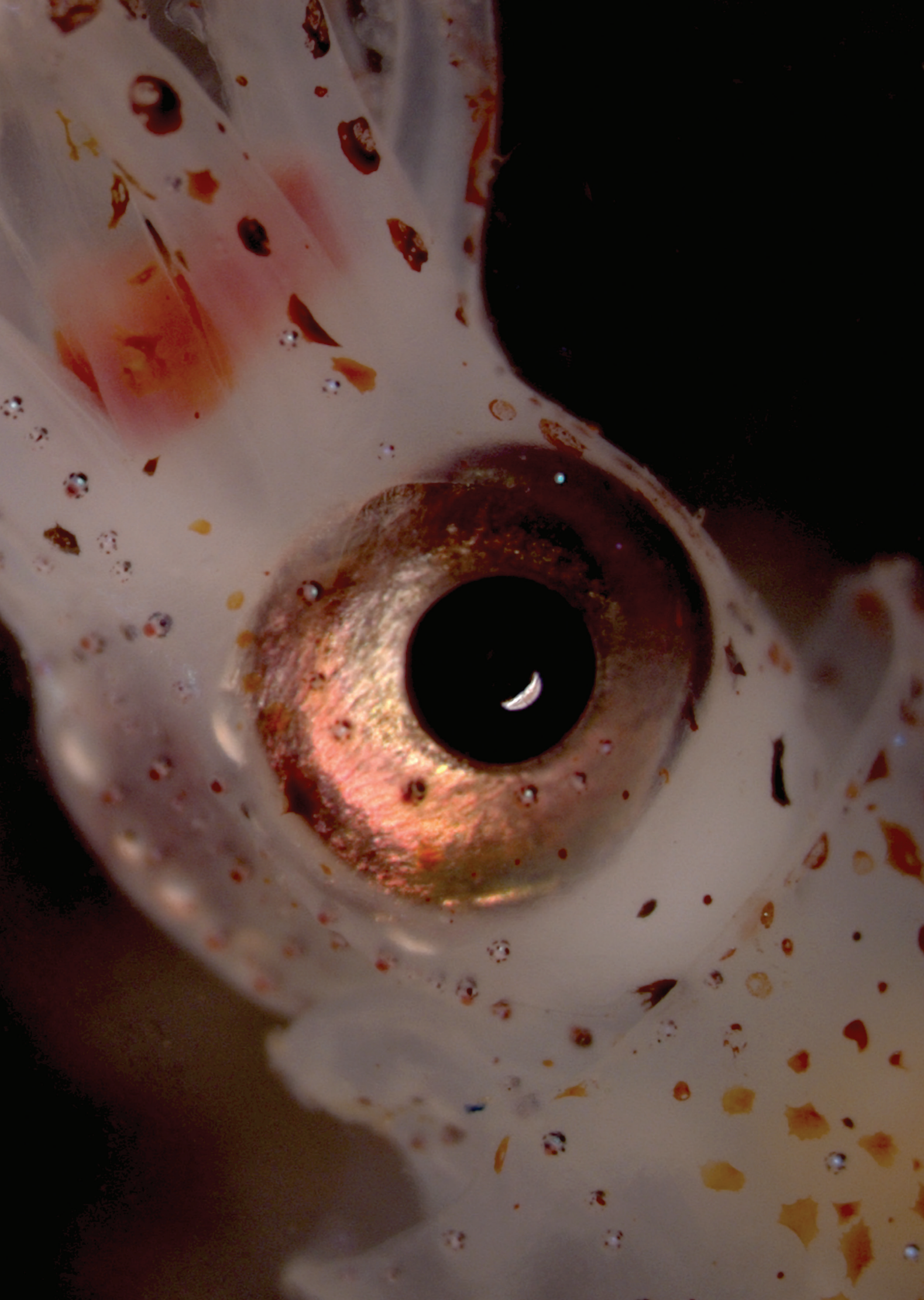
Sean Fennessy and Andrew Green

Continental shelves are submerged margins of continents that are the flattest areas on the earth's surface, acting as halfway houses for sediment moving from the coast to the deep oceans. On average, the shelf break occurs at a depth of 140 m where the continental slope falls steeply to greater depths. The continental shelves in the region are tectonically passive, i.e. they do not constitute earthquake or volcanically active zones. They are also relatively narrow, 15-25 km wide, except where major rivers such as the Zambezi have pushed the shelf break further offshore, in this case to 140 km. Sediments on the continental shelf are mostly unconsolidated and terrestrial in origin, but show evidence of past fluctuations in sea level. Where accretive reefs occur, they add bioclastic sediment to the mix. Fauna of different size live in the interstitial spaces of the sediment, on its surface or just above. These range from microscopic plants and animals to small invertebrates and larger molluscs, echinoderms, crustaceans and fish. The latter two include harvestable stocks of prawns, langoustines, lobsters and demersal fish. The nature of the different communities associated with the sediments differs according to depth, sand grain size and content of silt or mud, the latter being more productive due to detrital input from rivers and estuaries.

This habitat is exposed to threats that are mainly human and terrestrial in origin, comprising pollution from outfalls and riverine input as well as dredge spoil. River impoundment has, in turn, altered the natural nutrient and silt supply to this environment. While most shelf sediments are unsuitable for trawling, harvestable fishing grounds are being altered by this activity. Disturbance from offshore prospecting for minerals and fuel is also a growing concern. It is recommended that the WIO community foster the skills needed to investigate the biological shelf communities for their management, and attempt to obtain benthic and sedimentological information useful for this purpose from the prospecting industry.

Shelf bottoms hold economic potential but are fragile

Opposite page: Sediment banks off Maputo Bay, Mozambique. © José Paula.



9
Deep sea and Offshore/Pelagic Habitats

David Obura

The deep sea habitats of the WIO have been poorly studied because of limited capacity in the region to undertake work of this nature. Continental drift has given rise to an ocean floor which has some of the deepest fracture zones, some of the thickest sedimentary deposits and the most complex ridge configurations separating various ocean basins in the world. The ocean floor is still tectonically active, with a rift spreading downwards in the south-west Indian Ocean and northwards into the Red Sea. Seamounts rise from the mid-ocean ridges and volcanic activity has, in places, given rise to islands such as Mauritius, Reunion and the Comoros; the only volcano still active is at Reunion. The South Equatorial Current flows from east to west between 5-16°S and is obstructed in its crossing of the Indian Ocean, giving rise to the other regional currents, primarily the East Madagascar, Somali, Mozambique and Agulhas Currents. The Mozambique Current consists of a series of eddies rather than a true current. All affect the productivity and biodiversity of the WIO. For example, the Somali Current causes seasonal upwelling during the SE Monsoon but not when its flow reverses during the NE Monsoon. Cyclonic eddies of the Mozambique Current similarly generate upwelling but its anticyclonic eddies generate down-welling; complex combinations of these eddies further affect productivity in the Mozambique Channel.

The different conditions outlined above influence the presence and passage of the creatures that live in the deep sea which, for the most part, have received little study. There is nevertheless some information on the whales, turtles, sharks, fish (such as the valuable tuna stocks) and seabirds that employ this habitat, including the living fossil, the coelacanth. Deep sea cruises of the MESOBIO and ASCLME programmes have started elucidating the complexities of the oceanographic and ecological processes in this habitat but more research is needed.

The deep sea offers opportunities but remains unexplored

Threats which this habitat faces are ignorance of its importance and its governance needs, pollution from terrestrial run-off as well as global shipping, the hazards of deep sea exploration and mining, overfishing of pelagic species, and the effects of climate change, including ocean acidification. The deep sea offers unknown benefits for economic development – the Blue Economy - but funds are needed to investigate these adequately to prevent unwise and unsustainable use of these resources. Recommendations have, in the meantime, been made for the protection of Ecologically and Biologically Sensitive Areas (EBSAs), Vulnerable Marine Ecosystems (VMEs) and Particularly Sensitive Sea Areas (PSSAs) in international fora with the participation of WIO member states.

Opposite page: Larval squid in the plankton of the WIO. © Cedric Guiguand/Emmanuel G. Reynaud.

10 Threatened Marine Species

Matthew D. Richmond

Human activities have extinguished many plants and animals, and are endangering others to such an extent that systems have been developed to categorise these as part of a process to ensure their protection and survival. Of the estimated number of 11 000-20 000 marine species believed to occur in the WIO, 161 are listed as threatened in the IUCN Red List. Of these, 126 are listed as Vulnerable, 27 as Endangered and eight as Critically Endangered. These may seem low numbers but one must remember that the aforementioned estimate of species believed to occur in the WIO includes undiscovered species; these may already be in jeopardy. The bulk of the species under threat comprise corals (vulnerable due to habitat degradation, disease and exploitation), sea cucumbers (overharvested) and marine mammals, particularly the dugong, some species of whale and dolphin (overharvested and endangered by shipping, fishing nets, etc.), or sharks, fish and turtles (many being Endangered or Critically Endangered by fishing). Even a Vulnerable plant is found on the list, the seagrass *Zostera capensis*. The overall trend in most of these species is one of continuing decline but with encouraging signs of a global increase in the population of some threatened whales, and the local increase of some species such as turtles in the Seychelles.

The threats that threatened marine species face are manifold and include habitat degradation from agriculture and coastal development, pollution, accidental capture while harvesting other species, damaging fishing practices and targeted harvesting. The regional capacity to prevent the decline of these species is limited and exacerbated by poverty, ignorance and indifference. It is recommended that a concerted, regional effort be made to stem their decline. This will entail raising awareness regarding their plight and importance, increased funding for marine resource management, targeted monitoring and research, the development of alternative livelihoods and food sources, the development of a WIO Threatened Species Task (like that for corals), and cohesive national and regional strategies.

Threats to marine species are manifold and require monitoring

Opposite page: Sperm whales in the WIO. © Hughes Vitry.


PGBMC
MICOA
PLANTIO DE MANGAL
PROIBIDO PASSAGEM
CUVIALIWA KWA APA
WACATAZA KUPITA.

11

Significant Social and Economic Aspects of Biodiversity Conservation

Rosemarie Mwaipopo

Current coastal and marine resource management practices in the WIO have many economic and social consequences in the environment. Coastal communities in the region are growing demographically and, being impoverished, are heavily dependent on natural resources. The regional marine biodiversity is thus in decline and this is exacerbated by inconsistent government policies, failure to enforce environmental laws, centralisation of decision-making in resource management, and misguided political interventions. Ecosystem-based management approaches that include community participation are broadly needed to resolve the problem. Trade-offs between the conservation needs of resources and the economic benefits derived from their use are essential. Regulation of the rights to marine commons by traditional customary laws can be useful to accomplish this but can be controversial.

Biodiversity has social and economic dimensions

The valuation of ecosystem services is not simple as ecosystem processes are complex and not fully understood. The Total Economic Value (TEV) method can be used to assess, for example, the cost of the destructive effects of mangrove clearance or dynamite fishing on coral reefs. Ecotourism is often seen as an alternative to consumptive resource use to implement conservation measures but the benefits of this must be demonstrated. Willingness-to-pay (WTP) provides a means of determining whether this will be effective in terms of what is known as the consumer surplus above the current market price. Examples of ecotourism ventures in which community participation is drawing such benefits are the mangrove boardwalk tours in Kenya (operated mainly by women) and dolphin observation tours in Zanzibar. Species-specific conservation can be accomplished by replacing dependence on the unsustainable extraction of a resource with alternative livelihoods; the trade in hawksbill turtle shell was dealt with in this manner in the Seychelles, leading to an increase in the hawksbill turtle population and associated tourism.

It is thus recommended that the social and ecological dimensions of resource conservation and management be incorporated within a decentralised process that includes community participation to ensure benefit-sharing and a sense of ownership (which encourages compliance). Marine protected areas (MPAs) or no-take zones (NTZs) are useful tools in such conservation measures, particularly if implemented as Community Conservation Areas (CCAs) or Local Marine Management Areas (LMMAs). More research is needed with regional dissemination of good practices and innovative methods, and upscaling of the results into policy. Ways must also be found to incorporate ecosystem services that lack ready economic value, such as cultural values, into conservation measures.

Opposite page: Community-based mangrove plantation with children as "no trespassing" guards, Ulo village in north Mozambique. © José Paula.

12
Summary on Marine Biological Diversity

Michael H. Schleyer

The scope of the Assessment of Marine Biological Diversity and Habitats was wide and the various chapters dealt with the multiple ecosystems found in the region, as well as the full diversity of biota they support. Some of the latter are found in a number of environments at different stages of their life cycle and thus warranted inclusion in a number of chapters; the best example is that of turtles which nest on beaches, feed on reefs, seagrass beds or in pelagic waters, and traverse the open ocean in their movements. For completion, the assessment also included a chapter on human dependence on the region's biodiversity.

Biodiversity loss is economic loss

The region is endowed with ecosystems known for their rich biodiversity. While coral reefs are considered amongst the most biodiverse of habitats, tropical and subtropical estuaries, mangroves, seagrass beds and nearshore environments are also well-endowed with prolific lifeforms. There is also considerable interdependence between these ecosystems as they mutually provide shared biota with feeding, breeding and nursery grounds. This interdependence must be born in mind: a threat to one will have a cascade effect on the others.

In conclusion, the region has a diversity of marine resources but much of this natural capital is either threatened or declining. A simple summary of the combined recommendations for regional needs that could mitigate or reverse the current negative trends follows:

- Raised awareness and communication on all fronts.
- Increased funding for research.
- Increased employment opportunities in marine conservation and management.
- Increased funding for marine resource management.
- A WIO Threatened Species Task Force.
- National and regional integration and cross-sectorial cooperation.
- Viable alternative livelihoods.
- Alternative food sources/equivalents.
- Value-adding to improve the benefits derived from existing harvests.
- Monitoring the harvest of, and targeted research on, vulnerable species.
- MPAs and closures with the prioritisation of areas for protection.
- Identification of areas of resilience.
- Restoration and rehabilitation of degraded areas.
- Sustainability in the harvesting of renewable coastal and marine resources.
- Compliance with CBD biodiversity protection targets by 2020.
- Increased investigation of shelf sediments and deep sea phenomena, an imperative to meet WIO expectations of a Blue Economy.

Opposite page: Marine biodiversity in the WIO is found within varied habitats such as coastal dunes, beaches and nearshore rocky reefs.

Part IV
Assessment of Major Ecosystem Services from the Marine Environment

Jared Bosire

13
Scientific Understanding of Ecosystem Services

Jared Bosire

There are cosystem services that are less tangible including critical buffering, regulating and life-supporting services or processes, recreational, aesthetic, cultural and spiritual values that are important in fulfilling people's emotional and psychological needs which are commonly neglected or taken for granted by society.

Healthy ecosystems supply a range of services useful for well-being of millions of inhabitants in the WIO region and include: security (which deals with personal safety and security from disasters eg coastal protection), materials for a decent life (livelihoods and shelter), health (eg feeling of well-being and access to clean water) and good social relations (social cohesion, respect and ability to help others).

Healthy ecosystems provide services for well-being and poverty alleviation

However, coastal and marine ecosystems in the WIO are threatened by various direct and indirect pressures, which eventually compromise their ability to provide inherent services. Generally, the poor have had minimal impacts overall on changes in ecosystem services and have also received a disproportionately small share of the benefits of ecosystem services in coastal and marine systems. However, in particular locations, the unsustainable use of these services by poor stakeholders with limited options is a major driver of degradation of ecosystem services. The way that coastal ecosystem services are distributed and degraded is currently making the poor poorer, more vulnerable and more marginalized thus undermining their ability and incentive to contribute to preserving the ecosystems services that sustain them.

Many of the drivers of change within marine and coastal social-ecological systems lie outside the strict boundaries of the coastal zone and seascape. They concern global economic processes, markets and trade; economic policy and environmental governance; and land use and resource management in terrestrial systems. It is therefore critical to understand the interactions between drivers and impacts of change across coastal, marine terrestrial and global systems in order to better devise and implement integrated policy and responses to support ecosystem services and poverty alleviation.

More investments are thus required for research into climate change mitigation and adaptation and enhanced management of the region's coastal and marine ecosystems for improved ecosystem integrity and continued provision of requisite ecosystem services. Ecosystem restoration has proven critical in returning ecosystem goods and services, when there is positive recovery, especially for mangrove ecosystems.

Cultural ecosystem services are often neglected when conducting ecosystem assessments. Interdisciplinary approaches are therefore needed to improve the understanding of cultural ecosystem services that takes into account the dynamic nature of human–environment interactions and possible synergies and trade-offs between cultural, supporting, provisioning and regulating ecosystem services.

Opposite page: Mangrove clearing for port construction at Lamu, Kenya. © Mike Olendo.

14
The Oceans' Role in the Hydrological Cycle

Issufo Halo

More than 70 per cent of the earth's surface is covered by the ocean. Because of the water's high heat capacity, the oceans absorb and retain a greater amount of solar energy, far more than the land and atmosphere. Almost half of the absorbed solar energy at the sea surface is released back to the atmosphere in form of outgoing longwave radiation (OLR) and latent heat flux. The latter produces atmospheric water vapour. Water vapour plays a key role in the Earth's energy balance and drives important processes within the hydrological cycle, upon which human existence and permanence on Earth's surface depend

Warming of the WIO is the fastest of any tropical ocean

Freshwater systems interact with the seawater in diverse and complex ways, causing both short and long-term impacts on the compartments of the Earth's environment, with significant social, economic and ecological implications. For example, large amounts of inland sediments transported by the rivers, when deposited in the coastal ocean systems can lead to high levels of ocean turbidity that can reduce penetration of solar radiation in the water column. Deficiency of solar radiation can negatively affect photosynthetic processes, thus reducing primary production.

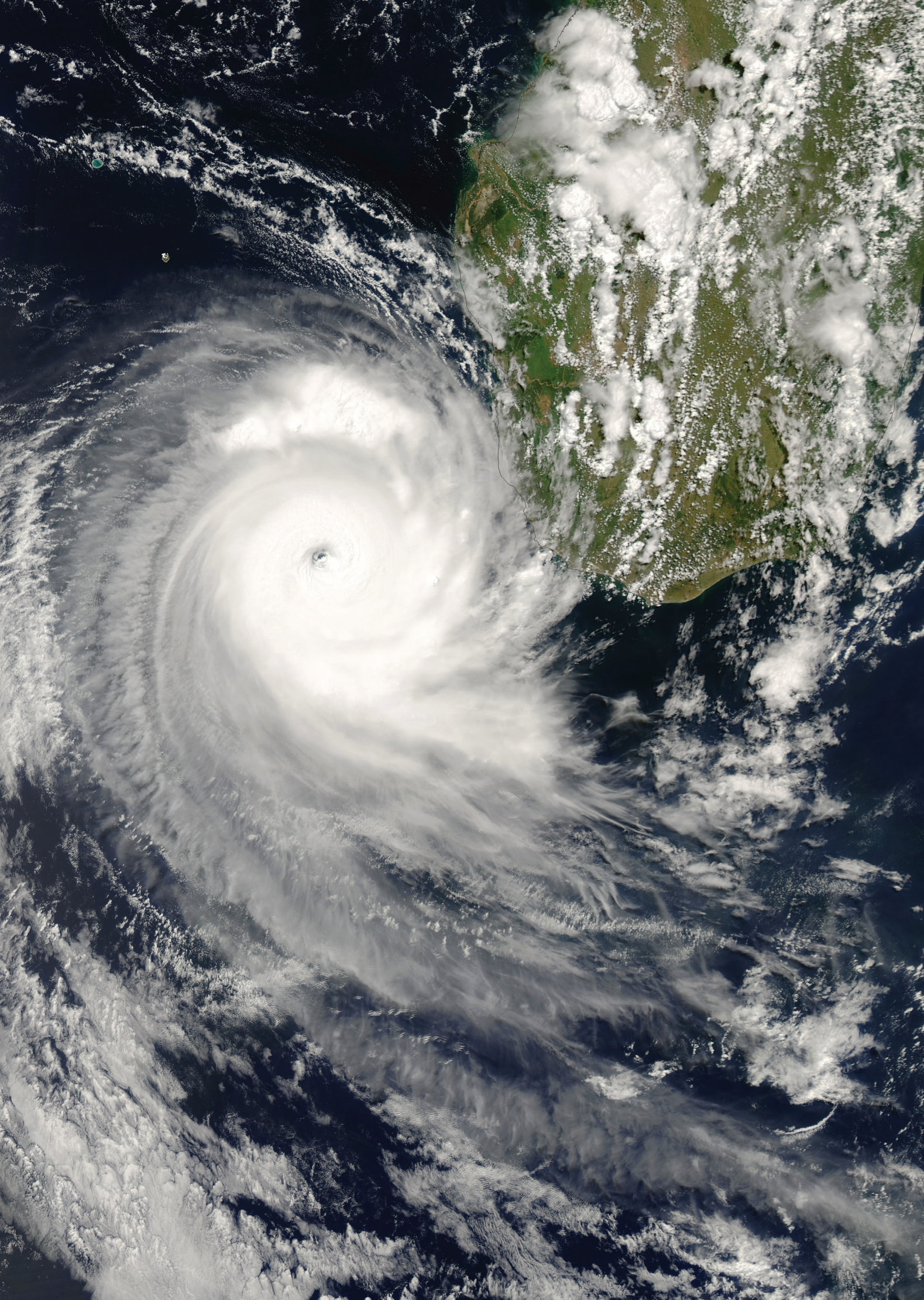
River flows and freshwater discharge into the Indian Ocean are critical in influencing productivity of ecosystems and fisheries. Studies on the effect of climate change on water resources indicate that in tropical regions rivers runoff regime and water resources depend entirely on changes in annual precipitation and its distribution during a year. Global warming is expected to result in more changes in extreme minimum and maximum discharges of rivers.

The El Nino Southern Oscillation ENSO, which is a warming of the tropical Pacific occurs roughly every three to seven years and lasts for 12–18 months. It is the dominant mode of natural climate variability. The ENSO causes significant climatic disturbances in most parts of Africa, either inducing drought or flooding, or increasing sea temperatures leading to cyclones. The 1997-1998 ENSO devastated both northeastern and western Indian Ocean countries, with unusual torrential convective rains that flooded Somalia, Ethiopia, Kenya, Sudan and Uganda, and severe droughts in Papua New Guinea and Indonesia. These had severe social consequences: extensive crop failures and livestock losses, food and drinking water shortage. Over a thousand people died and hundreds of thousands misplaced.

Increased warm sea surface temperature (SST) leads to increased cyclone activity, which often causes destruction of infrastructure, particularly in low-lying areas and where settlements have encroached into flood-prone areas. This natural phenomenon also has strong social impacts. For example, cyclones Eline (mid-February) and Gloria (early-March) in the year 2000 in Madagascar left 184 000 people in need of immediate relief support of the total 737 000 affected. According to official retrospectives relating to the year 2000 floods in Mozambique, the costs were estimated at US$ 273 million in physical damage, US$ 247 million in lost production, US$ 48 million in lost exports and US$ 31 million in increased imports.

Many coastal states in the region are considered as being highly vulnerable to sea level rise with countries further south being relatively more vulnerable indicators of climate change, such as unprecedented ocean warming, sea-level rise, and changes on freshwater fluxes into the sea will occur more frequently in the future. Many sectors will be threatened by rising sea level including: infrastructure, tourism, aquaculture and agriculture. For instance, in Tanzania, looking at the economic implications of such rising sea-level, the projected damage estimated in Tanzanian currency shillings was about 50 billion for a 0.5 meters rise and 86 billion for 1 meter rise.

Opposite page: Splashing waves at Inhaca Island, Mozambique. © José Paula.



15
Sea/Air Interaction

Shigalla Mahongo

The biogeochemical interaction between the sea and the air that involve gas and chemical exchanges are important to life processes. This interaction is sustained by the mixing of the surface by wind and waves to keep a balance between the ocean and the atmosphere.

About half the world's oxygen is produced by phytoplankton in the sea, which are at the base of the marine food web. The phytoplankton, through the photosynthesis process, also extract carbon dioxide (CO2), a greenhouse gas that contributes significantly tocurrent global warming. The oceans therefore act as major sinks for atmospheric CO2.

Whereas photosynthesis is one of the major biogeochemical processes, which take the CO2 from the atmosphere to the ocean, there are other biogeochemical processes, which eventually lead to the removal of CO2 from the sea. The dissolved CO2 may either react with the seawater to form carbonic acid or with carbonates already in the water to form bicarbonates. Either of the two processes removes dissolved CO2 from the seawater. Many marine plants and animals use the bicarbonate to form calcium carbonate skeletons (or shells). If the sea/air interaction processes remained unchanged, there would be a permanent balance between the concentrations of CO2 in the atmosphere and the ocean. However, the levels of CO2 in the atmosphere have been rising, so more of the gas is dissolving in the ocean.

Increasing CO2 levels in seawater leads to acidification, which causes many calcifying species to exhibit reduced calcification and growth rates, and an increase in carbon fixation rates in some photosynthetic organisms. Acidification is also known to increase erosion of coral reefs, thus threatening coral reef fisheries and tourism. Taking climate change considerations into development programmes and adopting a development paradigm, which minimises GHG emissions will be critical.

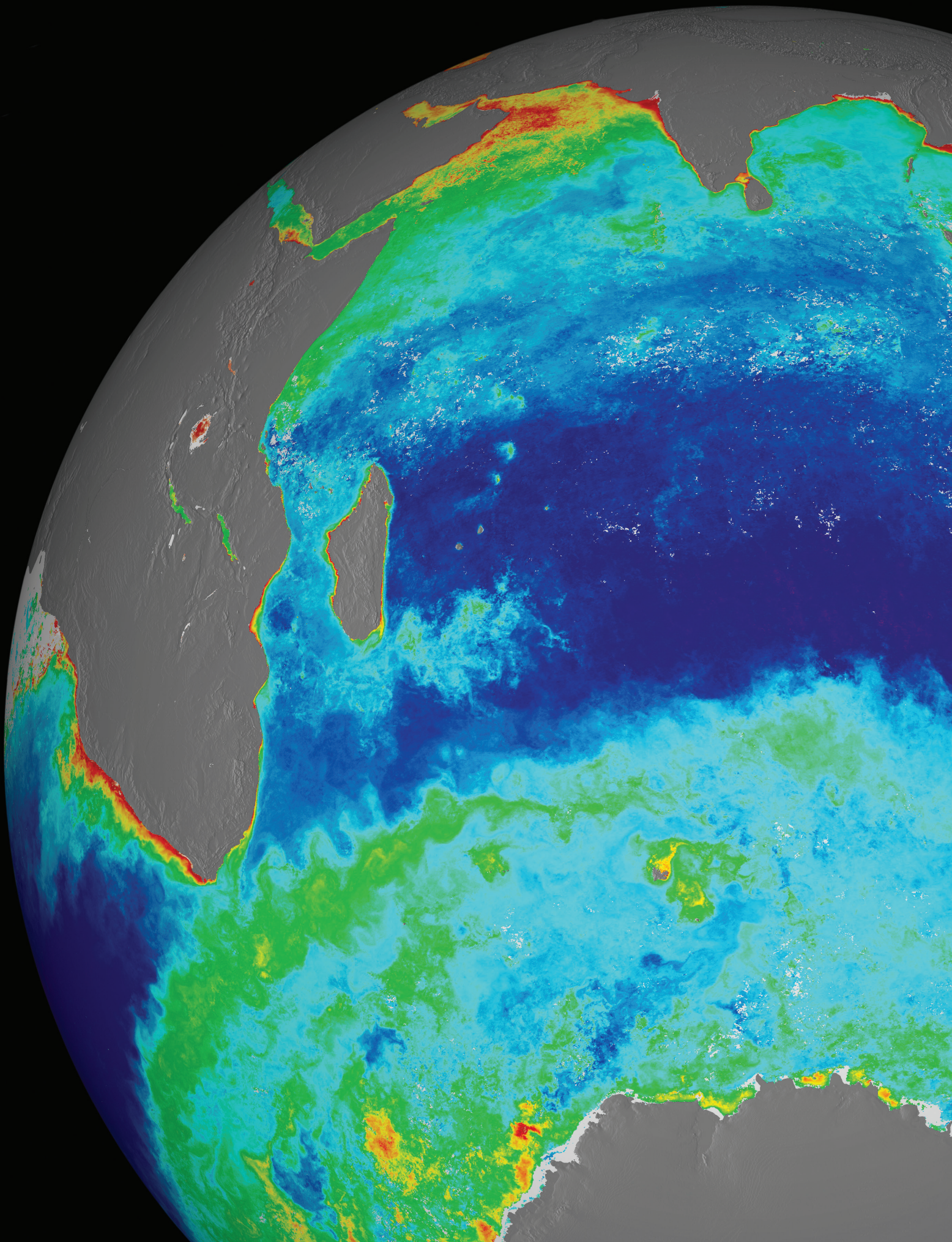
The turbulent fluxes of heat, water and momentum through the sea surface constitute the principal coupling between the ocean and the atmosphere. The fluxes play an important role in driving both the ocean and atmospheric circulations, thereby redressing the heat imbalance. The air–sea fluxes also influence temperature and humidity in the atmosphere and, hence, the hydrological cycle. Consequently, the exchange and transporting processes of these fluxes are essential components of global climate.

Better monitoring and forecast tools should be a priority

The ocean's large mass and high heat capacity allow it to store huge amounts of energy. However, due to increasing concentrations of greenhouse gases, heat radiated from the earth's surface does not escape freely into space. Most of the excess heat is therefore stored in the upper ocean, leading to the rising of the upper ocean heat content.

The WIO region's meteorology is dominated by the seasonal reversal of the monsoon wind systems, leading to the largest annual variations in SSTs found in any of the tropical oceans. On the inter-annual timescale, the SST in the WIO region is primarily influenced by the El Nino Southern Oscillation and the Indian Ocean Dipole (IOD).

Opposite page: Cyclone Favio entering the Mozambique Channel on 20 February 2007. © Nasa/Jeff Schmaltz/Goddard Space Flight Center.



16
Phytoplankton Primary Production

Margareth Kyewalyanga

The main primary producers in the ocean are phytoplankton, which include: cyanobacteria, diatoms, dinoflagellates, green algae and coccolithophores. In addition to phytoplankton, other primary producers contribute to ocean primary production, especially in the coastal areas. These include mangroves, seagrasses, macroalgae and salt marshes. Furthermore, symbiotic algae, some epiphytes and benthic microalgae are also producers. However, phytoplankton contributes to more than 90 per cent of total marine primary production. Through sinking of the fixed organic matter, primary production acts as a biological pump that removes carbon from the surface ocean, thereby playing a global role in climate change.

Primary production drives marine fisheries

Marine primary production plays an important role in food web dynamics, regulation of biogeochemical cycles and drives marine fisheries. Primary producers are linked to fisheries because they are at the base of the marine food webs. Furthermore, some fishes like parrot fish are herbivorous, thus feeding directly on marine plants (seagrasses, seaweeds). This implies that a change in the trend of primary production will also affect fish spawning, growth and/or reproduction.

Primary production, phytoplankton distribution and abundance are influenced by several factors, thus they vary both seasonally and spatially. Primarily, phytoplankton depends on carbon dioxide, sunlight and nutrients for growth, but some other factors such as water depth, water temperature, wind and grazers also play a significant role.

Climate change is associated with increased irradiance, causing warming, which raises sea-surface temperature. Increased temperature causes stable water-column, resulting in stratification that might limit nutrient injection into the euphotic zone, needed for primary production. Besides climate change, anthropogenic activities such as increased coastal development to accommodate increased tourism as well as destruction of habitats and damming of the rivers, increases sedimentation in coastal waters thereby reducing light availability for photosynthesis to both phytoplankton and macro-algae.

When establishments discharge untreated wastewater into the ocean, ideal conditions for the development of harmful algal blooms (HABs) that affect the environment as well as the surrounding communities may be created. This phenomenon also called eutrophication has potential to compromise food safety as well as public health of coastal communities.

To combat the effect of eutrophication, that causes HABs and other nuisance blooms, the countries of the WIO region are trying to reduce the input of waste waters into the ocean and by also treating the water to reduce contaminants and nutrients before release into the environment. Investment in waste water treatment by regional governments will therefore be critical to enhance the integrity of coastal waters for biodiversity conservation, fisheries production and public health.

In other areas, nutrient input originates from mariculture activities. Effluents from mariculture farms may contribute significant nutrient loading into coastal waters, which may result in unwanted nuisance or harmful blooms. What is needed is sustainable aquaculture in which the effluent water is treated before being released into the ocean. Alternatively, mariculture systems considering integration of finfish, shellfish and seaweed is recommended.

Opposite page: Chlorophyll concentration in the WIO during the austral summer (Dec 2011-Mar 2012). © Nasa/Suomi NPP/Norman Kuring

17

Ocean-sourced Carbonate Production

Jacqueline Uku

Most of the calcium carbonate production in the sea is attributed to corals, calcifying algae, foraminifera, echinoderms, molluscs and bryozoans and in these organisms the calcification process involves the formation of calcium carbonate deposits in shells and other skeletal parts. In the open ocean, the carbonate producers are microscopic foraminifera (microscopic animals) and coccolithophores (microscopic algae), which are carried around in the oceanic systems and once they die their calcareous skeletons sink to the bottom of the ocean and form part of the oceanic bed.

Carbonate production organisms contribute to beach formation

Benthic and planktonic foraminifera currently produce approximately 1.4 billion tonnes of calcium carbonate per year, which ends up buried in oceanic sediments, representing approximately 25 per cent of the global ocean carbonate production. Foraminifera have also been shown to contribute to the cementation and stability of coral reefs. In addition to the foraminifera, coccolithophores are widely distributed in the world's oceans and play a major role in the oceanic carbon cycles.

Among coastal systems, coral reefs form one of the most diverse environments of the ocean and are estimate to host one third of all marine species and they are the most visible carbonate producers. They are found in over 110 countries and contribute 900 million tonnes of global carbonate production annually. Coral reefs in the WIO region shield the coastline from wave action and erosion and the effects of sea level rise, thus protecting lagoons and mangroves and helping to maintain habitats for a variety of commercial and non-commercial species.

The calcification process is important in the building of coral reefs and for the supply of carbonate sands to coastal lagoons. Calcium carbonate from corals and calcifying algae is the greatest source of sediment in the oceans and the contribution of carbonates to the sedimentary composition of the marine environment in the WIO region is significant. Calcium carbonate deposits function as deterrents to predators and therefore protect the soft tissues of the organism from predation. Other benefits include structural support, increased surface area and the elevation of calcifying organisms above the sediment level to enable them to maintain proximity to high light levels and to keep up with the rise in sea levels as is the case with corals.

In the WIO region, the sediment found on beaches is comprised of carbonates from various sources including coral fragments, calcareous green algae, shells of molluscs and spines of sea urchins (echinoderms). The reef environments of the WIO region provide habitats for many tropical fish species that are important for commercial and artisanal fisheries. They also provide materials such as shells for sale and coral rock used in the construction industry. As a result, many coral reefs around the WIO region are under threat from over-utilization as well as from visible anthropogenic influences such as pollution, sedimentation, nitrification and the damaging effects of fishing.

Opposite page: Biogenic rocks and sediments at Ibo Island, Mozambique. © José Paula.

18

Aesthetic, Cultural and Spiritual Services from Coastal and Marine Environments

Rosemarie Mwaipopo and Mwanahija Shalli

The interaction between human culture and the coastal and marine environment in the West Indian Ocean region has over time produced unique cultural products, practices and cultural influences.

Several historical and archaeological sites, some attached to the region's rich maritime history, slave trade and evolution of cultures over the years provide to people a range of heritage values, cultural identities and certain forms of spiritual services. Some of these landscapes also attract significant tourism due to their aesthetic and historical value.

Natural landscapes of cultural significance include the sacred Kaya forests situated along the coastal plains and hills of Kenya. They have rich botanical properties and certain sacred sites in the area are still maintained through a pattern of ritual practices in honour of the ancestors of the original inhabitants, overseen by community groups and elders.

Equally important are traditional knowledge systems and institutions, some of which are given anecdotal or mythical reference, yet which illustrate existence of customary systems of resource management and local people's understanding as well as appreciation of ecosystem functioning.

Traditional knowledge should be incorporated into management systems

Customary marine resource use systems make an important part of coastal people's cultural heritage. These practices have been known to regulate resource use patterns, or to restrict certain forms of behavior around ecosystems that are known to be detrimental to the system. Traditional patterns of closed seasons for the octopus fishery in response to resource cycles (or in response to perceived or proven resource abuse) have been known to be practiced in Nosy Fay in Madagascar, and in Kizimkazi in Menai Bay, Zanzibar. In the northern coast of KwaZulu Natal Province in South Africa, among the Kosi Bay fishing community, a number of shared norms and rules relating to access, ownership and use of the *utshwayelo*, a decision-making, dispute resolution and monitoring system still exists.

Many products from coastal and marine ecosystems have been appropriated for direct use by coastal people for household consumption, health care, ornaments and income. During the Indian Ocean trade, cowrie shells are said to have fulfilled a function similar to copper coins as token currency, although their monetary value was recognised.

The current state of most of the cultural heritage in the WIO region is however in disrepair. The dynamics of society and the evolution of cultures has changed people's value systems and hence their uses of the environment. Many of the traditionally revered landscapes and seascapes, or customary practices have deteriorated and eroded in their cultural value. Lack of skills to maintain intangible heritage and erosion of collective memory and oral histories to uphold the worth of cultural assets through time is a major challenge.

Additionally, the competition between traditional and modern (commercial) resource extraction, overriding economic investments such as tourism, and other forms of recreation have negatively affected ecosystems and their productivity. At the same time, extreme weather events such as flooding and drought together with their associated impacts on marine ecosystems, for example, through sedimentation and acidification also destroy production capacities of natural habitats that people have been using/protecting/depending on for a livelihood thereby diminishing their immediate cultural relevance.

Appropriate assessment of the value and contribution of cultural heritage to the conservation of coastal and marine resources in the WIO region is necessary. Documentation and incorporation of traditional knowledge systems into modern management systems will be most critical.

Opposite page: Fort Jesus on Mombasa Island, built in the XVI century, a UNESCO World Heritage Site. © Alex Wafula.

19
Summary on Major Ecosystem Services

Jared Bosire

Ecosystem services are commonly forgotten or taken for granted and provide less tangible benefits such as recreational, aesthetic, cultural and spiritual values that are important in fulfilling people's emotional and psychological needs.

The ocean's role in the hydrological cycle is critical in sustaining life on earth, because it influences the process of water circulation and exchange. Global warming disturbs the balance, by melting polar ice caps and glaciers, and releasing water into the oceans, causing a rise in sea level and other impacts. Hence, future inundation of low-lying coastal areas is expected, with implications for infrastructure (e.g., coastal developments or cities), agriculture, trade and tourism. It is forecast that the greatest impact will be on the economies and livelihoods of the developing world, such as the SW Indian Ocean.

Sea/air exchange affects biogeochemical processes, weather and climate. If the sea/air interaction processes remained unchanged, a dynamic balance between the concentrations of CO2 in the atmosphere and in the ocean would be maintained. However, rising atmospheric concentrations of CO2 increases its level in sea water, thus leading to ocean acidification, with major negative implications for calcifying organisms, marine ecosystem functioning and ultimately food security.

Phytoplankton primary production forms the basis of oceanic food webs, on which marine ecosystems and fisheries production rely on. Principal drivers of primary productivity in the Indian Ocean are monsoon seasons, ocean circulation, upwelling and eddies, irradiance and water temperature. Reduced primary production in the region would cascade through the trophic levels thus producing less fish for capture. Conversely, Elevated primary production may cause harmful algal blooms (HABs), with implications for food safety, human health, and income-generating activities.

Production of ocean-based carbonates drives the calcification process that builds coral reefs and supplies carbonate sands to coastal lagoons and beaches. Major anthropogenically induced threats to carbonate producers are acidification and coral bleaching, eutrophication and poor land-uses, which enhance bioerosion and disease prevalence.

Important aesthetic, cultural, and spiritual services are also derived from Western Indian Ocean coastal and marine environments. Some sites attract significant tourism because of these values, for instance iSimangaliso wetland park (South Africa) and Lamu Old Town (Kenya). In some cases, historical sites and landscapes have suffered from poor management, or physical intrusion. Equally important are traditional knowledge systems and institutions, such as *Kayas* in Kenya and *Dina* in Madagascar. Such systems illustrate the existence of customary resource management methods, or a traditional understanding and appreciation of ecosystem functioning.

Some of the key recommendations on the effective management of marine and coastal ecosystems for the sustenance of inherent services include: holistic ecosystem services valuation to inform policy/development decisions; a blue economy approach, which integrates planning tools (e.g. SEA), marine and spatial planning, and Integrated Ocean Management (IOM to safeguard ecosystem services; traditional knowledge integration (through which local communities have sustainably managed their natural resources for millennia) with modern management; Investment in research to address gaps e.g. valuation of ecosystem services; productivity trends; status of traditional management systems; and climate change vulnerability and mitigation; and sustained environmental awareness.

Safeguarding marine ecosystem services needs integration in the blue economy

Opposite page: Waterfront of Lamu old town, Kenya. © Kiunga Kareko.

Part V
Assessment of Food Security from Marine Resources

Johan Groeneveld

20

The Western Indian Ocean as a Source of Food

Johan Groeneveld

The Southwest (SW) Indian Ocean between Kenya and eastern South Africa and around Madagascar and other small islands has a subtropical / tropical climate, with warm water characterised by high biodiversity, hotspots with high endemism, fishes with unique behaviour, special design or physiology. Coastal inhabitants rely heavily on fishing as a source of food and economic activity, and over many centuries fishing has become part of local culture and customs. Capture fisheries are of two types: artisanal fisheries using small craft in nearshore waters, and industrial fisheries that operate further from the coast using ocean-going fishing vessels. Migrant fishers follow fish movements along the coast, in a social adaptation to a complex environment. Processing and trade of fish catches at local markets are important economic activities, often performed by women, who play a key supporting role.

Too many fishers, too few fish

Total reported landings of marine species are highest in Madagascar and Mozambique, two countries with long coastlines and well-organized industrial fisheries. Per capita seafood consumption on small islands such as Comoros, Mauritius and Seychelles is much higher than in Madagascar and the African mainland states, reflecting the relatively limited space for agriculture, and maritime culture of small island communities.

Marine fisheries resources are mostly fully or overexploited in nearshore waters, with several long-standing and emerging issues that need urgent attention. These issues include:

- Open access fisheries (where numbers of fishers, methods used, and harvest quantities are not controlled);
- Illegal, Unreported and Unregulated (IUU) fishing;
- Resource user conflict between different sectors;
- Development of deep-sea fisheries to offset declining nearshore catches;
- Moving from single species- to ecosystem management approaches;
- Co-management of fisheries, taking all stake-holders into account;
- Strengthening of research capacity and forging better linkage between applied research and fisheries management actions.

Mariculture is a newcomer to food production, and is supported by governments, but its popularity and development has lagged. Seaweed culture is prominent in shallow subtidal areas in Tanzania (particularly Zanzibar), where farmers are mostly women. Dried seaweed is sold on to middlemen and exported without further processing or value-adding taking place.

Climate change will potentially cause changes to sea level and chemical processes in seawater, affecting the capacity of the SW Indian Ocean to produce food. Overfishing, degradation of coastal areas important for the maintenance of healthy fish stocks, and unplanned urban development along the coast may threaten the habitats and fish stocks that contribute to food security along the coast. The spectre of 'too many fishers, too few fish' can be countered by interventions to reduce fishing pressure, stimulate development of alternative livelihood options, and mitigate coastal development impacts on marine environments.

Opposite page: Fish drying at the Ruvuma Estuary, Tanzania. © José Paula.


MPT-8596-P

21
Capture Fisheries

Johan Groeneveld

Artisanal fishers with small amounts of capital and access to simple gear are ubiquitous along the coasts of eastern Africa and Madagascar, and around small island states such as Mauritius, Seychelles and Comoros. They collect a mixed basket of fish and shellfish, where the distinction between target and bycatch is vague. Industrial fleets of pelagic longliners and purse-seiners target tuna and tuna-like species, and bottom trawlers target prawns on offshore mudbanks. The artisanal and industrial fishing sectors differ from social and economic perspectives, and serve separate market economies. Governments submit landings data to the FAO, but official statistics substantially underreport artisanal catches. Consequently, abundance trends are unavailable for many species, hindering decision-making. Landings data are better reported in tuna and prawn industrial fisheries, where stock assessments support management decisions in some countries.

Today's by-catch is tomorrow's catch

Mozambique, Madagascar and Tanzania (incl. Zanzibar) contribute most to regional landings. Foreign tuna fleets land and process their catches in Seychelles. Comoros, Mauritius and Kenya report lesser quantities, presumably because of shorter coastlines and fewer artisanal fishers. Pelagic fish make up 67% of the regional landings by weight, demersal fish 20% and crustaceans a further 10%. Cephalopods and molluscs are collected in the intertidal zone, often by women, and landings are infrequently reported.

Few countries have adequate infrastructure and trained manpower to effectively combat IUU (Illegal, Unreported, Unregulated) fishing. Illegal catches are therefore substantial, contributing to depletion of fish stocks threatening food security. Economic impacts are a direct loss of revenue to governments, and diminished catch rates in legal fisheries – thus increasing cost per kg caught. EU access agreement funds are used to combat IUU fishing by improve monitoring, control and surveillance, or providing technical assistance. Nevertheless, effective prevention of IUU fishing requires greater political will and investment, probably at an integrated regional level.

Capture fisheries affect the environment in which they operate by removal of targeted and bycatch species, and by altering habitats on which fish depend. Although a legal requirement, bycatch reduction devices are inconsistently used. SW Indian Ocean countries are all signatories to the Law of the Sea, and subscribe to the FAO Code of Conduct for Responsible Fisheries and Ecosystem Approach to Fisheries. Nevertheless, they lack the capacity to implement specific management strategies. Co-management of artisanal resource use and conservation through local beach management units is now legalized in Kenya and Tanzania. Multi-national tuna fisheries are managed by the IOTC located in Seychelles. Other fisheries are managed nationally, with some regional context provided by the SW Indian Ocean Commission, established in 2004. Between 2011 and 2015, only modest progress was made towards World Summit of Sustainable Development commitments to implement EAF strategy.

Gaps remain in the capacity to engage in capture fisheries and assess their status, trends and environmental impacts. Few species or fisheries have effective management plans, whilst most are at risk of overexploitation by a growing human population in coastal areas. The influence of environmental fluctuations on fish stocks and ecosystems functioning is weakly understood – this factor is exacerbated by global climate change. Nevertheless, there is unprecedented local and international interest in marine resource conservation and sustainable use in the region at present, with some optimism that downwards trends in capture fisheries can be redressed.

Opposite page: Prawn trawler operating in Maputo Bay, Mozambique. © José Paula.

22
Mariculture

Aviti Mmochi

Aquaculture (including mariculture in marine and brackish waters) is a fast-growing industry, showing a 12-fold increase worldwide over the past three decades, or average annual growth of 8.8%. Contrary to the global trend, mariculture in the SW Indian Ocean has struggled for a foothold, and apart from seaweed culture, has failed to grow substantially since the 1990s. A successful mariculture sector could bring much needed benefits to local communities, in the form of increased income and employment. It is therefore generally supported by local communities, investors, NGOs and governments.

Mariculture can provide benefits to local communities

Production of seaweed has grown rapidly in Tanzania (particularly Zanzibar) over the past two decades. Red seaweeds *Eucheuma* and *Kappaphycus* are produced for the high-value extract known as carrageenan. Seaweed is a fast-growing crop in the intertidal and shallow subtidal zone, and is harvested after 6 weeks, mostly by women farmers. It is then dried, and the raw product is sold to middlemen who export it to processors in Europe and America, with very little value-adding accruing to locals.

Prawn farming takes place on an industrial scale in Madagascar and Mozambique, but has been constrained at times by the global economic slowdown and the spread of whitespot disease. Farming of other species such as milkfish, rabbitfish, mangrove crab and pearl oysters are still on a small scale, and production statistics are often not reported. The number of candidate species for mariculture is rising, and challenges to the growth of a mariculture sector are a lack of technical expertise and infrastructure, weak business skills of farmers, inconsistent or inaccessible markets, and a lack of leadership, planning and enabling by governments.

Potential environmental impacts from mariculture expansion depend on the culture systems used and site characteristics. Collection of seed from the wild for farming may put pressure on wild populations. Some high-end farmed species such as prawns and salmon are carnivorous, requiring more protein than herbivorous and omnivorous species. Using fishmeal to feed them may stimulate capture fisheries to catch more, usually species lower down in the food chain. Instead of reducing fishing pressure on wild stocks, mariculture can therefore potentially increase it. Clearing mangrove areas to build ponds may lead to loss of mangrove common property and a reduction in ecosystem services such as nursery and filtration functions. Unregulated mariculture can cause eutrophication and pollution through effluents, spread diseases to other farms and wild stocks, or introduce alien species that threaten indigenous populations. The present regulations and their enforcement are inadequate to cope with growth in the sector. Mariculture competes with tourism for beachfront space and access routes (particularly in Zanzibar) – conflicts between the sectors can be moderated through marine spatial planning.

Mariculture in the SW Indian Ocean region is presently at an important junction: it can either develop along a planned path supported by good governance, private sector investment, and NGOs support; or it can spread unchecked as returns from capture fisheries decrease, with scant regard for longer term impacts on coastal ecosystems. The development of a mariculture sector in a region with a low human development index is a challenge, particularly in cases where extension systems fail to disseminate technical know-how required for successful farming and marketing. Targeted human resource and capacity development is therefore essential.

Opposite page: Sea cucumber pens: village-based aquaculture of sea cucumbers in Tampolove, southwest Madagascar. © Garth Cripps.

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Social and Economic Impacts of Capture Fisheries and Mariculture

Jacob Ochiewo

The SW Indian Ocean countries have a low human development index, and rapid population growth and high levels of poverty are pervasive. Fishing in nearshore areas contributes substantially to food security and economic activity in coastal communities. The numbers of fishers vary seasonally and between years, and many of them have more than one occupation, for instance fishing and farming. Women and children also participate in gathering marine organisms in the intertidal zone, but are not generally counted as fishers. Estimating the number of fishers based on the number of fishing licenses issued has limitations, because licensing requirements tend to be weakly enforced. Nevertheless, surveys suggest that 400 000 - 700 000 fishers were engaged in marine fishing between 2004 and 2013. Considering that there is a dependency ratio of about 7: 1 this means that almost 5 million people are directly dependent on fishing for their livelihood.

Fisheries dominate the social structure in coastal WIO

Fisheries are a major determinant of social structure in coastal communities. Women play a prominent role in the processing and marketing of fish. Middlemen usually own gear (seine or gill nets) or vessels (dhows or boats with engines), which they rent to fishers. Fisher migrations along the East African coast is centuries old, and illustrates social adaptation to a complex environment. Drivers of fishing migrations are a search for better catches and increased income. Migrations bring social and economic challenges at home and host destinations. Fisheries co-management is a wider trend in the region. This addition to the social structure of fishing communities still needs to mature.

On a worldwide scale, per capita fish consumption continues to rise – up from 10 kg/year in the 1960s to more than 19 kg in 2012. The opposite trend is apparent in the SW Indian Ocean, where per capita fish consumption is the lowest in the world, and declining. Decreasing fish availability in coastal waters (due to overexploitation) and increasing human population size and poverty levels can explain the anomaly. Declining catches of some artisanal fisheries have resulted in conflicts among fisher groups, attributed to high dependence on fisheries resources.

Fish production generally contributes 0.5 – 2.5 percent of GDP, but the contribution can be much higher in developing countries, where fisheries play a more central role in economic development, poverty reduction and food security. Fisheries' contribution to GDP (without value adding) was exceptionally high for small island states (30% for Seychelles and 15% for Comoros) and above the world average for Mozambique (4%) and Tanzania (2.7%).

Seaweed farming takes place in about 80 villages in Zanzibar, and of estimated 23 000 people involved, 90% are women. Prawn farms in Madagascar employ about 4 000 workers, and offer several thousand indirect jobs. Mariculture of most species has not progressed past the pilot phase over the past 2 decades, despite suitable natural conditions and technically successful pilot results. Plausible explanations include economic isolation, insufficient training and degraded road infrastructure.

There is a lack of alternatives to capture fisheries, even when catches from coastal areas are declining, and the populations of coastal areas are increasing. Mariculture, as an alternative to fill the gap has not taken root as expected to fill the gap. Nevertheless, fisheries and mariculture will remain important factors in determining the social and economic welfare of coastal communities in the near future.

Opposite page: Improvised fishmarket at landing site, Inhaca Island, Mozambique. © José Paula.

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Summary of Food Security from Marine Resources

Johan Groeneveld

Capture fisheries have a history of many centuries in the SW Indian Ocean, where they are integral to the food security and culture of coastal communities. Conversely, mariculture is a new sector with few successful commercial ventures, while many initiatives remain at subsistence level. Demographic pressure along the coast, coupled with dwindling nearshore fish resources, has emerged as a potential threat to food security in recent decades.

Ironically, the high biodiversity of this tropical region and multiplicity of methods used to exploit the coastal and marine environment for food and economic activity is the source of many governance headaches. Only modest governance resources are generally available to address complex issues. Nevertheless, good progress has been made over the past decade: governance systems are in place; capacity building is progressing; governments are signatories to international treaties; a shift towards EAF instead of single-species management; co-management through development of BMUs; regionalization of research and management; and the realization that mariculture will be key to food security and social and economic systems in the near future. Finding and implementing a long-lasting solution to the conundrum of declining coastal fish stocks and increasing human populations along the coast needs to be high on the agenda of governments in the region.

Few species have effective management plans, nor sufficient data and expertise to fully describe their fisheries and anthropogenic pressures. Projects at regional level have recently compiled existing fisheries information by sector. The linkage between science and management is weak; consequently crucial studies are not prioritized, or their conclusions are ineffectively communicated or implemented. The science / management linkage must be strengthened within a governance setup, and regionally.

Modest monitoring, control and surveillance capacity make enforcement of laws ineffective. Consequently IUU fishing is common, and responsible for considerable economic and ecological losses. Support for expanding and maintaining MCS systems needs to be sought. Co-management of artisanal fisheries with stake-holder involvement is a promising development. Government-supported implementation of EAF needs to be entrenched, by popularizing it among coastal communities. In cases where transboundary fish stocks can be demonstrated, cooperative management may confer ecological and economic advantages, and regional strategies should be considered. Mariculture is encouraged by governments as an alternative activity to generate fish protein and wealth, but it has failed to find a significant foothold. Impediments to its growth include lack of skills, technology, infrastructure and marketing, but a common problem appears to be the remoteness of the region from large urban centers and foreign markets. An integrated approach of collaboration between farmers (rearing), NGOs (technology) and business (marketing) is needed, over an extended period, to ensure a gradual transfer of skills. Mariculture undoubtedly has high growth potential, and can play an important role in empowering women in culture and business aspects.

Linkages between science and fisheries management need strengthening

Overfishing of marine resources is a serious concern, but placing limits on harvests cannot be done without major social, economic and political upheaval, and the provision of alternative livelihood means. Consequently, there is limited political will to effect change. Expanding coastal fisheries into deeper waters is an option to be tested, before it is implemented; it might work for pelagic species but not for slow-growing bottom fish species with low productivity.

Opposite page: Fish in the Palma fish market, north Mozambique. © José Paula.

Part VI
Assessment of Other Human Activities and the Marine Environment

Louis Celliers

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Maritime Activities

Lynn Jackson

Shipping is essential to the global economy, providing the most cost-effective means of transporting bulk goods over long distances. Around 80 per cent of global trade by volume and over 70 per cent by value is carried by sea and is handled by ports worldwide, with these shares being even higher in the case of most developing countries.

Some six per cent of the world trading fleet travels to ports in the Indian Ocean. In addition, vessels such as oil tankers frequently travel through the Western Indian Ocean (WIO) because it forms part of the route between the major oil-producing countries and their markets.

While ships are essential to the global economy, they have a variety of negative environmental impacts. These include pollution resulting from the ship's day-to-day operational activities, and as a result of shipping accidents; impacts related to ship recycling; and, translocation of invasive alien species primarily via ballast water and hull-fouling.

Ports are the interface between maritime and land-based activities and are generally located in sheltered environments such as bays and estuaries in close proximity to urban complexes. Such locations are invariably environmentally sensitive and can be negatively affected both by port construction and operations depending on the proximity to natural resources and the nature of the adjacent activities. Although there is limited specific information on pollution in ports for most countries in the WIO, the majority of the pollution hotspots identified were in or adjacent to ports.

The African Union 2050 Africa's Integrated Maritime Strategy (AIM) Strategy identifies the African Maritime Domain as an opportunity for the growth and development of a maritime economy whilst acknowledging that this must be done in a sustainable manner. 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.

The recent discovery of significant additional oil and especially gas resources in the WIO, together with a more general increase in trade and the AIM Strategy, suggests that it is highly likely that maritime activities are set to increase significantly in the region. This, together with factors such as climate change, heightens the environmental risks and points to the need to urgently develop regional policies on:

- The implementation of Flag and Port state controls and the need to develop capacity in this regard;
- Regional co-operation around maritime surveillance which could be extended from the current co-operation around combatting piracy to include illegal, unregulated fishing, oil spills and other ship-related pollution, amongst others;
- Scientific monitoring and reporting of pollution levels and incidents;
- Prevention and control of alien and invasive species introduced by ships;
- The provision of adequate waste reception facilities at ports;
- Building awareness of the impacts of marine litter and increasing capacity to address the sources thereof;
- Response to the potential impacts of climate change on the maritime sector including, for example, the inclusion of climate change concerns into risk assessments and the development of Climate Adaptation Plans for ports;
- Financial mechanisms to provide for the required management activities.

The WIO abounds in opportunities for the growth of a maritime economy

Opposite page: Evening in Port Louis, Mauritius. © Peter Kuchar.


Statoil
Transocean

26
Oil, Gas and Renewable Energy

Matthew D. Richmond

A common feature of the Western Indian Ocean (WIO) countries is the generally poor coverage and availability of electricity. All nine countries in the WIO region rely on the importation of oil to generate electricity. For some, fossil fuel is the main source of energy including the smaller island states like Mauritius, Comoros, Seychelles, but also France (Reunion), Madagascar and Kenya. In Mozambique and South Africa, coal is the predominant source of energy for power stations, with significant contributions from hydropower. The WIO offers considerable potential for future use of renewable (tidal, wave, currents, thermal properties) and non-renewable (fossil fuel) energy sources from the ocean.

The WIO is rich in renewable and non-renewable energy sources

There are a number of impacts from the exploration, development and production of energy from the sea. These include impacts common to all structures placed in the marine environment; impacts from fossil fuel exploration, and impacts from fossil fuel production. Physical obstruction and interference with access for navigation or fishing activities, similarly affecting the movement of marine mammals and fish are the most obvious impacts from structures.

Sound generated by prospecting ships does affect sea life in close proximity and can affect marine mammals up to considerable distance. Disposal of waste drilling muds in the deep sea or open water may have widespread impacts, though toxicity is typically rapidly diluted by the receiving environment. The transportation of fossil fuels is vulnerable to poor maintenance, weak infrastructure and accidents, resulting in potential threats to the coastal and marine environment. Many of these impacts can be successfully mitigated.

The need for transparency, national dialogue and sound fiscal management of the natural gas revenue cannot be over-emphasized. Recommendations for regional energy opportunities include:

- The development of awareness and capacity building in all areas associated with energy exploration are desperately needed in most countries in the WIO. This includes the environmental regulators and those charged with developing contracts and agreements with energy sector investors;
- Promotion of effective management and good governance of the extractive sector, as suggested by the Extractive Industries Transparency Initiative (https://eiti.org/home) and establish a rigorous fiscal regime with transparent tracking of incomes generated. Establish ring-fencing of revenues from the profitable sectors to avoid politicising the resource and its benefits and ensure transparency and its wise use, while encouraging participation of civil society watchdog organisations;
- Protect the marine environment and ensure oil pollution preparedness and that oil and gas companies have adequate insurance in the event of a spill and can cover clean-up costs and compensation for loss of livelihoods;
- Sign and ratify all International Maritime Organisation conventions relevant to oil and gas exploration, shipping, transportation of oil etc;
- Review legal mandates to ensure that compensation for damages caused by marine-based energy companies are streamlined;
- Adhere to the conditions of the Nairobi Convention. The most relevant articles, among others, are: 5 (pollution from ships), 8 (pollution from seabed activities, including oil and gas exploration), 12 (co-operation in combating pollution in cases of emergency) and 16 (liability and compensation);
- Develop and promote alternative, renewable energy alternatives;
- Promote regional coordination on 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.

Opposite page: Ultra-deepwater drillship active in waters 2 000 m deep, off Tanzania. © Matthew D. Richmond.

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Coastal Mining and its Influence on Coastline Stability

Laurie Barwell

The coastal regions of Sub-Saharan Africa are generally endowed with non-renewable mineral resources such as pyrochlore, gypsum, barites, iron ore, clay, apetite, galena, manganese and semi-precious stones. Dune fields and beaches located closer to river deltas consist of quartz sand and may contain other minerals, such as heavy minerals. In other areas, many of the beaches are composed of shell and coral fragments that are of organic origin and are known as carbonaceous sands. The availability of such aggregates along the coast is often seen as a "free" resource along with the demand from the construction industry offer opportunities in both the formal and informal sectors.

The types of coastal mining activities in the WIO countries include; quarrying of coral rock and limestone for cement; manufacturing and course aggregates for concrete and road building; artisanal sand mining from the catchment, floodplains, river banks, estuaries and lagoons; informal removal of sand from beaches and foredunes; formal mining of minerals from titaniferous sands; and the production of sea salt from saltpans typically located on estuary flood plains.

Coastal tourism in the WIO is a driver of the state of the coast

In cases where mining for minerals is indeed undertaken, there are reported examples of major environmental changes. Infrastructural development results in heavy dependence on natural resources, including the basic components of building material, namely cement, sand and coarse aggregate (stones) for concrete and mortar, and clay for bricks. Furthermore, geological exploration of the WIO is far from comprehensive so that unknown deposits are likely to exist.

In the majority of cases, coastal mining results in the over-exploitation of resources, modification and loss of habitats, and uncontrolled development or encroachment onto the dynamic beach and coastal system. The impacts of coastal mining includes environmental degradation with a concomitant reduction of the natural dampening effect normally provided by coral reefs, beaches and dunes during sea storm surges.

The following pointers can be considered for incorporating into existing policies that relate to managing of coastal mining activities in WIO countries:

- Explicit policies that relate to coastal mining activities do exist in most of the WIO countries under consideration. A policy of explicitly sharing good practice within the WIO could be strengthened;
- A policy of active succession planning and multi-national skills development will secure a sustainable research and management capability within the WIO countries;
- It appears that (some) authorities are finding it challenging to implement policies especially in areas where informal mining activities prevail. A policy that guides the utilisation of a valuable natural resource should be formulated when more detailed quantifiable research is undertaken;
- The importance and value of the coastal sand system as a regulating ecosystem service within the coastal social-ecological system should be acknowledged and recognised in coastal zone management policies;
- The opportunity exists to use the sand that is left over from commercial heavy mineral mining activities in Kenya and Mozambique as a commercially exploitable natural resource for export to WIO countries where this resource is limited. A policy of ensuring the direct participation of current artisanal (informal) sand miners in the whole value chain of this venture would enhance the socioeconomic benefit across the whole WIO at a local as well as national level whilst ensuring the integrity of the coastal sand system.

Opposite page: Artisanal sand mining near Mombasa, Kenya. © Laurie Barwell.

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Tourism and Recreation

Sachooda Ragoonaden

The tourism and recreation sector is a global force for socio-economic development, promotion of economic growth and alleviating poverty with direct economic as well as significant indirect and induced impacts. Coastal tourism in the WIO is both a direct and indirect driver of the state of the coast. The region provides a range of unique attractions and recreational activities for local and international tourism. Coastal tourism is very popular among local populations, particularly in the Small Island Developing States and coastal region of the mainland states of the WIO. The main tourism features of the region include sandy beaches, clean water, abundant sunshine, mangrove forests, and lagoons and seas. The region has a high diversity of coral reefs with significant economic value, particularly for dive tourists.

Coastal tourism in the WIO is a driver of the state of the coast

The marine environment offers many opportunities for employment to local communities and in places provides economic incentives to protect the marine ecosystems. Although tourism has immense potential to enhance socio-economic development and contribute to environmental rehabilitation, it also has a wide range of negative social and environmental impacts.

Sustainable coastal development needs to adopt a long-term planning and management timeframe to promote sustainable tourism in order to maintain environmental and cultural Integrity. Some specific recommendations include:

- Promote mutually beneficial tourism and conservation. Tourism has the ability to motivate large-scale positive change in land use by generating financial and political support for conservation;
- Promote whale and dolphin watching. If responsibly developed and managed, it could bring much needed income to the region. To make it sustainable, proper adaptive management should be developed;
- Encourage cruise tourism and manage impacts. Although uncontrolled cruise vessels can cause much damage to the environment, some cruise operators have made significant investments in advanced solid waste and waste-water processing equipment;
- Promote research and monitoring. Local researchers should be provided with facilities and encouragement to undertake research and publish findings, and research should be catalogued and made available, preferably in an electronic format;
- Establish more Marine Protected Areas. The protection of existing MPAs and establishment of more MPAs should be promoted with increases in fees and licenses where they exist, for increased revenue for the benefit of the tourism industry and local population;
- Curb Piracy. The threat of pirate attacks has curtailed many tourism activities and in some instances dampened the fishing industry in the WIO. This includes the threat to cruise liners;
- Improving coastal and shoreline management. Four issues are responsible for the changing relationship between coastal tourism and shoreline management; an increase in, and the changing nature of tourist-related pressure at the coast; advances in shoreline management approaches including the adoption of Integrated Coastal Zone Management (ICZM) principles; the geomorphologic behaviour of coastal systems; and, climate change and sea level rise;
- Introducing beach awards systems. The Blue Flag Programme (www.blueflag.org), which has been claimed provide an excellent opportunity to promote sustainable coastal development, improve coastal infrastructure and attract international tourists has been adopted by many countries around the world;
- Promote domestic tourism. Coastal tourism within the region represents a considerable opportunity for growth and development that needs to be exploited. Studies should be conducted to identify strengths and weaknesses to develop sustainable domestic tourism in the coastal zone, and strategies developed to encourage a strong domestic tourism market.

Opposite page: Touristic activities at Grand Baie, northwestern Mauritius. © José Paula.

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Urbanisation, Coastal Development and Vulnerability, and Catchments

Louis Celliers and Cebile Ntombela

URBANISATION AND VULNERABILITY

The change from natural coastal areas and catchments to urban and built-up areas is considered a permanent effect of economic growth and development. Thus urbanisation directly and negatively affects biodiversity and human well-being. Eastern Africa is the world's least urbanised but fastest urbanising sub-region in Africa.

Land transformation is considered a permanent effect of urbanisation

The "high road" to improved urban economies and development requires more widely shared benefits to all inhabitants. There is however a number of related factors that limits the physical growth of cities which includes local biophysical constraints due to human activities; large-scale environmental change; uncertainties of future economic growth; and the effectiveness of urban planning institutions. The existing and emerging issues require a number of policy responses in order to mitigate negative environmental, social and economic consequences and include:

- Disaster risk reduction and climate change adaptation should be prioritised;
- Promote and undertake research devoted to address the climate problem;
- Encourage and promote robust urban planning processes that seek to reduce the gulf between formal governing institutions and networks of local actors;
- Reduce the high levels of vulnerability and low adaptive capacity in local governments with poor capacities and resources;
- Authorities need to identify and establish the environmental baselines to inform appropriate zoning incorporating the onset of climate change;
- Mainstream adaptation options into integrated coastal management and sustainable development plans;
- Planning regimes of WIO coastal cities should consider the requirement for socio-political reforms and changes;
- Improve the capacity of municipal and central governments to govern urban land markets by collecting revenue from land and property transfers, sales, rates and taxes;
- Initiate a debate on coastal urban equity;
- Develop effective adaptation strategies for port cities of the WIO region.

CATCHMENTS

The interaction between catchments and the coastal and marine environment has been identified as one of the processes subject to environmental pressures in coastal zones of the WIO. Three major issues linked to river-coast interaction in the WIO are the modification of river flows, water quality and sediment loads, primarily as a result of abstraction; damming; inappropriate land-use practices; and increased floods and seasonal flow patterns. Some suggestions for regional policy interventions include:

- Development of coordinated, non-conflicting and relevant 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 and the involvement of the stakeholders from the sectors involved in water resource management;
- Improvement in the collection of data and information relevant for water resource management;
- Improved financial investment in the development of human capital in order to facilitate and promote the effective implementation of agreements and water management programmes; and,
- The development of integrated regional policies for water resource management in order to address the growing demand on water resources.

Opposite page: Coastal development at Catembe with Maputo in the background, Mozambique. © José Paula.

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Marine Genetic Resources and Bioprospecting in the Western Indian Ocean

Rachel Wynberg

Over the last few decades, increasing attention has been given to the commercial potential of exploiting marine genetic and associated natural product resources for a range of industries including pharmaceuticals, food and beverage, cosmetics, agriculture and industrial biotechnology. Most research, development and commercialisation of marine genetic resources are currently located outside of the WIO, as is the ownership of associated intellectual property rights.

Marine genetic resources found within the Exclusive Economic Zone (EEZ) are subject to national laws, and to provisions of the recently adopted Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation, under the Convention on Biological Diversity. The concept of "access and benefit sharing" (ABS) originated as a legal expression arising from the unequal distribution of biodiversity throughout the world, the desire of biodiversity-poor but technology-rich industrialised countries to have continued access to these resources, and the determination of biodiversity-rich but technology-poor developing countries to benefit from the exploitation of their resources.

Several areas in the WIO are of interest for natural products. The presence of biodiversity hotspots in the WIO also suggests that the area is likely to be of increasing interest for marine natural products. Only a fraction of this biodiversity has been explored for its commercial potential and it is likely that there is significant potential in the WIO to generate interesting new leads and that industry interest in the region will increase.

Only a fraction of genetic resources in the WIO biodiversity has been explored

Major constraints that prevent this potential from being realised are the low levels of scientific and technical capacity that exist in most countries, and insufficient biodiversity knowledge. Without concerted efforts to strengthen this capacity and improve knowledge, benefits derived from the region's genetic resources are likely to continue to be reaped by developed countries.

The following recommendations are made to address some of these challenges:

- WIO countries should develop or strengthen national and regional ABS laws for marine biodiversity in the EEZ, with an emphasis on ensuring sufficient control over access and benefits, but without impeding research endeavours;
- Particular attention should be given to promoting research that contributes to the conservation and sustainable use of biodiversity;
- Marine bioprospecting should be regarded as an opportunity to build scientific capacity in WIO countries and to transfer appropriate technology and access to technology from developed countries and institutions;
- Attention should be given to improving scientific knowledge about the marine biodiversity of the WIO, and in particular under-explored groups, including microorganisms and microalgae;
- Benefit sharing should include measures to strengthen the conservation of the area of collection and/or species collected, as well as improved access to raw and published data;
- Attention should be given to the possible development of a regional ABS approach for marine genetic resources in the WIO region, in line with the multilateral mechanism proposed by the Nagoya Protocol;
- Efforts should be undertaken to develop ABS rules for genetic resources in the high seas to ensure these potential benefits are gleaned by humanity as a whole; and
- WIO countries should support improved disclosure of the origin of material in patent applications to ensure greater transparency and improved tracking of the source of the material.

Opposite page: Nudibranchs are of interest in bioprospecting programmes and have been the source of dolastatins, under investigation for their anti-tumour activity. © Hendrik Martens / Shutterstock.


CAUTION
SLIPPERY SURFACE
TAHADHARI NA UTELEZI
Switch off engine

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Summary of Other Human Activities in the Coastal and Marine Environment

Louis Celliers

The Western Indian Ocean (WIO) offers a wealth of opportunity for the profitable and beneficial use of coastal and marine resources – a prospect for a true ocean economy. These benefits are derived from a range of human activities in the coastal and marine environment. Shipping moves, by a large margin, the bulk of the goods to the region. The region is also a source of, amongst others, fossil fuels for the generation of energy, and minerals for manufacturing and other uses. These extractive and non-renewable resources offer substantial economic benefit, if the negative environmental and social impacts can be mitigated. Coastal land as a resource allows for development, settlement and recreation opportunities, but is also a source of biodiversity and ecosystem services. Urbanisation and coastal development result in permanent conversion of this resource and often the loss of most of the freely provided ecosystem goods and services. The exploitation of WIO genetic resources is a largely unexplored opportunity for the benefit of the regional and indeed the global population. Furthermore, the attractive and desirable coastal and marine habitats of the WIO, a non-extractive and renewable resource, are the basis for a growing tourism industry in the region.

The Western Indian Ocean offers prospects for a true ocean economy

In light of the many opportunities and threats, it is important to know more about the resources of the WIO, the environment, the people using and exploiting such resources, and the way in which we govern. The development of a Blue Economy relies not only on scientific data, information and knowledge in many different scientific disciplines, but also mechanisms for integrating this cross-discipline information. National and regional research agendas should recognise the need for inter- and trans-disciplinary research. Not only is it important to understand value and worth, but it is also important to ensure equitable access, to and benefit-sharing of coastal and marine resources.

Ecological, social and economic vulnerability to hazards incurred in human activities such as shipping and mining, as well as hazards caused by the proximity of coastal communities to the ocean climate needs to be better understood. The consequences of global change also create vulnerability and the language of resilience, adaptation and mitigation should be reflected in policy and legislation.

There is also a need to develop mechanisms and tools for the capture, exploration and archiving of data, information and knowledge. Coastal and marine spatial data archiving, coastal atlases and information clearinghouses are some of the mechanisms that should be used to improve the return on investment in scientific research.

The region requires a suite of planning tools and mechanisms for the management of coastal land-use and conversion at all scales – regional, national and sub-national. Forethought in coastal development and growth is a priority. Approaches such as seamless terrestrial and marine spatial planning should be part of a suite of adaptive management tools. The city-port-environment interface needs to be recognised in policy.

The development and implementation of integrated coastal management (ICM) has become a priority for the management of coastal areas and associated human activities through The plethora of coastal and marine activities require management approaches that are adaptive, rely on appropriate and scientifically defensible data and information, and include the entire spectrum of users, stakeholders, decision- and policy-makers to negotiate effective and sustainable use and exploitation of coastal and marine resources. This also requires the availability of relevant legal frameworks that enable rather than frustrate efforts to develop environmental management solutions for sustainable development.

Opposite page: Commuting in the Likoni ferry at the entrance of Kilindini Harbour, Mombasa, Kenya. © José Paula.

Part VII
Scenarios, Policy Options and Capacity Building

José Paula

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Scenarios: WIO Coastal and Marine Environmental Futures

Washington O. Ochola

The explored scenarios considered changes in the physical environment, the biogeochemical environment, food-web dynamics, and the human dimension. Many recent environmental and socio-economic assessments have adopted this integrated approach, including UNEP and IOC-UNESCO. The assessment used two main scenarios: (1) The Conventional World Scenario (CWS) representing a business as usual pathway (BAU); (2) The Challenge Scenario or Sustainable World Scenario (SWS) representing a sustainable future as captured in the WIO Strategic Action Programme (WIO-SAP) aspirations and the Sustainable Development Goals (SDGs).

Both the SDGs and WIO-SAP goals focus on sustainable coastal and marine management; ecosystem based management; environmental governance including implementation of the protocol on land-based sources and activities (LBSA); development of protocol on integrated coastal zone management (ICZM) under the Nairobi Convention; information and awareness; policy options on climate change; ports and harbours development; oil and gas; green economy; and description of Ecologically or Biologically Significant Marine Areas (EBSAs), Vulnerable Marine Ecosystems (VMEs), Areas Beyond National Jurisdiction (ABNJ), and Particularly Sensitive Sea Areas (PSSAs).

The Western Indian Ocean has a promissing future only if…

CONVENTIONAL WORLD SCENARIO

Current trajectory results in ongoing degradation of the coastal and marine environment, including poor coordination, lack of environmental awareness, weak legislation and a lack of adequate institutional frameworks and capacities. With these trends and the impacts of climate, widespread degradation is likely to continue. The projected exponential increase in population, coupled with a high reliance on coastal and marine resources is likely to compound the challenges facing biodiversity conservation. Major maritime activities continue and increase without any evidence of risk minimisation or of mitigation action, with consequences on pollution and translocation of invasive alien species. Various concerns continue to prevail including piracy, the illegal dumping of toxic waste and potential impacts of climate change on shipping and uncontrolled growth in urbanisation and port infrastructure.

SUSTAINABILITY WORLD SCENARIO

The empowerment of inter-ministerial committees and regional task forces strengthened implementation of ICZM or EBM approaches. On-going regional dialogue and implementation of normative frameworks for policy reforms are expected to limit environmental degradation. National Plans of Action (NPAs), Integrated Coastal Zone Management (ICZM) plans or National Environmental Management (NEM) plans are developed by all WIO countries by 2025, including strengthening of transboundary collaboration.

Countries have intensified efforts towards the development of a regional maritime surveillance system and establishment of pollution monitoring and reporting systems. The draft Regional Contingency Plan developed under the WIO Marine Highway Project in 2012 is established within the framework of the Emergency Protocol and establishment of a Regional Coordination Centre (RCC) for Marine Pollution Preparedness and Response in the Western Indian Ocean by 2018.

HOW MIGHT THE WIO 2050 SCENARIOS BE USED?

Potential users of scenarios include conservation managers, regional land-use planners, as well as coastal and flood-defence managers. The WIO coastal scenarios also target government departments, fisheries organisations, offshore oil and gas operators, coastal engineers, marine biologists, conservationists, regional development agencies and tourist authorities, amongst others.

Regional stakeholders will need to adopt policies, strategies and long-term plans to take account of the future changes. Guidelines are needed on dealing with uncertainty in decision-making and risk assessment.

Opposite page: Can WIO coastal landscape paradises like this one in Seychelles still exist in the future under change scenarios?

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Governance: Legal and Institutional Frameworks

Akunga Momanyi

Governance of oceans and coasts is better understood as the process for policy making by competent institutions in a system of negotiation between nested governmental institutions at several levels (international, (supra) national, regional and local) on the one hand and market parties and civil society organizations on the other.

KEY GOVERNANCE CHALLENGES

Major governance weaknesses impinging on the coastal and marine environment of the WIO region include policy and legislative inadequacies, limited institutional capacities, inadequate awareness, inadequate financial resources and mechanisms, as well as poor knowledge management. There are many policy and legislative gaps, and there is inadequate domestication of relevant international commitment and obligations, an apparent lack of mechanisms for effective coordination and inter-sectorial governance, and an inadequacy of human and technical resources and capacity. Key generic governance challenges are (i) inadequate technical capacity, (ii) lack of sufficient financial resources, (iii) overlapping or uncoordinated institutional mandates, (iv) multiple sectors affecting coastal and marine issues, (v) political goodwill and prioritization, (vi) language and legal system constraints, and (vi) multiple regional affiliations.

LEGAL AND INSTITUTIONAL FRAMEWORKS

Legal and Institutional frameworks include constitutional provisions, framework Environmental Laws and sector based laws. Constitutional provisions are generally not explicit, and specificity and detail is addressed in framework legislation or sectorial laws. All WIO countries have framework legislation and instruments for environment affairs, including coastal and marine environments, and sector-based legislation and regulatory frameworks.

The national institutions in most of the countries exist as overseers of the entire spectrum of the national environment. Technical personnel and financial means are often insufficient to deal with the myriad of challenges posed by the use of coastal and marine environments – many of which are multi-sectorial and multi-disciplinary. An important challenge is to align institutions to give more deliberate attention to the use of coastal and marine environments.

A number of regional institutions tackle environmental related issues in Africa, namely AMCEN, NEPAD and AMCOW. Four main regional economic integration organizations are relevant to the WIO region: SADC, COMESA, EAC and IOC. Non-state actors often lack traditional forms of political power or authority (legislative and executive). The governance profile of environmental non-governmental organization (NGOs) stands out as particularly strong on raising awareness and, representing public opinion. The most relevant Regional and International Civil Society Organizations in the WIO are WIOMSA, WIO-C, IUCN, and the WWF. The relevant Global Inter-governmental Institutions are UNEP, IMO, FAO, UNESCO-IOC, and UNDP.

Participatory regulation introduces a paradigm shift

GOVERNANCE RESPONSES AND INTERVENTIONS

Numerous national, regional and global institutions, laws and conventions operate in the WIO region, often with overlapping mandates, and all too often in an uncoordinated manner. Nevertheless, legal, institutional and policy responses appear to have been characteristically similar, both acknowledging that many anthropogenic activities causing coastal and marine pollution and degradation stem from legitimate socio-economic activities, and that these activities have environmental consequences that need to be regulated. The evolving ICZM laws and policies are more participatory, and may bring a future paradigm shift.

Opposite page: Aerial view of Dar es Salaam and the entrance of the port. © Matthew D. Richmond.


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Policy Analysis and Options

Akunga Momanyi

In most of the countries in the WIO region, there are public policy frameworks that support the legal and institutional governance of coasts and oceans. An important challenge however, is the need to align existing sector based policy instruments so as to give more attention to an integrated approach in the management of the coastal and marine environment. At the same time, there is need for regional harmony, which calls for new or evolving policy instruments at the national level to closely align to the Nairobi Convention framework to allow for regional consistency.

SYNERGIES AND TRADE-OFFS BETWEEN POLICIES

In view of the challenges discussed above, there is justification and scope for the review of existing sector based policies to create synergies and trade-offs in new intergrating policies. Sector-based approaches that are common in all the countries across the region, can be realigned and feasiblly integrated for policy synergies at the national level through over-arching policy frameworks, including ICZM frameworks or an integrated marine policy.

National marine policies for cross-sector coordination

CHALLENGES AND GAPS, INCLUDING KEY ISSUES FOR POLICY IMPROVEMENT AND REALIGNMENT

The WIO countries are closely connected however, their national legal, institutional and policy frameworks are not adequately harmonized. Countries could harmonize their policies and legal frameworks through the Nairobi Convention, its protocols and Action Plan. The Nairobi Convention, as a regional framework, promotes a region-wide approach to the management of coastal and marine environmental problems and challenges facing the region. The main challenge is the extent to which countries are willing to align their national frameworks to regional legal and policy frameworks that they are party to.

Legitimate socio-economic activities which should be protected, encouraged and enhanced, cummulatively impact the environment in a manner that cannot be controlled through sector based regislations. The traditional sector approach to policy formulation, creates numerous areas of overlap, duplication, contradiction and legislative gaps. The main policy dilemma is how to encourage or enhance integrated policy, legal or institutional approaches without undermining governance structures that have been established over long periods.

Fortunately, there is increasing understanding and adoption of integration, with a trend towards multi-sectorial legislation, policy and institutional arrangements to facilitate a more cohesive vertical and horizontal co-ordination and integration.

POLICY OPTIONS AND THEIR IMPLICATIONS

Various policy options exist with regard to the protection of the coastal and marine environment both at the national and regional level, including (i) overarching policy instrument with sector players taking primary responsibility, (ii) maintaining sectorial policies and providing an integrative or coordinating mechanism, and (iii) maintaining sector policies as well as sectorial implementation of the policies without having a coordinating mechanism (the "business as usual" model).

POLICY EMPHASIS SCENARIOS

There are several options and scenarios that WIO region countries need to consider. Firstly, countries may consider policy instruments which largely or primarily provide incentives for voluntary compliance. Secondly, countries may consider strengthening the "command and control" approach in their policy formulation. Finally, a scenario where a hybrid system, with both elements of incentives and policing co-existing, is presented.

The time has come for countries in the WIO region to clearly invest in the management coastal and marine resources for the future. Economic development and population projections, as well as trends in environmental degradation and/or recovery and climatic change implications, should be included in the analyses that contribute to the much-needed guiding policies of the future.

Opposite page: Opening a trench for electric cables in the coast of Zanzibar. © Matthew D. Richmond.


GPS
GPSmap 60CSx
GARMIN

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Coastal and Marine Research and Capacity Building

Julius Francis, Louis Celliers and Sérgio Rosendo

Managers, decision- and policy-makers and the various end-users have access to the products of scientific research in order to wisely govern and manage resources. Also, both the management of resources and the underpinning knowledge base rely on the availability of people with the appropriate capability. Accordingly, education, awareness and training offer a long-term solution for the sustainable development of a coastal and ocean economy. National research and development (R&D) activities and supporting institutional frameworks in the WIO are not homogenous. Most countries in the WIO hold some level of science, technology and innovation (STI) "system", as an attempt to create a relationship between national growth and development objectives through scientific research priorities.

Research and capacity: A foundation for ocean economy

RESEARCH PRIORITIES

On a global scale, the Global Biodiversity Outlook and WWF's Living Planet Report identified priorities to achieve sustainable use of the planet's resources. When placed in the context of global climate change, the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation has proposed a number of specific objectives towards our future on the changing planet, as a global scientific initiative of UNEP, UNESCO and WMO. In recognition of threats to global sustainability of human activities in the ocean and coastal environment, IOC/UNESCO, IMO, FAO and UNDP have identified the following problems as being the priority concerns: (1) unsustainable fishing, (2) climate change and ocean acidification, (3) pollution and waste, and (4) loss of habitats and biodiversity.

At the regional level, a major concern for the future prosperity of WIO countries is ensuring the wellbeing of human populations through the maintenance of biological diversity and the ecological function of coastal and marine environments. Accordingly, a number of priority research themes and cross-cutting activities have been identified by different regional processes. For instance, WIOMSA, through its MASMA Programme, has identified the following as its priority research themes: Vulnerability, Resilience & Adaptation; Coastal Livelihoods; Governance for the Future and Ecosystem service research.

DEVELOPMENT OF CAPACITY FOR RESEARCH

Different types of management authorities are responsible for policy implementation and day-to-day management of coastal and marine resources, which are vastly different in character and have different capacity-building requirements. On the whole, at the national level, there is often requisite capacity to source and apply science to policies, legislation, plans and strategies. Some relevant capacity-building interventions are needed, aimed at management authorities: (1) reinforcing the capacity of decision-makers to formulate policy and associated research needs, and (2) enhancing mutual understanding of how scientific and management communities operate through specific training.

Overcoming the barriers to effective integration of science into decision-making and management processes cannot be achieved through capacity building alone. There are, however, a number of additional strategies that would strengthen such integration: (1) support for knowledge brokerage in boundary organisations, (2) compilation of project-level lessons-learned that link science and policy and management, and (3) supporting projects that combine research and demonstration or implementation activities. Capacity-building initiatives included individuals, institutions and society in general: (1) technical short-term courses, (2) writing workshops, (3) practitioner short courses, (4) multi-stage courses, (5) certification of professionals, (6) tertiary education leading to BSc, MSc and PhDs, (6) increasing accessibility of research results, and (7) the development of training materials and guides.

Opposite page: Crossing hands for action, Reunion. © Anne Lamahieu.

Part VIII
Overall Assessment

José Paula

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

José Paula

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 the 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 upon them through 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 Western 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 in 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 services assessments, both related to food security from marine resources as well as those other than provisioning also emphasized the same challenges and the increasing pressures of the variety of human activities in the marine and coastal environment.

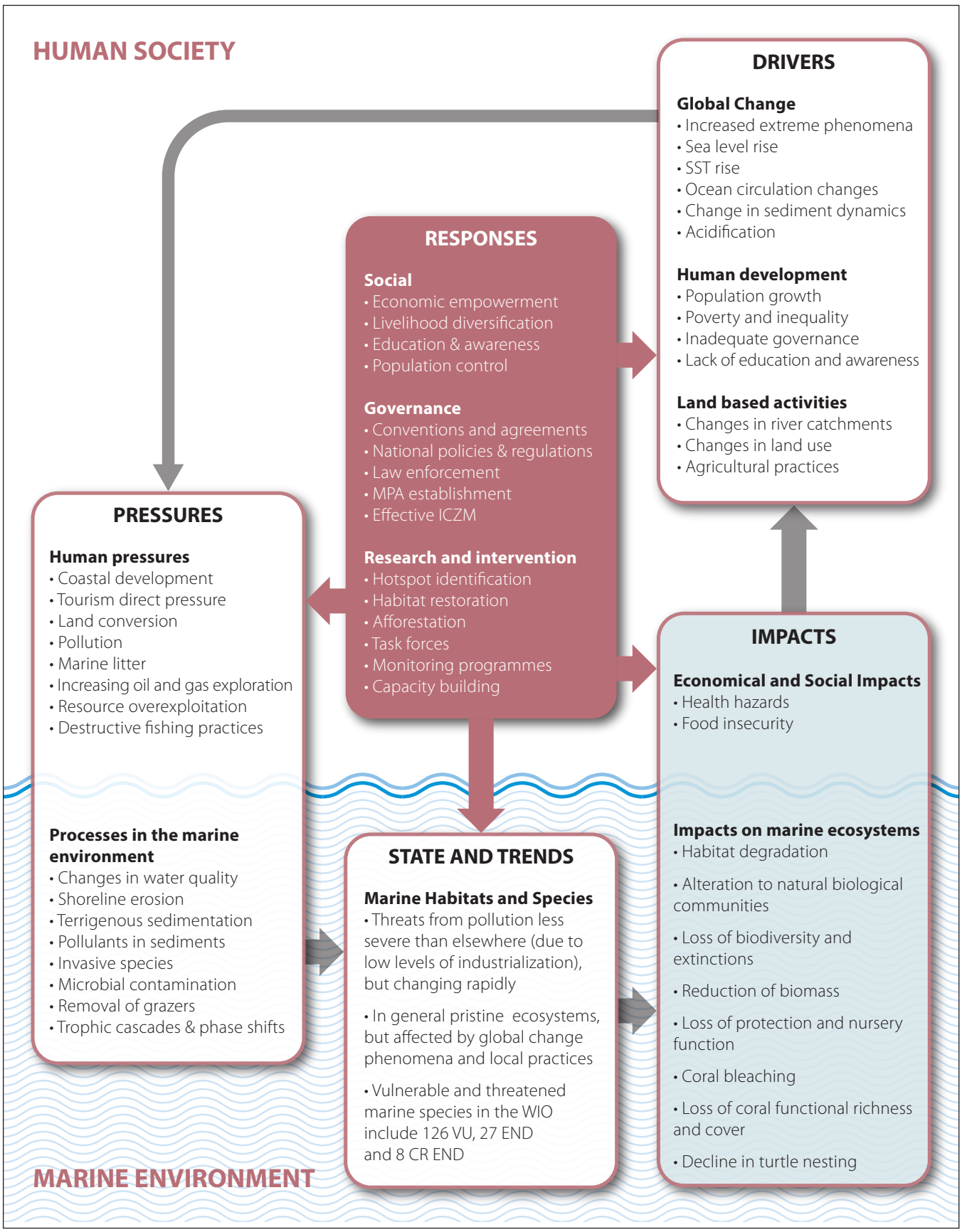
Other human activities are increasing in the region, such as maritime activities and mineral extraction from the coast, as also emergent and fast growing socioeconomic activities like oil and gas exploration, tourism and bio-prospecting. While these sectors offer present enormous opportunities for economic development, their potential impacts are challenging sustainability and should be addressed with integrated sound management strategies.

The analysis of possible future scenarios shows that the Sustainable World Scenario will allow for long-range planning, enabling decision-makers to evaluate predictions and explore a range of possible alternative futures in order to identify possible options for policy and management, effectively managing the coasts and oceans, promote adaptive management, but also to monitoring programmes set for the refining of scenarios in view of observed change trends. While capacities are limited in the region, both economical and human, investment and innovative approaches to building human capacity development should remain at the top of priorities for countries in the WIO, at all levels.

A state of the coast report is a tool which needs perpetual adjustment and adaptation

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

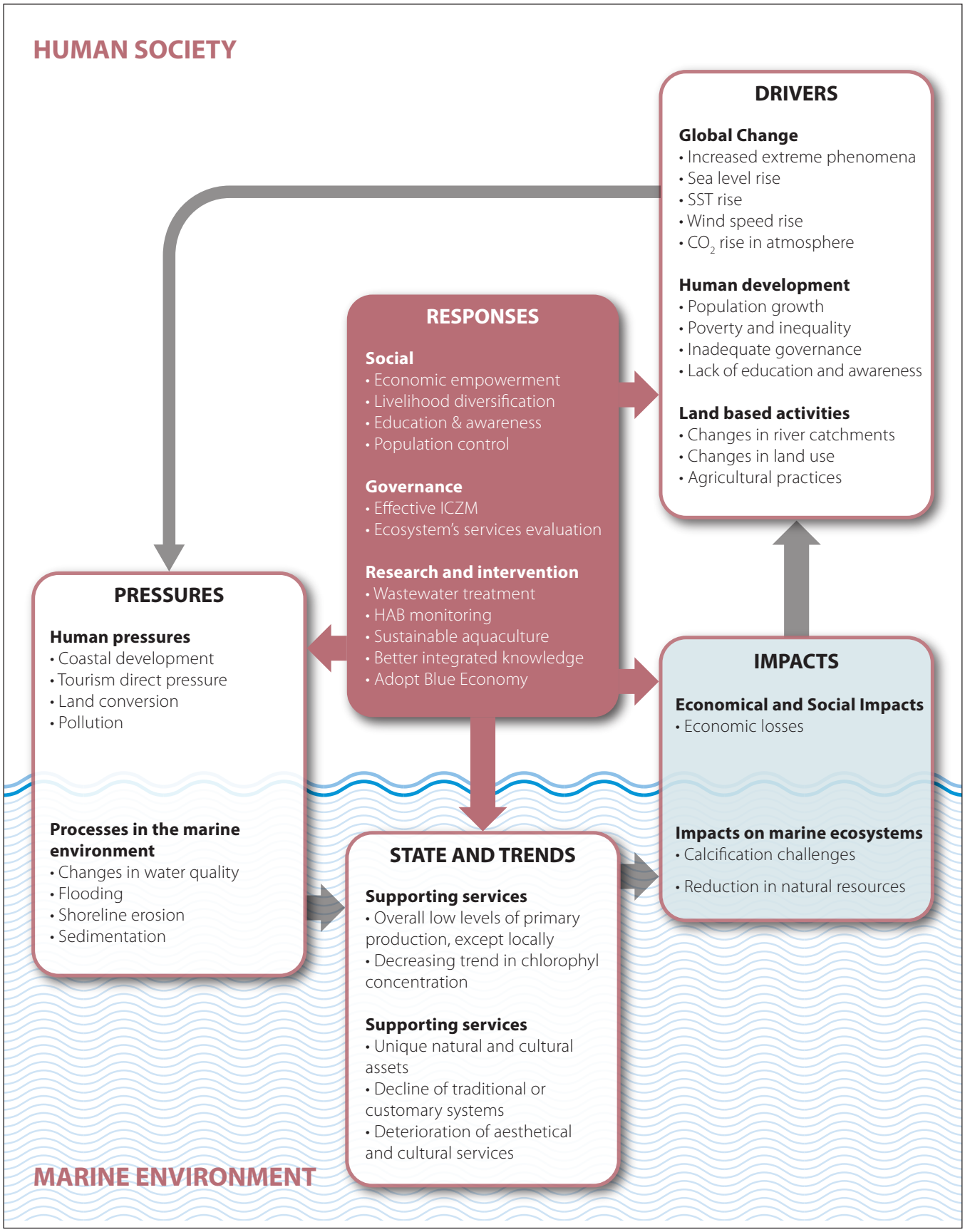
Opposite page: Will the marine resources these girls collect in the tidal flats near Ulo village, north Mozambique, be available in the future for food security or will they benefit from economic development and depend on modern amenities instead? © José Paula.



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

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

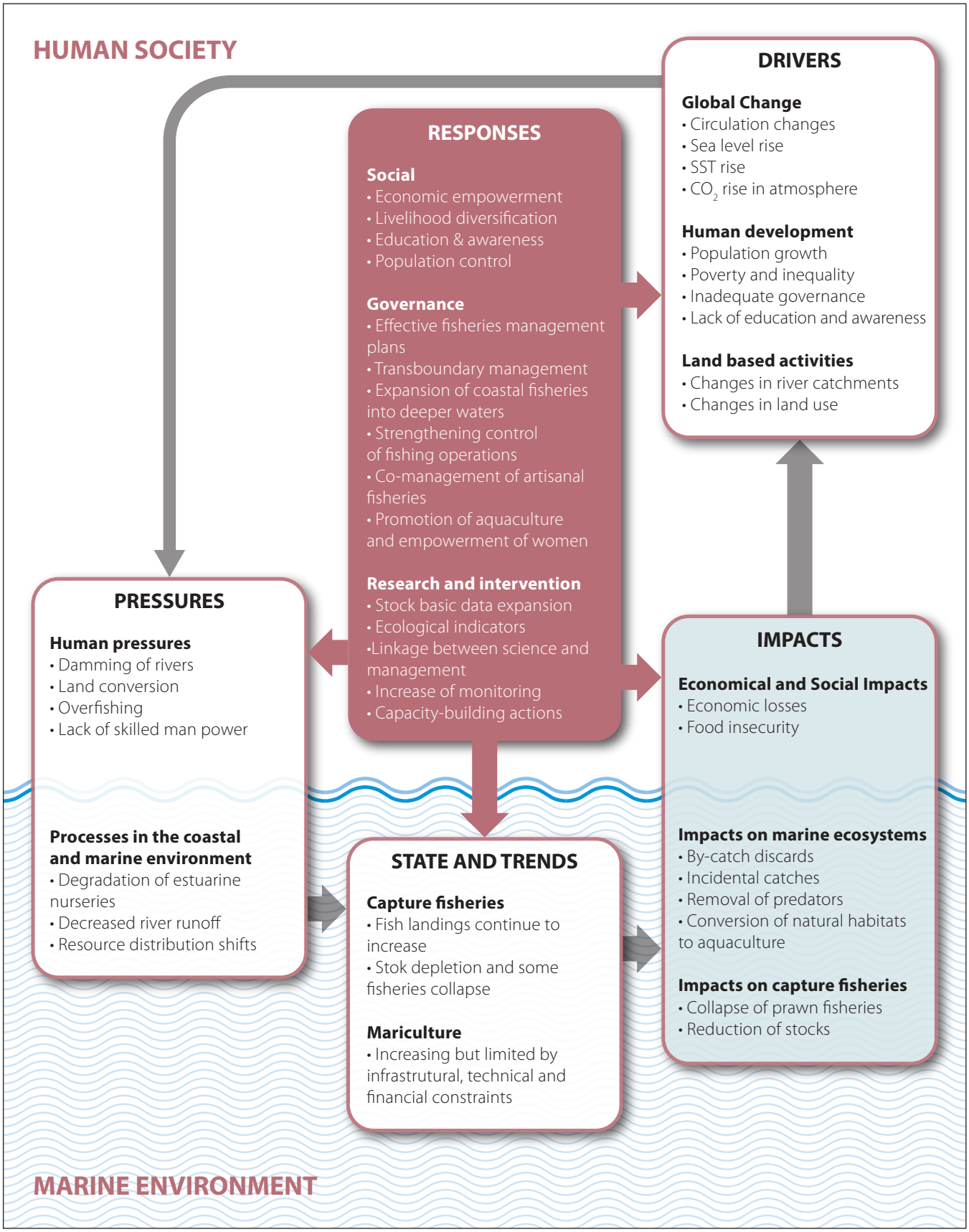
- Promote **awareness** at various levels (resource users and managers, the public, politicians and authorities) regarding the value and vulnerability of the WIO's natural marine capital.
- Increase **funding for research**, to create the knowledge needed for a greater understanding of WIO coastal and 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 transboundary 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**.



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

General recommendations regarding ecosystem services other then 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**.



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

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.

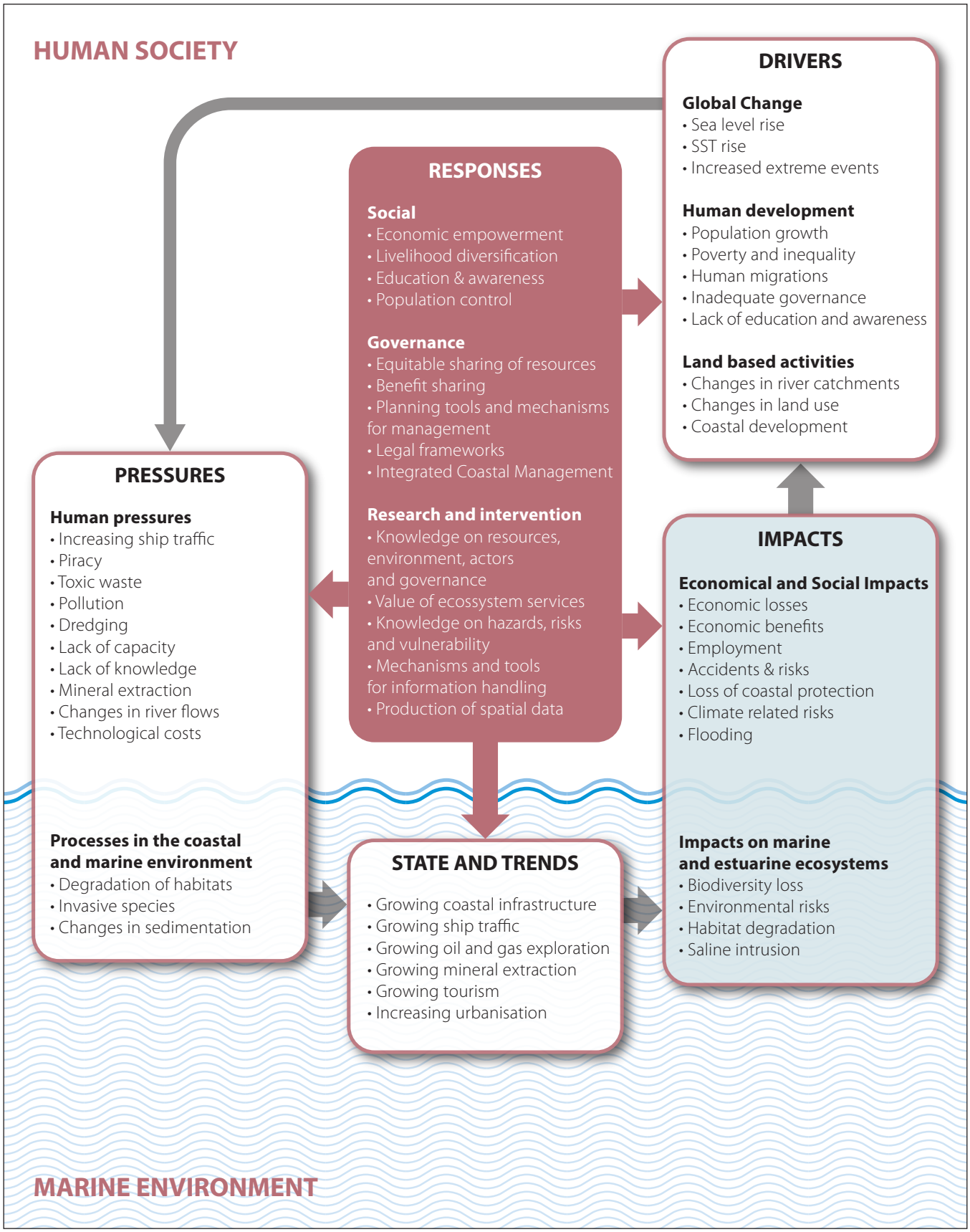
• Promote cooperative **transboundary fish stock management** in the WIO.

• 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.



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

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.

ABBREVIATIONS

ABNJ	Areas Beyond National Jurisdiction
ACLME	Agulhas Current Large Marine Ecosystem
AEO	Africa Environment Outlook
AMCEN	African Ministerial Conference on the Environment
AMCOW	African Ministerial Conference on Water
AQUAMAY	Mayotte Aquaculture Development Association
AR5	IPCC Fifth Assessment Report
ARDA	Association Réunionanaise de Développement de l'Aquaculture
ASCLME	Agulhas and Somali Current Large Marine Ecosystems
ASFIS	Aquatic Sciences and Fisheries Information System
BAU	Business As Usual pathway
BMU	Beach Management Unit
BP	Before Present
CBD	Convention on Biological Diversity
CBO	Community-Based Organization
CCA	Community Conservation Area
CCP	Community Fishing Council
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CDA	Coast Development Authority
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals (also known as Bonn Convention)
COMESA	Common Market for Eastern and Southern Africa
CONNEPP	Consultative National Environmental Policy Process
COP7	Seventh Meeting of the Contracting Parties
CORDIO	Coastal Oceans Research and Development in the Indian Ocean
CPUE	Catch per Unit Effort
CRP	Coordinated Research Project
CRTF	Coral Reef Task Force
CSIR	Council for Scientific and Industrial Research
CWS	Conventional World Scenario
DAFF	Department of Agriculture, Forestry and Fisheries
DDT	Dichloro-diphenyl-trichloroethane
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DESA	Department of Economic and Social Affairs
DEWA	United Nations Environmental Programme's Division of Early Warning and Assessment
DGE	Direction General de l'Environment
DNV	Det Norske Veritas
DOE	Division of Environment
DoT	Department of Transport
DOWA	Deep Ocean Water Application
DPSIR	Driving forces, Pressures, States, Impacts, Responses
DWFN	Distant Waters Fishing Nations
EAA	Ecosystem Approach to Aquaculture

EAC	East Africa Community
EACC	East Africa Coastal Current
EAF	Ecosystem Approach to Fisheries
EARO	East African Regional Programme Office
EAWLS	East African Wildlife Society
EBM	Ecosystem-Based Management
EBSA	Ecologically or Biologically Significant Marine Areas
ECA	Environment Conservation Act
EEZ	Exclusive Economic Zone
EFA	Awareness of Environmental Flow Assessment
EMCA	Environmental Management and Coordination Act
EMPS	Environmental Management Plan of Seychelles
ENSO	El Niño Southern Oscillation
EOF	Empirical Orthogonal Function
EPA	Environment Protection Act
ESIA	Environmental and Social Impact Assessment
ESV	Ecosystem Services Valuation
ETP species	Endangered, Threatened or Protected species
EU	European Union
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organization of the United Nations
FPA	Fisheries Partnership Agreement
GBIF	Global Biodiversity Information Facility
GCRMN	Global Coral Reef Monitoring Network
GDP	Gross Domestic Product
GEF	Global Environment Facility
GPA	Global Programme of Action
WIOMHD	Western Indian Ocean Marine Highway Development and Coastal and Marine Contamination Prevention Project
GEO	Global Environment Outlook
GNP	Gross National Product
GOBI	Global Oceans Biodiversity Initiative
GRID	Global Resource Information Database
HAB	Harmful Algal Bloom
HACCP	Hazard Analysis Critical Control Point
HDI	Human Development Index
IAEA	International Atomic Energy Agency
ICARM	Integrated Coastal Area and River Basin Management
ICZM	Integrated Coastal Zone Management
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IIOE	International Indian Ocean Expedition
IMO	International Maritime Organization
INFOPECHE	Intergovernmental Organization for Marketing Information and Cooperation Services for Fishery Products in Africa
IOC	Indian Ocean Commission
IOC-UNESCO	Inter-Governmental Oceanographic Commission
IOD	Indian Ocean Dipole

IOM	Integrated Ocean Management
IOSEA	Indian Ocean and South East Asia
IOTC	Indian Ocean Tuna Commission
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPOA	International Plan of Action
IISD	International Institute for Sustainable Development
ITCZ	Inter-Tropical Convergence Zone
ITF	Indonesian Through-Flow
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated
JGOFS	Joint Global Ocean Flux Studies
JPOI	Johannesburg Plan of Implementation
KCDP	Kenya Coastal Development Programme
KCMCA	Kuruwitu Community Managed Conservation Area
KCWA	Kuruwitu Conservation and Welfare Association
KFS	Kenya Forest Service
KMA	Kenya Maritime Authority
KMFRI	Kenya Marine and Fisheries Research Institute
KPA	Kenya Ports Authority
KWS	Kenya Wildlife Services
LBSA	Land Based Sources and Activities
LDC	Least Developed Countries
LIP	Large Igneous Province
LME	Large Marine Ecosystem
LMMA	Locally-Managed Marine Area
LNG	Asian Liquefied Natural Gas
MADE	Mitigating Adverse Ecological impacts of open ocean fisheries
MARPOL	MARine POLlution
MASMA	Marine Science for Management programme
MCS	Monitoring, Control and Surveillance
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MEAs	Multilateral Environmental Agreements
MEDA	Marine Ecosystem Diagnostic Analysis
MEOW	Marine Ecoregions of the World
MICOA	Ministry for Coordination of Environmental Affairs
MLRA	Marine Living Resources Act
MMO	Marine Mammal Observer
MNP	Marine National Parks
MOE	Ministry of Environment and National Development Unit
MoET	Ministry of Environment and Transport
MPA	Marine Protected Areas
MTNRE	Ministry of Tourism, Natural Resources and Environment
NATO	North Atlantic Treaty Organization
NBSAP	National Biodiversity Strategy and Action Plan
NCEP	National Centres for Environmental Prediction

NDEIE	National Directorate of Environmental Impact Evaluation
NDS	National Development Strategy
NEAP	National Environmental Strategy and Action Plan
NEC	National Environment Council
NECC	North Equatorial Counter Current
NEM	National Environmental Management
NEMA	National Environmental and Management Authority
NEMA	National Environmental Management Act
NEMC	National Environment Management Council
NEP	National Environment Policy
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
NMEDA	National Marine Ecosystem Diagnostic Analysis
NPA	National Plans of Action
NSP	National Sewerage Program
NTA	Northern Trans-Boundary Section
OBIS	Ocean Biogeographic Information System
OBP	Oceans Beyond Piracy
ODINAFRICA	Africa Marine Atlas
OLR	Outgoing Longwave Radiation
OSS	Ocean Water Salinity
OTEC	Ocean Thermal Energy Conversion
PADH	Physical Alterations and Destruction of Habitats
PAR	Photosynthetically Active Radiation
PES	Payment for Ecosystem Services
PETM	Paleocene / Eocene thermal maximum
POPs	Persistent Organic Pollutants
PSSA	Particularly Sensitive Sea Area
RAC	Regional Activity Centre
RCC	Regional Coordination Centre
RCP	Representative Concentration Pathways
REDD	Reduction of Emissions from Deforestation and forest Degradation
RFMO	Regional Fisheries Management Organization
RSA	Republic of South Africa
RSOCR	Regional State of the Coast Report
RSP	Regional Seas Programme
SABBWWA	South African Boat–based Whale Watching Association
SADC	Southern African Development Community
SAEO	South Africa Environmental Outlook
SAMSA	South African Maritime Safety Authority
SAPO	South African Port Operations
SCLME	Somali Current Large Marine Ecosystem
SCUBA	Self-Contained Underwater Breathing Apparatus
SDG	Sustainable Development Goal
SEA	Strategic Environmental Assessment
SEC	South Equatorial Current
SIDS	Small Island Developing States

SIODFA	Southern Indian Ocean Deep-sea Fishers' Association
SMP	Sewerage Master Plan
SOSA	Subregional Office for Southern Africa
SRC	Service de la Réglementation et du Contrôle
SSH	Sea Surface Height
SSLA	Steric Sea Level Anomaly
SSM	Sub-Surface Chlorophyll Maximum
SSOP	Standard Sanitary Operation Processes
SST	Sea Surface Temperature
STA	Southern Trans-Boundary Area
SWIO	Southwest Indian Ocean
SWIOFC	Southwest Indian Ocean Fisheries Commission
SWIOFish	Southwest Indian Ocean Fisheries
SWIOFP	Southwest Indian Ocean Fisheries Project
SWS	Sustainable World Scenario
TARDA	Tana and Athi River Development Authority
TDA	Trans-boundary Diagnostic Analyses
TEV	Total Economic Value
TRANSMAP	Transboundary networks of Marine Protected areas for integrated conservation and sustainable development: biophysical, socio-economic and governance assessment in East Africa
UN/OLA/DOALOS	Division for Ocean Affairs and the Law of the Sea of the Office of Legal Affairs of the United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNWTO	United Nations World Tourism Organization
UVR	Ultra-Violet Radiation
VME	Vulnerable Marine Ecosystem
WCS	Wildlife Conservation Society
WEIO	Western Equatorial Indian Ocean
WIO	Western Indian Ocean
WIO-C	Consortium for Conservation of Coastal and Marine Ecosystems in Western Indian Ocean
WIOMSA	Western Indian Ocean Marine Science Association
WIO-SAP	Western Indian Ocean Strategic Action Programme
WMA	Waste Water Management Authority
WOA	World Ocean Assessment
WPEB	Working Party on Ecosystems and Bycatch
WSSD	World Summit on Sustainable Development
WTP	Willingness to Pay Principle
WWF	World Wide Fund for Nature
ZATI	Zanzibar Association of Tourism Investors
ZSL	Zoological Society of London