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# Coastal and Marine Research and Capacity Building

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

Most, if not all, of the recommendations contained in this State of the Coast Report, relies on two cross-cutting and fundamental qualities. Firstly, 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 the use and exploitation of resources. In this context, data, information and knowledge are the basis for realising the benefit of an Ocean Economy. Secondly, both the management of resources and the underpinning knowledge base relies on the availability of people with the appropriate capability to be responsible custodians of such resources. Accordingly, education, awareness and training offer a long-term solution for the sustainable development of a coastal and ocean economy.

The core objectives of this chapter are first, to help in the understanding of how national and regional research agendas can contribute to a consistent and complete "bigger picture" of data, information and knowledge required to manage the coastal and marine resources of the Western Indian Ocean (WIO), and secondly, present processes that contribute to the regional and national knowledge-base. The first part of the chapter will examine the past, current and future coastal and marine research priorities at various scales and how research has been or is conducted in the region. The second part of the chapter will explore the development of regional capacity for coastal and marine research and how existing research has been supported in the past. The chapter will conclude with successes on how science has contributed to decision- and policy-making in the region.

## NATIONAL AND REGIONAL RESEARCH

National research and development (R&D) activities and supporting institutional frameworks in the WIO are not homogenous. Each nation has distinctive R&D characteristics, which are a reflection of the heterogeneity of structures and the concentration of R&D by region, institution, sector and even project (UIS, 2010). The heterogeneity of the R&D landscape is reflected in the supporting institutional frameworks and directly influences the coastal and marine research landscape.

Despite the differences in how countries structure their research infrastructure and priorities, Davis and Carden (1998) point out three related and common characteristics of developing countries also relevant to the WIO region. They suggest that not only is R&D in many developing countries highly constrained by funding, but also, that resource allocation procedures are sensitive to personal or political affiliations or entitlements. This is often not balanced out by considerations of efficiency, effectiveness, relevance, utility, or excellence. Secondly, they suggest that developing countries depend on international scientific assistance, which has its own frequently changing investment agenda. Finally, Davis and Carden (1998) argue that to be effective, R&D must be part of an "innovation system" or "innovation community", in which active relationships and communication exists between researchers

and other actors such as intermediaries, coordinating institutions, educators, extension agents and, especially, users.

### Research Investment

Socio-economic disparities between WIO states are stark, especially comparing literacy and unemployment rates. There are also large disparities in key socio-economic indicators that can influence R&D potential such as Gross Domestic Product (GDP), which varies from US$ 592 000 million for South Africa to less than US$ 1 000 million for Comoros. According to the World Bank (The World Bank, undated) R&D expenditure (per cent of GDP) is defined as the current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. Based on this indicator, less than 1 per cent of GDP is provided to R&D in all of the WIO countries (see Table 35.1). South Africa spends on average 0.8 per cent on R&D (intermittently measured between 1997 and 2009) while most other WIO countries report expenditure between 0.1 and 0.4 per cent on R&D. This does not compare favourably to developed countries which spend between 1.5 and 3 per cent of GDP on R&D. Encouragingly, Kenya has taken a formal position on the value of R&D for national development by passing into law the Science, Technology and Innovation Act of 2012, which mandates a 2 per cent GDP spend on R&D.

### Systems of Innovation

Most countries in the WIO hold some level of institutionalised science, technology and innovation (STI) "system". These are primarily organised by ministries assigned to manage science and technology. In many cases, there are institutions specifically constituted to facilitate and develop STI. These innovation systems often attempt to create a relationship between national growth and development objectives, and scientific research priorities.

Over and above our understanding of the regional R&D landscape as demonstrated by the examples in Table 35.2, some general comments can be made relating to countries in the region:

- The extent to which the coastal and marine environment is acknowledged as an important element of national growth and development varies between countries;
- Most countries in the WIO spends less than 1 per cent of GDP on R&D activities;
- National science, technology and innovation strategies and institutional frameworks exist in some WIO countries;
- The connectedness between coastal and marine research institutions and the national STI frameworks of the WIO is often weak;
- Coastal and marine research needs are not always clearly expressed within national STI frameworks.

## A HISTORY OF MARINE RESEARCH AND CAPACITY BUILDING IN THE WESTERN INDIAN OCEAN

Despite being regarded as the least studied region of the Indian Ocean, the WIO region has a long history of coastal and marine research and capacity building. Associates of Carl Linnaeus undertook the first known investigation of

**Table 35.1.** Research and development (R&D) expenditure (per cent of gross domestic product) of selected countries in the Western Indian Ocean compared with India, Portugal and the United States of America.

| Country Name | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Mean % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| India* | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | | | | | 0.7 |
| Kenya | | | | | | | | | | | | 0.4 | | | | | 0.4 |
| Madagascar | | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| Mozambique | | | | | | | 0.5 | | | | 0.5 | | 0.2 | | 0.5 | | 0.4 |
| Mauritius | | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | | | | | | | 0.3 |
| Portugal* | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.7 | 0.7 | 0.7 | 0.8 | 1.0 | 1.2 | 1.5 | 1.6 | 1.6 | 1.5 | 1.0 |
| Tanzania | | | | | | | | | | | | 0.4 | | | | | 0.4 |
| United States* | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.6 | 2.6 | 2.5 | 2.6 | 2.7 | 2.7 | 2.9 | 2.9 | 2.8 | 2.8 | 2.7 |
| South Africa | | 0.6 | | | | 0.7 | | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | | | 0.8 |

**Table 35.2.** Science, technology and innovation in selected countries (in alphabetic order) of the Western Indian Ocean.

| Recognisable Science, Technology and Innovation System | Legislation and Policy | Status in relation to Coastal and Marine Relevance |
|---|---|---|
| **Comoros** - Science and technology is primarily driven by the Ministry of National Education, Research, Culture, and Arts charged with youth and sports. | National Policy of Higher Education and Research 2020 (UDC 2013) | The focus is on strengthening the higher education and research systems which are considered extremely weak. Does not identify research priorities in any particular area. The concept of identifying or recognising coastal land marine issues with the national system of innovation is weakly developed. |
| **Kenya** – The National Commission for Science, Technology and Innovation (NACOSTI, undated) has the goal of establishing a strong foundation on science, technology and innovation (STI), with research playing a key role in generating a critical mass of technical and skilled manpower. | Science, Technology and Innovation Act, 2013 Science, Technology and Innovation Policy and Strategy (RoK 2008). | The Kenya Marine and Fisheries Research Institute is listed as an institution to which the act applies. This institute deals with natural resources, water development, health, and power and communications. Research into the marine and coastal environment features strongly in their mandate, as does environmental and ecological management studies. The STI policy specifically mentions the need for environmental management in order to provide a clean and safe environment for citizens while also protecting livelihoods. |
| **Mauritius** - There are a number of agencies dealing with STI ie Ministry of Industry, Science and Research, Mauritius Research Council, Rajiv Gandhi Science Centre. | Transforming Mauritius into a Knowledge Hub (HRDC 2006) | The concept of identifying or recognising coastal land marine issues with the national system of innovation is weakly developed. |
| **Mozambique** - Explicit policy measures are integrated into the Mozambique Strategy for Science, Technology and Innovation, which was proposed by the Ministry of Science and Technology. | Mozambique Strategy for Science, Technology and Innovation (RoMZ 2006) | The ability of the Strategy to drive coastal and marine research was difficult to assess but appears to be limited. The concept of identifying or recognising specific coastal land marine issues within the national system of STI is weakly developed. It does not appear to facilitate a process for the expression of national research priorities, and the engagement of research with national research funding instruments appears to be limited. |
| **South Africa** – The Department of Science and Technology (DST) is responsible for scientific research in the country and oversees the management of the country's relatively well-developed science system. The key institution, in the context of this strategy, for promoting science, is the National Research Foundation, which is linked to the higher education sector through the National Plan for Higher Education | National Research and Development Strategy (RSA 2002) | The strategy document does not make any special mention of the biophysical environment or the coastal/ marine environment. The concept of identifying or recognising coastal land marine issues with the national system of innovation is moderately developed. |
| **Tanzania** – The Commission for Science and Technology (COSTECH) is a semi-state organization with the responsibility of co-ordinating and promoting research and technology development activities in the country (COSTECH, undated). It is the chief advisor to the Government on all matters pertaining to science and technology and their application to the socio-economic development of the country. Major national research and development institutes are affiliated to COSTECH. | National Research and Development Policy (URT 2010) | It's quite difficult to discern the relevance of this organisation to coastal and marine environment issues in Tanzania. Very few of the R&D institutions listed on their website deal specifically with the coastal environment (Tanzania Fisheries Research Institute for example) while the majority of them are focused on agriculture and livestock, industry and energy, and medicine and public health. |

marine life in the WIO region in the mid-1700s (Richmond 2011). Further investigations followed years later and were undertaken as part of major global exploratory expeditions. These include expeditions such as H.M.S. Endeavour (1768-71), H.M.S. Beagle (1831-1935) and Challenger (1873-76) (Richmond 2011). Since then, scientific cruises and expeditions have continued to be an important means for conducting scientific research, particularly in offshore areas. Importantly, most of the cruises in the region were conducted by foreign countries such as Belgium, Norway, Germany, the Netherlands and United Kingdom. South Africa is the only country in the region that has organized regional cruises. In the other countries, locally organized cruises have concentrated on waters within national bor-

ders. Accordingly, most of the marine research conducted in the region to date has encompassed nearshore waters using small vessels that are limited in range and technical capacity. One outcome of this situation is that there is some reasonable understanding of a few of the key habitats and ecosystems close to shore, but the regional knowledge of deep-water habitats and resources is rather limited.

By the early 1960s, only five research institutions/stations existed in the WIO region. These were: the Maritime and Fisheries School of Mogadishu; the East African Marine Fisheries Research Organization (EAMFRO), with substations in Mombasa and Zanzibar; the Institut de Recherche Scientifique (Madagascar); the Inhaca Island Marine Biological Station (Mozambique) and the Oceanographic Research Institute (ORI) (South Africa). Their main focus was to compile inventories of marine life and resources, particularly fisheries. The situation is different today, as the number of academic and research institutions that deal with different aspects of marine science has increased significantly, with all the WIO countries having more than one institution (Table 35.3).

Most of the research institutes in the region have basic field instruments, boats, diving gear, and specialized laboratories, with infrastructure and laboratories in most cases developed intermittently through externally funded projects. Various capacity-building activities have been undertaken within and outside the region under the auspices of a range of donor organisations. Examples include support from the governments of Sweden (through Sida and SAREC), Norway (through NORAD), Japan (through JICA), and overseas development assistance (ODA) facilities offered by many other governments, as well as structured partnerships between local and foreign universities (historic), and China and South Korea, more recently. Within these initiatives, short-courses and training workshops (1-3 weeks), with some longer-term degree courses (1-4 years) has been a primary vehicle for improving local capacity.

The relationship between science and policy in the region has changed considerably over the years. Traditionally the pipeline mode existed in which scientists set the research agenda, conduct the research, and then transfer the results to potential users. This has evolved into co-production of knowledge under a more modern approach, whereby scientists and decision-makers define the research agenda and on a regular basis scientists provide feedback to the policy community. Whilst the full gains from this transition have not yet been totally appraised or audited (accounted) for, the extent to which this new approach has improved awareness and engagement in marine resource management is reflected by the investments being made in this domain. This change has been possible due to the associated change occurring in the way in which research topics are selected. Historically, research topics were commonly selected to meet academic criteria and most of the times reflected the interests of either students or supervisors with limited or no links to priority resource management questions. In the recent past, and through programmes such as Marine Science for Management (MASMA), through WIOMSA, inter and multi-disciplinary research has been promoted to address urgent societal and resource management issues.

**Pre-independence**

Prior to the 1960s most countries in the WIO region were under colonial rule. Accordingly, marine and coastal research in these countries was driven by the perspectives of remote decision-makers who relied on reports rather than direct local engagement. Importantly, however, a number of developments which took place during this period are the foundation for some of the institutional capacity currently existing in the region.

The notable pre-independence scientific cruises and expeditions that took place from 1789 to 1960 (described above), were followed by the 20th century expeditions of H.M.S. Mabahiss (1933-34) and the International Indian Ocean Expedition (IIOE) (1959-1965). The IIOE involved scientists from 23 countries, 44 research vessels and numerous airborne data-collecting devices and satellites (Morcos 2002). Whilst early expeditions focused mainly on the collection of biological specimens and plankton, the study of biological and chemical processes, inventories of marine life and resources, particularly fisheries, and recording of basic oceanographic processes, the later IIOE encompassed almost all marine science disciplines, except perhaps fishery research and marine microbiology (Rao and Griffiths 1998). The IIOE contributed a wealth of knowledge on many aspects of the WIO including the discovery of the mid-Indian Ocean ridges (including the Southeast Indian Ocean Ridge) the famous triple junction south of the Seychelles, where the southern end of the Carlsberg Ridge meets the Southwest Indian Ocean Ridge (Rao and Griffiths 1998), the effects of the monsoons on the Somali Current, and upwelling off the Somalia coast.

In addition to oceanic expeditions, this period was also characterised by the establishment of the first initiatives leading to the founding of marine biological stations. These were:

• The founding of the Zanzibar Marine Station in 1948 with the Mombasa Marine Station and the ensuing formation of the East African Marine Fisheries Research Organization (EAMFRO), in 1953. The Zanzibar Marine Station has become the Institute of Marine Science (IMS) of the University of Dar es Salaam and the Mombasa Marine Station is now the Kenya Marine Fisheries Research Institute (KMFRI).

• The Inhaca Island Marine Biological Station, established by the Portuguese administration in 1953 in conjunction with the University of the Witwatersrand, is now part of the Universidade Eduardo Mondlane (UEM).

• Between 1962 and1973, the French organization 'Office de la Recherche Scientifique et Technique d'Outre-Mer' (OSTROM) established and managed a marine station in Nosy-Be, Madagascar, later reopened in 1978 as the Centre National de Recherches Oceanographiques (CNRO).

• In 1961, the University of Marseille established 'Station Marine de Tuléar', attached to the Faculty of Science, University of Antananarivo. This station became L'Institut Halieutique et des Sciences Marines de l'Universite de Tuléar.

• The Oceanographic Research Institute (ORI) was established as the research wing of the South African Association for Marine Biological Research, a non-profit NGO affiliated to the University of Natal, in 1953/4.

Despite the existence of these stations during the IIOE, their limited human resources and technical capacity largely prevented them from participating in the expedition or benefitting directly from training and educational opportunities provided by the International Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

In addition, there were no universities or colleges in the region offering courses in marine sciences during this period, such that apart from ORI, all of the scientists working in these research stations were foreigners.

**Post-independence to the 1980s**

Most of the countries in the WIO region achieved independence between 1961 and 1976. As governments across the region strived to consolidate their economies and infrastructure in the early 1960's, marine science research was not given priority. For instance, in 1962, a decision was taken to close the EAMFRO as it was argued that marine science was unlikely to provide immediate economic benefit to East Africa. This decision was later rescinded (EAMFRO 1965).

From the 1970s onwards, a change in thinking began to emerge, resulting in the implementation of a range of initiatives that played a catalytic role in the development of marine science in the region, including capacity-building programmes. In April 1974, the International Centre for Marine Resources Development of the University of Rhode Island organized the International Conference on Marine Resource Development in East Africa in collaboration with the University of Dar es Salaam. This conference was specifically aimed at providing a discussion forum for scientific and developmental issues pertaining to marine science capabilities in the region. It also encompassed issues related to the marine resource potential and capacity needs of the East Africa region. Notably, the conference recommended the establishment of an institute of marine sciences at the University of Dar es Salaam (Morcos 2002). Three years later, with the collapse of the East African Community (EAC) and EAMFRO, the University of Dar es Salaam took over the facilities in Zanzibar and established the Institute of Marine Sciences in 1978.

Another important event that played a key role in the development of scientific research in the region was the creation of a regional body, the Cooperative Investigations in the North and Central Western Indian Ocean (IOCINCWIO), by the IOC of UNESCO. Two preparatory meetings were held to prepare for the establishment of the IOCINCWIO, the first in Zanzibar in 1975, and the second in Nairobi the following year. Several oceanographic and atmospheric research programmes were undertaken in the region between these meetings and the first session of the IOCINCWIO was convened in 1982. The initial research programmes included the Special Observing Period Program of the Monsoon Experiment (MONEX) which took place in 1978 to 1979 and carried out oceanographic and atmospheric observations on the whole of the Indian Ocean north of 10°S. In the WIO region, the studies focused on phenomena such as the Equatorial Current, Somali Current and upwelling currents off Somalia (Morcos 2002).

Throughout the 1970s governments in the region increasingly recognised the importance of marine science and awareness of coastal and marine issues grew widely.

This was significant in influencing the Third UN Conference on the Law of the Sea, which started in 1973, and culminated with the adoption of the UN Convention for the Law of the Sea in 1982. The latter resulted in the establishment of the United Nations Environment Programme (UNEP) in 1973 and subsequently a Regional Seas Programme by UNEP that also helped to enhance technical support on marine research from UN organizations and developed countries. Between 1970 and 1980, technical assistance and financial support for national and regional marine science projects came from UN organizations such as the IOC, UNESCO, FAO, and World Meteorological Organization (WMO). Developed countries, such as the US, Norway, UK, Canada and France provided technical assistance and opportunities for undergraduate and postgraduate training through bilateral programmes. The Norwegian Government provided the R/V Fridtjof Nansen to the Mozambique Government, and later to other governments, to conduct fisheries and oceanographic surveys in Mozambican waters in 1977-1978.

The 1970s were also marked by missions to the region by developed countries on their own initiative or in collaboration with the UN organizations. These commonly aimed to investigate the priorities and needs for capacity-building in the marine sciences and included visits to Kenya, Madagascar, Somalia and Tanzania.

### From the 1980s to the present

As a reflection of the importance of marine and coastal resources, the past 35 years has seen a remarkable growth in marine science research across countries in the WIO region. This is exhibited by both the enhancement of existing programs and the development of new initiatives. This has encompassed regional legal and institutional frameworks, academic and research institutions, regional research programmes, increased financial and technical support, and increased partnerships.

### *New and Existing Regional research and management Frameworks for marine and coastal environment*

A number of collaborative activities between funding agencies, donors and regional governments were implemented between 1997 and 2001. Notably, the IOC-INCWIO, funded by IOC, Sida, the Belgian Government and UNEP implemented a number of activities. These included providing funds for regional cooperation in scientific information exchange, ocean mapping, a regional nutrient and water quality monitoring network, the installation and maintenance of sea level stations and strengthening regional institutions such as WIOMSA. Activities on scientific information exchange were built on the foundation laid by the Belgium Government-supported project 'Regional Cooperation in Scientific Information Exchange in the Western Indian Ocean region' (RECOSCIX-WIO), which was established in 1989 and focused on the development of capacity and infrastructure for the collection, processing, archiving, analysis, interpretation and dissemination of data and information. The RECOSCIX-WIO project ended in 1997 and was replaced by the Ocean Data and Information Network for Africa (ODINAFRICA), which started in 1997 and is now in its fourth phase. The focus of the current phase of the project is on product development and dissemination and strengthening of the Pan African network of National Oceanographic Data Centre (NODCs). The project has produced directories, catalogues, atlases and portals.

With more of a focus on management and coastal protected areas, the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region (Nairobi Convention) was enacted in 1985 and came into force in 1996 through its East Africa Action Plan. This initiative supported the implementation of a number of projects focusing on management and protection of coastal areas (EAF/5), the control of marine pollution (EAF/6) and a regional database and atlas of coastal and marine resources (EAF/14). In contrast to the historic situation in the 1970s and 1980s, the projects in this program were implemented by research and academic institutions in the Convention countries rather than by external research organisations or institutions.

In 2004, the Nairobi Convention facilitated the establishment of the Forum of Heads of Academic/Research Institutions (FARI). Core objectives of the Forum were to facilitate the sharing of information between these institutions and the Nairobi Convention, as well as amongst themselves; engage and facilitate opportunities for collaborative research that are relevant to the Nairobi Convention; and offer scientific and technical advice on priorities for management, assessments and information dissemination within the Nairobi Convention.

The Nairobi Convention Secretariat was the Executing Agency for the GEF-funded project "Addressing land-based Activities in the Western Indian Ocean," (WIO-LaB

Project), which undertook a region-wide assessment of transboundary problems and issues affecting the marine environment in the WIO region between 2004 and 2010. The outputs of these assessments led to the formulation of a Transboundary Diagnostic Analysis (TDA), detailing key problems and causes of degradation of the coastal and marine environment in the WIO region, with special emphasis on land-based sources and activities (LBSA) and the Strategic Action Programme (SAP) to address the challenges faced by governments in the region.

Both IOCINCWIO and the Nairobi Convention leveraged national support by involving research and academic institutions in the region in the implementation of their activities and, thereby, contributed to strengthening national institutional and human capacity.

### *New and Existing Legal and Institutional Frameworks*

Both the 1992 UN Conference on Environment and Development in Rio de Janeiro, and the 2002 World Summit for Sustainable Development in Johannesburg, prompted many countries, including the WIO countries, to revise or develop national legal instruments, on environment, by incorporating principles of sustainable development. For instance, Tanzania developed the following environmental-related policies and acts after these major conferences: the Marine Parks and Reserves Act (1995), the National Environment Policy (1997), the National Fisheries Sector Policy (1997) and the National Integrated Coastal Management Strategy (2003). Similar action was taken by the other WIO countries.

Research and academic institutions were involved in the revision and development of new legal instruments, and further provided technical inputs to the processes and benefitted from the policy-making community thereby strengthening the relationship between science and policy making. Research and academic institutions have contributed to the implementation of some of the aspects of the legal instruments. In Tanzania, research and academic institutions were actively involved in the drafting of the Marine Parks and Reserves Act and the National Integrated Coastal Management Strategy and their implementation. As an example of the latter, the Institute of Marine Sciences played an important role in the establishment of the Mafia Island Marine Park and Mnazi Bay Marine Park between 1995-2000 as part of the implementation of the Marine Parks and Reserves Act.

### *New and Existing Academic and Research Institutions*

The increase in human capacity for marine science research, as well as increasing recognition of the importance of the marine ecosystem goods and services by governments has led to the establishment of new academic and research institutions (Table 35.3). More universities in the region are now offering postgraduate degree programmes in areas of marine and coastal science and associated resource management disciplines. For instance, in Kenya, the number of universities that teach courses with a marine and coastal focus has increased from one before 1980 (ie University of Nairobi) to more than five. In the 1980s, the University of Dar es Salaam offered courses on marine systems in the Department of the Zoology and Marine Biology but this was changed first to the Faculty of Aquatic Sciences and Technology and later to the Department of Aquatic Sciences and Fisheries, which currently offers two degrees programmes at the undergraduate level. Both the Department of Aquatic Sciences and Fisheries and the Institute of Marine Sciences now offer Masters and PhD degree programmes. In Mauritius, both the Albion Fisheries Research Institute and the Mauritius Oceanography Institute were established after 1980.

At present, there is at least one University offering degree programmes on marine related field in all the countries in the region except Somalia. Additionally, a number of non-governmental organizations have increased their support to research by publishing seminal papers to complement the traditional academic and research institutions. The Wildlife Conservation Society, through its Kenya and Madagascar offices, and CORDIO have been the most active.

### *Development of Bilateral and Regional Research Programmes*

Since the 1980s the region has benefited from a number of bilateral and regional research programmes which have contributed significantly to strengthening of human and institutional capacity in regional academic and research institutions. Perhaps just as importantly, these programmes have also underpinned the development of strong partnerships between regional institutions and their counterparts in developed countries. Examples of such programmes include the following:

- The **Sida/SAREC Regional Marine Science Programme** started in 1993 with the aim to carry out

research on the sustainable use of coastal and marine resources, and environmental management of the coastal zone. This Programme supported the two Ministerial Conferences on Integrated Coastal Zone Management (ICZM) in Arusha, Tanzania (1993), and the Seychelles (1996). These events set the stage for coastal management initiatives at local and national levels in the region and successfully initiated dialogue between the scientific community and high-level policy-makers. The programme made modest investments in capacity building in the social sciences, which resulted in notable achievements in this arena. This Programme also facilitated the establishment of WIOMSA and CORDIO.

• The **Sida/SAREC Marine Science Bilateral Programme for Tanzania and Mozambique**. The Bilateral Program for Mozambique was initiated in 1985 while the Bilateral Program for Tanzania started in 1990. Both programmes are still ongoing. Their combined impact has produced significant advances towards the goal of a diversified resident capacity in the marine sciences that will contribute towards effective management of coastal ecosystems. This has, in turn, prompted greater local investments in the natural sciences to increase this diversity and the wider local capability in coastal resource management disciplines. The programme's most notable achievement has been the transformation of the Institute of Marine Sciences (IMS) of the University of Dar es Salaam into an internationally recognized institution. IMS is attracting funds from a diversity of sources, hosts visiting scholars from many nations, and is making significant contributions to public policy and resource management in Zanzibar, Tanzania and the region.

• The **Kenya – Belgium Programme in Marine Sciences**. This programme started in 1985 and involved the Free University of Brussels (VUB) and the KMFRI, resulting in the training of a number of Kenyan students to Masters and PhD level. The programme also supported a number of studies in Kenya undertaken by Kenyan and Belgium scientists. It also constructed and equipped laboratories at KMFRI.

• **GEF-funded regional programmes**. The region implemented three regional GEF-funded projects during the ten years from 2004 to 2014. These were 'Addressing Land-Based Activities in the Western Indian Ocean' (WIO-LaB), 'the Southwest Indian Ocean Fisheries Project' (SWIOFP) and the Agulhas and Somali Current Large Marine Ecosystems Project' (ASCLME). Scientists and experts from regional universities and research institutions, as well as government agencies, were closely involved in project activities including through participation in regional and national task forces and working groups, preparation of the TDA and SAP and in advisory roles to the demonstration projects. The project collaborated closely with WIOMSA and facilitated creation of the Forum of Heads of Academic and Research Institutions (FARI) in the region as a mechanism to coordinate research activities and assure the quality of scientific work in the region. The ASCLME and SWIOFP Projects, together with partners in the EAF Nansen Project, NOAA, NIOZ, IUCN and the IRD, undertook or co-funded over 50 offshore expeditions in the WIO region (Box 35.1).

• **EU-funded projects.** From the mid-1990s up to 2010, the European Union supported a number of research programmes in the region through its framework programme: Specific Measures in Support of International Co-operation (INCO-DEV). These included the 'Transboundary networks of marine protected areas for integrated conservation and sustainable development: biophysical, socio-economic and governance assessment in East Africa (TRANSMAP)' and the 'Peri-urban mangrove forests as filters and potential phytoremediators of domestic sewage in East Africa (PUMPSEA)'. A total of 24 research and management authorities in regional participating countries and European institutions were involved in these projects. They supported a number of Masters and PhD candidates, undergraduate students, provided equipment, and produced a number of high quality publications and scientifically based advisory documents for application in policy development and management.

• **Marine Science for Management (MASMA).** In 2001, WIOMSA initiated a regional programme known as Marine Science for Management (MASMA) with financial support from Sida/SAREC. A principal component of MASMA is a competitive grants programme to support regional research. In addition to this, there are three other related and mutually reinforcing operational components of MASMA: 1) Institutional strengthening of WIOMSA to administer and coordinate research activities; 2) training and outreach in the region, regional networking, research priority setting and professional development through short courses, seminars, and workshops; and 3) the communication and dissemination of research results and information. WIOMSA has organized eight Scientific Symposia through this programme, which have been held triennially since 1997, it has established the Western Indian Ocean

Journal of Marine Science in 2002, produced 16 books under its Book Series, and supported other books published by prominent publishing firms such the Oxford University Press and University of Cape Town Press. Between 2000 and 2014, WIOMSA supported at least 210 Marine Research Grant (MARG-I) projects and 46 large regional research projects, which were implemented in all the countries in the region except Somalia. Over 600 publications have been produced through these grants (Figure 35.1).

### *Increased financial and technical support*

In most of the countries in the region budgetary allocations for research and capacity-building by governments are generally insufficient and highly variable. Government funds are almost exclusively sed to pay for salaries alone. This funding limitations means that most of the research and capacity-building initiatives in the region have been, or are funded by bilateral and multilateral funding agencies, international NGOs and foundations.

As indicated previously, marine sciences and capacity-building initiatives in the WIO region have historically received significant levels of support from these external sources. This support has been directed towards research projects, the provision of scholarships for postgraduate training, organisation of workshops and courses, and, in some cases, the provision of physical infrastructure (including laboratories, libraries and lecture rooms) and supplies. To illustrate the increasing levels of support received in the WIO through WIOMSA, the Government of Sweden financial support to WIOMSA from its establishment in 1995 to 2011 is used as an example (Figure 35.2).

### *Increased Partnerships*

Different types of partnerships have been developed through bilateral and regional programmes, including south-north and south-south partnerships. These partnerships have resulted in enhanced collaboration in research and capacity-building amongst experts, both within the region and between the region and outside. Successes of these partnerships are reflected in the increased number of joint proposals developed and implemented, an exchange of students and staff, and the joint production of publications.

The Sida/SAREC Regional Marine Science Programme, Sida/SAREC Marine Science Bilateral Programme for Tanzania and Mozambique, the Kenya–Belgium Programme in Marine Sciences, EU-funded programmes under the Framework programme and MASMA, have all contributed to strengthen the collaboration between research and academic institutions in the WIO and those in Europe (such as the Stockholm University in Sweden, University of Lisbon, Free University of Brussels), Australia (the University of Queensland and James Cook University) and USA (University of Rhode Island).

Partnerships between and among institutions in the region have also improved over the last decade. This improvement is also largely attributable to the bilateral and regional programmes that have catalysed exchange, inter-

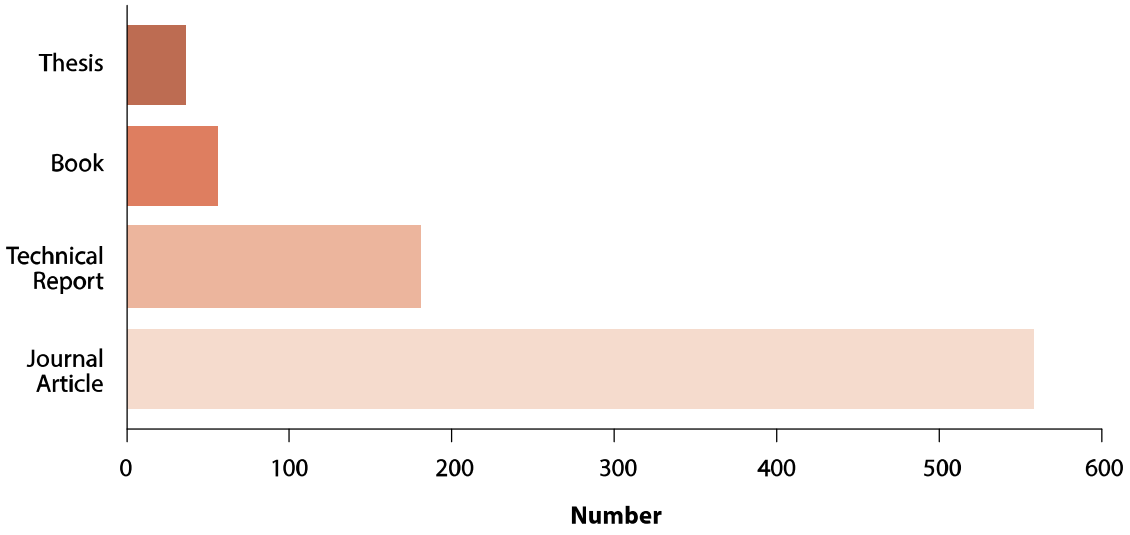



**Figure 35.1.** Publications produced with support of WIOMSA between 2000 and 2014. Source: data from Google Scholar.

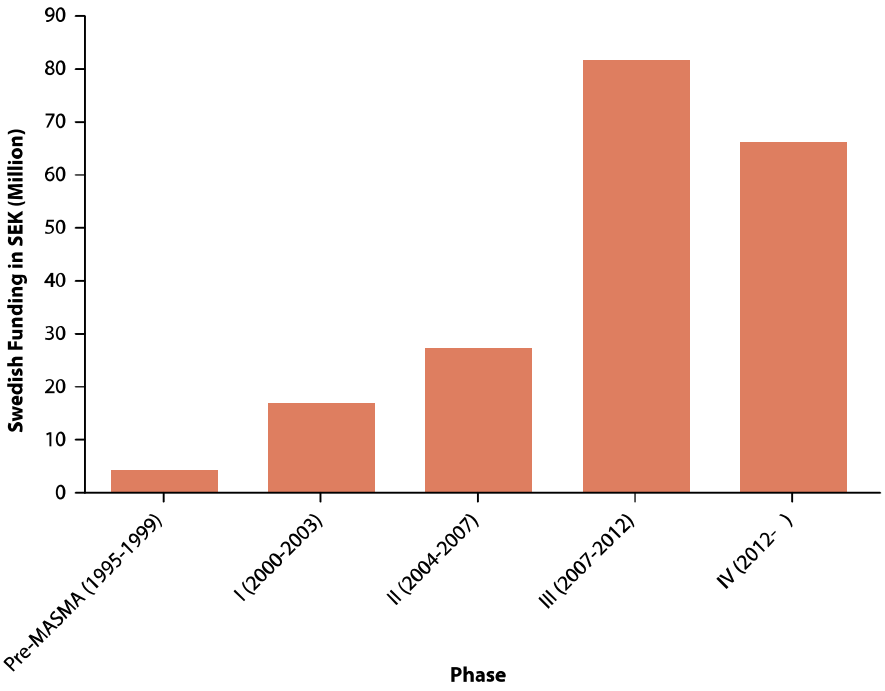



**Figure 35.2.** Government of Sweden support to WIOMSA from 1995 to 2015.

action and dialogue between organisations such that new relationships have been supported to become strong long-standing partnerships (eg KMFRI-IMS, ORI-UEM). MASMA has also played a key role in strengthening south-south partnerships by having this prerequisite as one of its main requirements to secure funding. Partnerships between academic and research institutions in Kenya and Tanzania, Tanzania and Mozambique, Mozambique and South Africa and South Africa with Mauritius and Reunion have been established through MASMA and EU-funded projects, a number of which are on-going.

## WHO IS CONDUCTING RESEARCH?

In the WIO, government research institutions are important actors in the production of knowledge relevant to the coastal and marine environment. This is particularly the case in fisheries, but some countries also have research institutions concerned with a variety of coastal and marine environment domains. In some government-affiliated research institutions, and in particular kinds of research, there is a direct linkage between the production of knowledge and its application. Management authorities in the region often meet their knowledge needs by commissioning studies to government research institutions, consultants and, sometimes, universities (Figure 35.3). In this case, there is also a direct link between research and its application. However, there are also a number of institutions producing unsolicited research that could contribute to coastal and marine management but there are no formal mechanisms that could be used to channel them through.

## RESEARCH UPTAKE

The use of research outputs by decision- and policy-makers cannot be represented as a linear relationship between supply and demand. How and why science is produced and balanced between national and local needs is influenced by, amongst other things, the availability of funds which may or may not be linked to national and sub-national (provincial, district, local) priorities. Given the significant percentage of the research budget that comes into the WIO from external sources, and not national budgets, research agendas may sometimes not be well harmonised with national or sub-national needs. In the WIO, lack of clearly expressed national research priorities for marine and coastal management is an important factor that limits the potential to improve this alignment need and, accordingly, the applicability of research for management, decision and policy

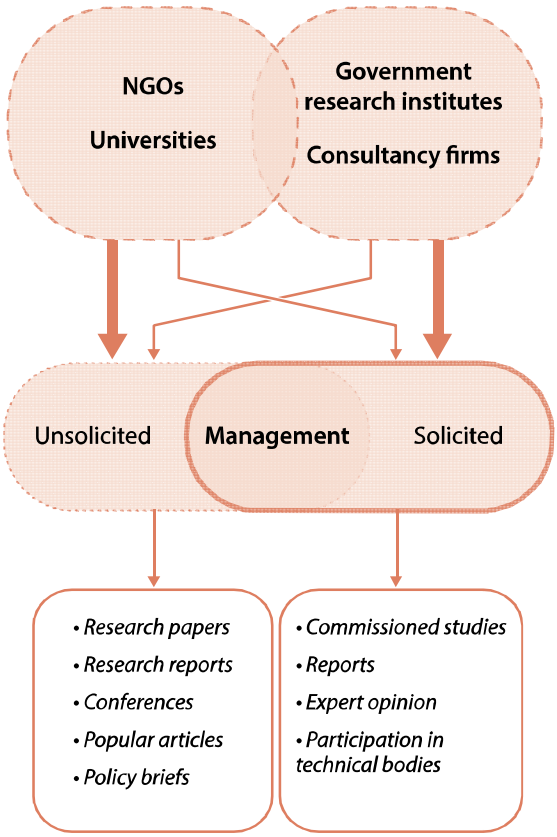



**Table 35.3.** Research and academic institutions in the WIO region (those with degree programmes in marine sciences are bulleted).

purposes.

The mechanisms used by research institutions to couple science to management, and barriers to achieve this, are contextual and vary between countries. Research institutions in the region are generally committed to producing research that contributes to national development needs, including those related to the sustainable management of the coastal and marine environment. Similarly, scientists in both government-affiliated and academic institutions recognise the importance of undertaking applied research and transmitting research results to potential users. Despite wide acceptance of the need to link science and management, the mechanisms to identify research priorities in the coastal and marine environment and to communicate research results to managers and policy-makers are often still poorly developed.

It is also clear that simply transmitting scientific results to decision-makers, while important, is not sufficient to effectively enable their uptake by managers. The use of science by decision-makers in the region, and elsewhere in the world, is influenced by many procedural, technical, and political factors. The role of individual and institutional values is also important. In this context, there continues to be a need for the development of new and innovative approaches to better integrating research agendas with management planning and decision-making processes such that both the development of research and the products it delivers are better integrated into an overall approach to natural resource management.

Examples of science that supports management can be gleaned from cases involving institutions and procedures that explicitly connect science to management. These can take many forms, but often involve mechanisms to identify and fund emerging research. Studies linked to extension or that include a demonstration of the feasibility of new approaches and solutions, and are ultimately aimed at replication, appear to be more successful in their 'uptake'. For instance, the MASMA-funded project, *"Determination of the Distribution and Characteristics of Fish Spawning Aggregation Sites (FSAS) and their Importance to the Artisanal Fisheries Resources of Seychelles"*, successfully convinced the Islands Development Company (IDC) of Seychelles (that was

**Figure 35.3.** Reported flow of communication between institutions producing science and agencies that use science related to research, development and management of the coastal and marine domain of the Western Indian Ocean states.

| Country | Government research institutions and Universities | Non-governmental organizations |
|---|---|---|
| Comoros | University of the Comoros | |
| Kenya | Kenya Marine and Fisheries Research Institute (KMFRI)<br>Technical University of Mombasa<br>BSc (Marine Resource Management & Fisheries and Oceanography)<br>MSc (Fisheries and Aquaculture)<br>Eldoret University<br>BSc (Coastal and Marin e Resource Management)<br>South Eastern Kenya University<br>BSc ( Fisheries Management and Aquaculture Technology; Aquatic Sciences)<br>MSc Aquaculture<br>Pwani University<br>BSc (Marine Biology and Fisheries)<br>PhD (Fisheries)<br>Jomo Kenyatta University of Agriculture & Technology (JKUAT)<br>BSc (Fisheries and Aquaculture Sciences and Marine Engineering)<br>MSc (Aquatic Ecology and Fisheries and Phycology) | |
| Madagascar | Institut Halieutique et des Sciences Marines (IHSM), University of Tuléar<br>BSc, MSc and PhD<br>Centre National de Recherche Oceanographic (CNRO)<br>Station de Recherche Oceanographique de Vangaindrano (SROV) | Blue Ventures, CETAMADA |
| Mauritius | University of Mauritius<br>BSc (Marine Science and Technology)<br>MSc and PhD<br>Albion Fisheries Research Institute<br>Mauritius Oceanography Institute | Marine Conservation Society |
| Mozambique | University of Eduardo Mondlane<br>BSc (Marine, Aquatic and Coastal Biology; Oceanography; Marine Chemistry; Marine Biology; Environmental Engineering; Fisheries Production)<br>MSc (Sustainable Aquaculture; Applied Oceanography; Marine Biology and Fisheries Management; Coastal and Environmental Geology; Environmental Engineering; Aquatic Biology and Coastal Ecosystems)<br>Nautical College of Mozambique<br>BSc (Marine Engineering; Law of the Sea; Maritime Shipping)<br>Polytechnic Institute of Gaza<br>BSc (Fish Farming)<br>National Institute for Hydrograph and Navigation (INAHINA)<br>National Fisheries Research Institute (IIP)<br>Centre for Research of Marine and Costal Environment (CEPAM) | CTV<br>Ocean Revolution |
| Reunion | University of Reunion<br>MSc (Biodiversity, Ecology & Evolution)<br>IFREMER<br>IRD | ARVAM<br>Globice<br>ARDA<br>CapRun<br>CRPMEM<br>BIOTOPE<br>Ocea-Consult<br>BRGM<br>Pareto<br>Vie Oceane<br>Ocea Consult |
| Seychelles | University of Seychelles<br>BSc in Environmental Science<br>Seychelles Fishing Authority | Nature Seychelles |
| South Africa | Council for Scientific and Industrial Research<br>University of KwaZulu-Natal<br>University of Cape Town<br>Nelson Mandela Metropolitan University | Oceanographic Research Institute |

| Country | Government research institutions and Universities | Non-governmental organizations |
|---|---|---|
| Tanzania | University of Dar es Salaam<br>Department of Aquatic Sciences and Fisheries (Aquatic Environmental Sciences and Conservation and Fisheries and Aquaculture and MSc in Fisheries and Aquaculture and PhD )<br>Institute of Marine Sciences (MSc in Marine Science and PhD)<br>Tanzania Fisheries Research Institute (TAFIRI) | Sea Sense |
| Regional NGOs | Wildlife Conservation Society<br>CORDIO<br>WWF<br>CI<br>IUCN<br>WIOMSA | |

involved in the fishing of grouper spawning aggregations) to agree to stop the practise after being presented with the project's results (Robinson and others, 2007).

Finally, projects that involve high degrees of collaboration between scientists, managers and resource users at all stages of the work are more likely to result in outputs that have a probability of being used by managers, decision- and policy-makers. Through another MASMA-funded project, *"Developing a model for strategic adaptive management of MPAs in the Western Indian Ocean"*, project members working with the staff and stakeholders of the Mombasa Marine Park and using their research results as the basis assisted the Park to set new management objectives with measurable targets. They have also used their research results to evaluate progress and determine necessary management actions, and evaluated effectiveness of actions (O'Leary and Tuda 2015).

The main barriers between scientific and policy-making/management communities in the region include:

• A paucity of relevant and timely research, coupled with a willingness and concomitant capacity of decision-makers to use it are important factors. An inadequate knowledge-base and the lack of an evidence-based management culture, technical capacity and funding are also important barriers ensuing from this.

• Several countries lack mechanisms and institutions to promote science-based management and decision-making. Such mechanisms and institutions are developing, often as part of the growing implementation of ICZM, or they may be project-based. Examples include working groups, forums and roundtables, where decision-makers and key stakeholders are engaged collectively. However, many of these mechanisms or institutions are short-lived if not supported by long-term commitment by stakeholders, or government institutions, and backed up by sufficient resources.

• Overall levels of funding for research and knowledge generation remain inadequate. This may be related to a continued lack of recognition of the socio-economic significance of marine and coastal issues in national systems of science and innovation, including research councils or their equivalent.

• Research in the countries in the WIO region for long periods has been dependent on donor funding. Donor funding, while valuable, does not promote an overall national research portfolio geared towards addressing national research priorities. Accordingly, whilst providing critical support and often strong catalytic inputs, donor-funded research contributions often do not fill research gaps since they are driven by donor priorities rather than specific national goals and needs.

• Local management authorities face many capacity challenges, which result from inadequate funding, a lack of suitably skilled staff, management tools and technical knowledge. The use of science and its products are particularly weak under these conditions.

• Many researchers and scientists do not understand nor engage with policy-making processes, which contribute to a disconnection between the scientific and policy-making communities. Scientists often conceive the link between science and policy as a one-way flow of information in which scientists convey scientific 'truth' to drive the

development of policy. Scientist often fail to appreciate the fact that research products, no matter how well-developed and tested, can often not be incorporated directly into decision-making without the inclusion of political, economic or social realities. Similarly, the outputs provided by scientists are often in a form that is not readily assimilated by decision-makers.

• Conversely, policy-makers expect science to provide definite answers and a full cost-benefit analysis of the implications of decisions. They also often assume that scientists fully understand and describe complex problems. These may be outdated ways of thinking about science and policy but they remain common.

• A greater emphasis on co-design of trans-disciplinary projects by stakeholder including scientists, managers and civil society, and the growing importance of the contribution of all stakeholders to the scientific process (co-production of knowledge) is not fully realised or practised in the region.

## RESEARCH PRIORITIES AND CAPACITY NEEDS

The Africa Progress Panel recently proclaimed that "*the time has come to unleash Africa's green and blue revolutions*", and, also that "*Africa's farmers and fishers are equal to the challenge, but they need the opportunity. They need their governments to demonstrate more ambition on their behalf. African governments must now scale up the appropriate infrastructure and ensure that financial systems are accessible for all*" (APP 2014). This State of the Coast Report has argued throughout that access to, and the use of defensible scientific data, information and knowledge is integral to management options, decisions, and policies, that the region requires to attain sustainability, as defined in the Scenario chapter (no. 32). Research funding in the region is scarce and should be optimised to achieve the most effective and longest-term outcomes possible. Regional coordination of research agendas could manage the necessary overlap of research activities in trans-boundary areas. Common priorities and coordinated research efforts could also attract funding from outside the region, especially where synergistic partnerships can be developed and co-investment can be leveraged. The sections below briefly consider some current global and regional research priorities. In most cases, these are embraced in reports or programmes that identify priority themes which are then translated into action.

### Global and regional research priorities

On a global scale, the Global Biodiversity Outlook (CBD 2014) reported on progress in meeting the Aichi Biodiversity Targets; achieving the 2050 Vision on 'Living in Harmony with Nature'; and on the importance of biodiversity in meeting broader goals for sustainable human development during this century. The Outlook identified a number of strategic goals aimed to achieve the objectives stated above. Most of the goals can be further refined for the global coastal and marine environment. The strategic goals were to:

• Address the underlying causes of biodiversity loss by mainstreaming biodiversity issues in governance processes; Reduce the direct pressures on biodiversity and promote sustainable use;

• Improve the protection of biodiversity by safeguarding ecosystems, species and genetic diversity;

• Enhance the benefits of biodiversity and ecosystem services to all; and

• Enhance implementation of biodiversity protection through participatory planning, knowledge management and capacity-building.

Similarly, the WWF published a Living Planet Report (WWF International 2014) which identified priorities to achieve sustainable use of the planet's resources. These priorities were:

• Equitable Resource Governance - Share the available resources, make fair and ecologically informed choices, measure success beyond GDP.

• Redirect Financial Flows - Value nature, account for environmental and social costs, support and reward conservation, sustainable resource management and innovation.

• Consume More Wisely - Through low-footprint lifestyles, sustainable energy use and healthier food consumption patterns.

• Produce Better - Reduce inputs and waste, manage resources sustainably, scale-up renewable energy production.

• Preserve Natural Capital - Restore damaged ecosystems, halt the loss of priority habitats, and significantly expand protected areas.

When placed in the context of global climate change, the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) has proposed a number of specific objectives towards our future on the changing planet. PROVIA is a global scientific initiative of the UNEP, the UNESCO and the WMO that seeks to har-

monise, mobilise and communicate the growing knowledge base on vulnerability, impacts and adaptation (UNEP 2013). A PROVIA report (UNEP 2013) emphasises the understanding of climate change vulnerability through mapping and measurement; development and strengthening of indicator and monitoring systems; an understanding of the risks of extreme climate events, non-linear impacts and tipping points. It also promotes:

- Advancing vulnerability reduction and adaptation solutions;
- Developing more inclusive cost estimates and prioritization criteria; and,
- Enhancing communication and stakeholder/public participation.

PROVIA has also identified key systems that need attention namely: food, water, ecosystems, energy, infrastructure and the built environment. Some of the emerging topics identified by the report include impacts of geo-engineering; legal principles and the role of law; food-water-energy-security; participatory processes for climate change mitigation and adaptation scenarios; decision theory; risk perception, climate knowledge and behaviour; governance, collaborative frameworks and networks; and long-term planning and design.

### Coastal and marine research priorities

In recognition of threats to global sustainability of human activities in the ocean and coastal environment, IOC/UNESCO, IMO, FAO, UNDP (2011) has identified the following problems as being the priority concerns:

- Unsustainable fishing;
- Climate change and ocean acidification;
- Pollution and waste; and
- Loss of habitats and biodiversity, in some cases because of invasive species.

Many international programmes have either been developed on climate change and variability, social needs and ecosystems, or have recently changed emphasis to focus on these issues. Examples include the International Geosphere-Biosphere Programme (IGBP), Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES), Scientific Committee on Oceanic Research (SCOR), Global Ocean Observing System (GOOS) together with its regional alliances, DIVERSITAS, the International Human Dimensions Programme (IHDP), the World Climate Research Programme (WCRP), Science Partnership for the Assessment of Complex Earth System Processes (SPACES), Ecosystem Services and Poverty Alleviation (ESPA), Global Ocean Ecosystem Dynamics (GLOBEC) and the Global Change, Biodiversity, Ecosystems and Society in Africa (GCBESA) programme.

A recent WWF International report on the development of the Ocean Economy (Hoegh-Guldberg and others, 2015) is of direct interest to the coastal and marine environment. In this, it is contended that assets that rely on a healthy ocean environment generate more than two thirds of the annual base economic value of the ocean. As a result of a decline in the state of these assets, the associated economic activities are faltering and not delivering to their full potential. There is, however, a growing need for food and resources from the ocean. The report identified eight actions to secure our ocean assets and restore the ocean economy:

- Ensure that ocean recovery features strongly in the UN Post-2015 Agenda, including the Sustainable Development Goals;
- Take global action to avoid dangerous climate change and further damage to the ocean;
- Conserve and effectively manage 10 per cent of representative coastal and marine areas by 2020, increasing coverage to 30 per cent by 2030;
- Rebuild fish stocks to ecologically sustainable harvest levels;
- Drive new global cooperation and investment in the ocean;
- Reinvent public/private partnerships;
- Build transparent accounting of the value of ocean assets to improve decision-making; and
- Share knowledge more effectively and drive institutional collaboration.

Finally, the UNEP Coastal and Marine Strategy (2011) provided some clear directives on coastal and marine actions (UNEP 2011) relevant to the need for scientific products in support of management, decision- and policy-making:

- Land-Ocean Connections: to integrate the management of coastal watersheds, the coastal area (including cities) and the marine environment to optimise the ecosystem services and resilience of marine and coastal systems. Meeting this objective will address the issue of degraded water quality in coastal water due to land-based activities.
- Ecosystems for Human Well-being: to identify, assess and value the status and key drivers of change in marine and coastal ecosystems, their services and their link to

human well-being. The need for a better understanding of ecosystem services and their value will be addressed to meet this objective.

• Reconciling Use and Conservation: to ensure that appropriate governance frameworks, management tools, capacity and options are available for regions, countries, communities and the private sector, to effectively engage in the sustainable management of marine and coastal ecosystems, including reconciling competing uses.

• Vulnerable People and Places: to strengthen the ecological, economic and social security of vulnerable communities and places, including SIDS, to adapt and respond to natural disasters and climate change, by enhancing the resilience of marine and coastal ecosystems and social capital, and improving access and benefit sharing. Meeting this objective will help to address issues specific to SIDS, coral reefs, seamounts and other sensitive marine ecosystems.

## DEVELOPMENT OF CAPACITY FOR RESEARCH

The National Research Council (NRC) of the National Academy of Science (NAS) (NRC-NAS 2008) describes capacity building as "*programs designed to strengthen the knowledge, abilities, relationships and values that enable organizations, groups and individuals to reach their goals for sustainable use of ocean and coastal resources. It includes strengthening the institutions, processes, systems and rules that influence collective and individual behaviour and performance in all related endeavours. Capacity building also enhances people's ability to make informed choices and fosters their willingness to play new developmental roles and adapt to new challenge.*" This holistic definition of the capacity building encompasses much more than training but also includes **different levels** (individual, institutional, enabling environment) and all **phases of the knowledge generation and knowledge translation cycle** (from setting the research agenda and research design to research use and communication). This is an important distinction as it reflects the reality of variable capacities across countries and regions, and also recognises that there are strong needs at all phases from research data collection through to the assimilation and mainstreaming of the knowledge gained into decision-making.

Though most of the countries in the region achieved independence between the early 1960s and mid-1970s, it was not until the 1970 that a noticeable increase in the number of marine scientists occurred. During this period the first marine scientists were completing their postgraduate studies. They were initially few in number and mainly fisheries biologists by specialisation. During the 1980s and 2000s, more marine scientists from a spectrum of disciplines (both in natural and social science) were trained.

### Capacity-building needs in resource management authorities

Different types of management authorities, from national ministries responsible for policy development to local governments and protected area management structures, are responsible for policy implementation and day-to-day management of coastal and marine resource use. These are vastly different in character and, as a result, have different capacity-building requirements.

Institutions responsible for development of policies, programmes and strategies at the national level include both politically-appointed officials as well as technical staff. The extent to which politically-appointed officials have adequate technical competence for marine and coastal management varies. However, these institutions also have technical personnel that are often highly qualified, in many cases in areas directly relevant to coastal and marine management, and with a good understanding of science. On the whole, at the national level in some countries, there is often requisite capacity (if not always the political will) to source and apply science to policies, legislation, plans and strategies.

At this level, and in view of the findings presented in previous sections of this chapter, some relevant capacity-building interventions are needed, aimed at management authorities. These include:

• **Reinforcing the capacity of decision-makers to formulate policy and associated research needs** through forward-looking methodologies such as envisioning future scenarios. These involve considering how emerging trends and developments might affect policy and practice. Policy-makers need to understand current and future drivers of change and plan accordingly, identifying and prioritizing research issues that will address emerging challenges.

• **Enhancing mutual understanding of how scientific and management communities operate** through specific training to address some prevailing misconceptions. Another way to enhance mutual understanding would be to promote secondment of managers to research institutions and scientists to management authorities for "job-shadowing".

### Capacity-building strategies to overcome barriers to effective integration of science

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 the link between science and marine and coastal management. These include:

• Support for knowledge brokerage in boundary organisations. These could identify, review and synthesise all available scientific information relevant for a particular policy or management issue and effectively interact with decision-makers.

• Compile project-level lessons-learned that link science and policy and management, highlighting successes.

• Support projects that combine research and demonstration or implementation activities. There are successful cases in the WIO that will yield useful lessons such as the Rodrigues octopus fisheries project (Yvergniaux, undated) and the MASMA-funded project "*Developing a model for strategic adaptive management of MPAs in the Western Indian Ocean*" (O'Leary and Tuda 2015).

### Regional capacity-building initiatives

Capacity-building initiatives have taken different forms in the region, including capacity building of individuals, institutions and society in general. Such efforts have aimed at improving their understanding of processes in, and the value of, coastal and marine environments. Capacity-building initiatives have also targeted institutions to improve their decision-making processes and build their technical skills to better fulfil their mandates. Some capacity-building initiatives have also targeted civil society with the aim of building their capacity to empower people to understand, engage in, and resolve issues associated with the better use and management of resources to maximize their opportunities for livelihood improvement.

In this context, several mechanisms have been used to deliver these different forms of capacity-building, including:

• **Technical short-term courses.** These types of courses have covered different types of specialised technical subjects that often represent enabling knowledge or skill sets such as nutrient analysis, coral reef monitoring, algal physiology, coastal erosion and leadership. The Nairobi Convention, in collaboration with the IOC-UNESCO and WIOMSA, organized a number of leadership courses targeting senior scientists and heads of research and academic institutions. Such short-term courses have been instrumental in laying the foundation for collaboration between national and regional institutions. They have promoted of the use of the same or comparable techniques in fieldwork and laboratory studies, as well as raised awareness and information dissemination and promoted leadership for marine related research and management at the highest levels of governance.

• **Writing workshops.** WIOMSA, through its MASMA Programme, has been providing grants for writing workshops. Specifically, these workshops seek to assist participants to attain a level of scientific and grant writing that can compete on a global scale for grants and publications. In these workshops, participants are asked to bring their own data with the aim of synthesizing information from multidisciplinary projects as well as information from relevant projects supported by other partners, leading to publications in peer-reviewed journals or books or policy briefs. Writing workshops have become a common feature of most of the MASMA-funded projects. They have provided opportunities to brainstorm on key research results, as well as for capacity building amongst emerging scientists in terms of approaches to data analysis, information synthesis and access, and the best methods for the dissemination of information and results.

• **Practitioner Short Courses.** These include broad-based training on marine protected area or natural resource management and ICZM that combine learning in a workshop setting with field visits and opportunities for the exchange of experience. Courses of this kind aim to address the need to rapidly develop a general understanding of emerging issues where there is limited capacity. Introduction level and general courses are then superseded by more specialised technical courses and /or integration into vocational and masters training courses.

• **Multi-Stage Courses.** Multi-stage courses combine on-the-job-learning and assignments with one or more intensive training sessions, often involving exposure to projects or other real-life management situations that provide the experience participants need to build their own capabilities. Participants then complete assignments and projects based on their workplace (or volunteer) experience (Coley and others, 2002).

• **Certification of professionals.** WIOMSA recognised the importance of the marine conservation and compliance sector when it instituted WIO-COMPAS (Box

## BOX 35.1. THE AGULHAS AND SOMALI CURRENT LARGE MARINE ECOSYSTEM PROJECT (ASCLME) – ACHIEVEMENTS IN RESEARCH AND CAPACITY BUILDING by David Vousden




R/V Dr. Fridtjof Nansen, one of the vessels used during the ASCLME-coordinated cruises. © EAF-Nansen project.

This Project ran from 2007 until 2014 and supported nine countries in the western Indian Ocean region to undertake an environmental baseline assessment of the Agulhas and Somali Current Large Marine Ecosystems, to fill the information gaps needed to develop a Transboundary Diagnostic Analysis (TDA) and to support improved management decision-making through development and adoption of a Strategic Action Programme (SAP).

The main achievements from the Project included the development of National MEDAs (Marine Ecosystem Diagnostic Analyses) as 'state of the marine environment' reports for each country; integration of the MEDAs into a single, regional Transboundary Diagnostic Analysis; a draft Strategic Action Programme for Management of the LMEs; and a Western Indian Ocean Sustainable Ecosystem Alliance of partners that agreed to support scientific research, monitoring, capacity building and training.

More specifically in the context of actual scientific research as well as capacity building and training, the project has listed the following deliveries and successes in collaboration with its many partners:

**Scientific Studies and Research**

- 50 individual cruises 'legs' around the western Indian Ocean
- Deployment of permanent ocean-atmosphere monitoring mooring systems
- Use of satellite imagery to track productivity hotspots and identify upwelling incidents
- Study of ocean kinetics, particularly in relation to eddies associated with the Mozambique channel
- Substantial data collected on primary and secondary productivity as well as fish biodiversity and genetics (including comprehensive fish collections)
- Fisheries data reconstructions to demonstrate significance of small-scale fisheries
- Studies on marine-based pollutants and extent of land-based pollution impacts offshore
- Mapping of invasive species distributions
- Mapping of critical habitats and vulnerable/endangered species along with proposed management measures
- National and regional policy and governance baseline assessments completed with recommendations for strengthening and harmonising across the region
- Regional 'Cost-Benefit of the Ecosystem Approach' assessment completed

Individual national demonstration on community engagement and evolution of local economic development plans)

**Capacity Building and Training**

- Nearshore and coastal monitoring programmes developed

and agreed with each country in support of the ecosystem-based management approach

• Training of more than 100 new scientists on ecosystem monitoring and assessment techniques

• A 3-week intensive study and filed-work course providing a grounding in theoretical oceanography follow by 'hands-on' training at sea in data collection, analysis and survey planning

• Co-development and co-delivery (with the International Ocean Institute and University of Cape Town) of a 4-week Ocean Governance Training Course for managers

• Numerous workshops on such topics as the use of GIS and remote sensing; marine pollution; invasive species, port control, taxonomy, etc.

• A regional Capacity Building and Training Needs road-map developed for the countries

Cooperative agreements with various 'Alliance' partners for long-term delivery of CB&T needs repatriation of data, where possible from previous scientific activities.

35.2), the Western Indian Ocean Certification of Marine Protected Area Professionals (WIO-COMPAS 2012). This is a joint initiative of WIOMSA and the Coastal Resources Center (CRC) at the University of Rhode Island (URI). The initiative was further refined in liaison with leading conservation professionals in a number of African countries. Entrants to the programme are assessed by leading professionals and are certified at three levels: Level 1 – Marine Field Operations; Level 2 – Site Management; and Level 3 – Policy and Planning. All of these levels of certification are of relevance to the management situation under consideration and the WIO-COMPAS initiative thus merits its support as it offers redress to what appears to be the most burning gap in the capacity-building needs of the region.

• **Tertiary education leading to BSc, MSc and Phds** has been accomplished by course work (for BSc) and via other mechanisms such as training abroad through scholarships programmes offered by various international organizations such as Sida, CIDA, NORAD, AusAid, Commonwealth, GTZ, Belgium and JICA, and 'sandwich' programmes, whereby students spend the majority of their time in their home countries working on a locally relevant research problem. There are two modes of training under such arrangements. In the first, candidates are registered at overseas universities and attend courses, undertake data analysis and thesis write-up at that university, while in the second mode, the candidate is registered at a regional university and part of the data analysis and thesis write-up takes place at an overseas university.

• Increasing accessibility of research results through organisation of the **conferences and scientific symposia.**

• The development of training materials and guides such as the *WIO MPA Toolkit* (IUCN 2004). This type of initiative aims to produce appropriately designed and relevant technical information, methodologies, guidelines and training to underpin best practise in one or more natural resource management areas.

## CONCLUSION

The WIO region has, over the years, built capacity for coastal and marine research and it is reasonable to state that increasing the pool of coastal and marine data, information and knowledge (scientific evidence) has resulted in an improvement of management of the coastal and marine environments. As indicated earlier, scientific research commissioned within the context of national growth and development is more likely to directly impact on resource management and the development of policy compared to research solely driven by external support. Where there is a clear expression of need for data, information and knowledge by managers and policy-makers in context of a national, regional or sub-national vision, the research is much more likely to be applied to solve real-world problems that then directly improve the situation locally, nationally, and, regionally. This does not, however, reduce the relevance of the global coastal and marine research agenda as expressed by the United Nations agencies and international NGOs such as WWF for the WIO, and these agendas can contribute to the basis for developing regional research priorities.

Most of the experiences of scientists and managers in the WIO region indicate a persistent perception that science to policy is predominantly a one-way affair, from producer to user. Whilst there is clearly a much stronger role for policy-makers and their advisers in developing research questions and agendas, it is also true that managers and decision-makers often do not understand the limits of scientific data, and their inherent risks and the issues of tem-

poral and spatial applicability. Concomitantly, in a space as complex as the coastal and marine environment, scientific data is not the only informant of decision-making and this perspective warrants development among researchers and research organisations alike. The task of connecting or co-producing scientific knowledge with users is not an automatic process and there needs to be a concerted effort to own the problem of producing usable science in the WIO.

The WIO encompasses a wealth of research and management institutions and agencies and yet, the overall human capacity in the region is still not consummate to the needs of addressing the complex and multidisciplinary issues in the coastal and marine environments it is comprised of. This is a result of amongst others, inadequate financial and human resources resulting from the low percentage funding for R&D in relation to GDPs of most countries, and insufficient investment in education and training, inadequate knowledge and awareness arising from factors such as lack of or inadequate regulations, and a lack of legal expertise. Generally speaking, the interactions between science, policy and management in the WIO take place in a context of limited, and often inadequate human capacity, including inadequate governance capacity, research capacity and capacity for fulfilling financial, operational and human resource functions. Investment and innovative approaches to building human capacity development remains a top priority for countries in the WIO.

**BOX 35.2.** WESTERN INDIAN OCEAN CERTIFICATION OF MARINE PROTECTED AREAS PROFESSIONALS (WIO-COMPAS) by Michael H. Schleyer

WIO COMPAS
Western Indian Ocean · Certification of Marine Protected Area Professionals

The overall goal of WIO-COMPAS is to establish a professional association that provides a framework to promote competence, professionalism, leadership, innovation and ethical conduct amongst Marine Protected Area (MPA) managers. It recognizes and accredits individuals working in MPAs whose knowledge and skills meet a clearly defined professional standard. It then further enhances their knowledge and skills through networking with other professionals, sharing new ideas and thinking about MPA management and coastal governance.

The WIO-COMPAS programme is structured around the four elements of Experience, Examination, Education and Ethics. While it does not provide training, it does provide candidates professional development sessions during the certification assessment. Applicants are selected on merit and undergo a rigorous assessment during which they are scored in their competence in multiple areas. A code of ethics binds together individuals who become certified - known as MPA PROs - to uphold the high standards of the programme and their profession. A total of 68 MPA PROs have been accredited since the launch of WIO-COMPAS in 2012.




Participants of the Western Indian Ocean Training on Understanding and Communication Climate Change on a field trip in Algoa Bay, South Africa. © Yoon Kim.

Source: Coastal Resources Center and WIOMSA (2012)

## References

References - Chapter 35 – Coastal and marine research and capacity building

APP (2014). *Grain, Fish, Money - Financing Africa's Green and Blue Revolutions*. Africa Progress Panel. Africa Progress

Report 2014

CBD (2014). *Global Biodiversity Outlook 4*. A mid-term assessment of progress towards the implementation of the Strategic Plan for Biodiversity 2011-2020. Secretariat of the Convention on Biological Diversity. Montréal

Coley, C., Squillante, L., Hale, L., Kiambo, R., Francis, J. and Mbarouk, F. (2002). *Learning and Performing: developing Skills for Coastal Management Practitioners*. Final Report on the First Course on building Capacity for Sustainable Integrated Coastal Management in the Western Indian Ocean Region. WIOMSA/CRC

COSTECH (undated). *Tanzania Commission for Science and Technology*. Available at http://www.costech.or.tz/

Davis, C. and Carden, F. (1998). Research effectiveness and R and D evaluation in developing countries. *Knowledge and Policy* 10(4), 7-30

EAMFRO (1965). *Annual Report*. East African Marine Fisheries Research Organization. East African Common Services Organization

Hoegh-Guldberg, O. (Lead Author) (2015). *Reviving the Ocean Economy: the case for action - 2015*. WWF International. Gland, Switzerland, Geneva

HRDC (2006). *Transforming Mauritius into a Knowledge Hub*. Human Resources Development Council. Ministry of Education and Human Resources Sectoral Committee Report

IOC/UNESCO, IMO, FAO, UNDP (2011). *A Blueprint for Ocean and Coastal Sustainability*. An inter-agency paper towards the preparation of the UN Conference on Sustainable Development (Rio+20). IOC/UNESCO. Paris, France

IUCN (2004). *Managing Marine Protected Areas: A Toolkit for the Western Indian Ocean*. IUCN Eastern African Regional Programme. Nairobi, Kenya, 172 pp. http://www.wiomsa.org/mpatoolkit/

Morcos, S. (2002). The Education Mission of Marine Sciences: A case study of East Africa, the early initiatives, 1930-1980. In *Oceanography History: The Pacific and Beyond* (eds. K.R. Benson and P.F. Rehbock) pp. 215-223. University of Washington Press

NACOSTI (undated). *National Commission for Science, Technology and Innovation*. Available at http://www.ncst.go.ke/

NRC-NAS (2008). *Increasing Capacity for Stewardship of Oceans and Coasts: A Priority for the 21st Century*. Committee on International Capacity Building for the Protection and Sustainable Use of Oceans and Coasts of the Ocean Studies Board. National Research Council of the National Academies of Science. National Academies Press, Washington, D.C.

O'Leary, J. and Tuda, A. (2015). *Using Science to Empower Communities and Improve Marine Protected Areas in East Africa*. Available at http://voices.nationalgeographic.com/2015/02/24/using-science-to-empower-communities-and-improve-marine-protected-areas-in-east-africa/

Rao, T.S.S. and Griffiths, R.C. (1998). *Understanding Indian Ocean: Perspective on Oceanography*. UNESCO. Paris, France

Richmond, M.D. (ed.) (2011). *A field guide to the seashores of Eastern Africa and Western Indian Ocean Islands*. Sida/WIOMSA

Robinson, J., Marguerite, M., Payet, R. and Isidore, M. (2007). *Investigation of the Importance of the Reef Fish Spawning Aggregations for Sustainable Management of Artisanal Fisheries Resources in Seychelles*. MASMA Final Technical Report. WIOMSA Book Series No 6

RoK (2008). *Science, Technology and Innovation Policy and Strategy*. Republic of Kenya. Ministry Of Science and Technology. Nairobi, Republic of Kenya

RoMZ (2006). *Estratégia de Ciência, Tecnologia e Inovação de Moçambique (ECTIM)*. Republic of Mozambique, Conselho de Ministros.

RSA (2002). *South Africa's National Research and Development Strategy*. Republic of South Africa.Department of Science and Technology, Government of the Republic of South Africa, Pretoria

The World Bank (undated). *Research and development expenditure (% of GDP)*. Available at *http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS*

UDC (2013). Politique Nationale de l'Enseignement Superieur et de la Recherche a l'Horizon 2020, Mars 2013. Union de Comores. Ministère de L'education Nationale de la Recherche de la Culture et des Arts Charge de la Jeunesse et des Sports. 25 pp

UIS (2010). MEASURING R&D: Challenges Faced by Developing Countries. UNESCO Institute for Statistics. Quebec, Canada. 40pp. www.uis.unesco.org/template/pdf/S&T/TechPaper5_EN.pdf

UNEP (2011). *Marine and Coastal Strategy: The Other 70% - Executive Summary*. UNEP. Kenya

UNEP (2013). *Research Priorities on Vulnerability, Impacts and Adaptation - Responding To The Climate Change Chal-*

*lenge: Priorities on Impacts and Adaptation to the Climate Change Challenge*. United Nations Environment Programme. Nairobi

URT (2010). The National Research and Development Policy. United Republic of Tanzania. Ministry of Communication, Science and Technology. United Republic of Tanzania

WIO-COMPAS (2012). W*estern Indian Ocean – Certification of Marine Protected Areas Professionals Program Handbook: Overview, Processes, Competences and Rules*. Coastal Resources Center and WIOMSA

WWF International (2014). *Living Planet Report 2014 - Species and spaces, people and places*. WWF International. Switzerland, Geneva

Yvergniaux, Y. (undated). *Management of the octopus fishery in Rodrigues*. Smart Fiche 12, SMARTFISH Programme

# 36

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

José Paula

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

## INTRODUCTION

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

### The WIO region main features

The WIO spans a large latitudinal range, from the Somalia region, influenced by the strong monsoon regime of the northern Indian Ocean, to the sub-tropical regime of the Kwa-Zulu Natal Province in South Africa. It thus encompasses tropical and subtropical regions of diverse nature, rich stretches of coast along the mainland countries of Somalia, Kenya, Tanzania, Mozambique and South Africa, and vast oceanic areas with the island states of Madagascar, Seychelles, Comoros, Mauritius and French Territories. The WIO region is essentially within the Western Indo-Pacific biogeographic realm, but its southwest limit enters the Temperate Southern Africa biogeographic realm (Spalding and others, 2007). The WIO region presents such uniqueness of features that render it a structural and functional unity within the world global ocean (Obura and others, 2012). The main portion of WIO region is also referred to as the Eastern African Marine Ecoregion (WWF 2001).

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

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

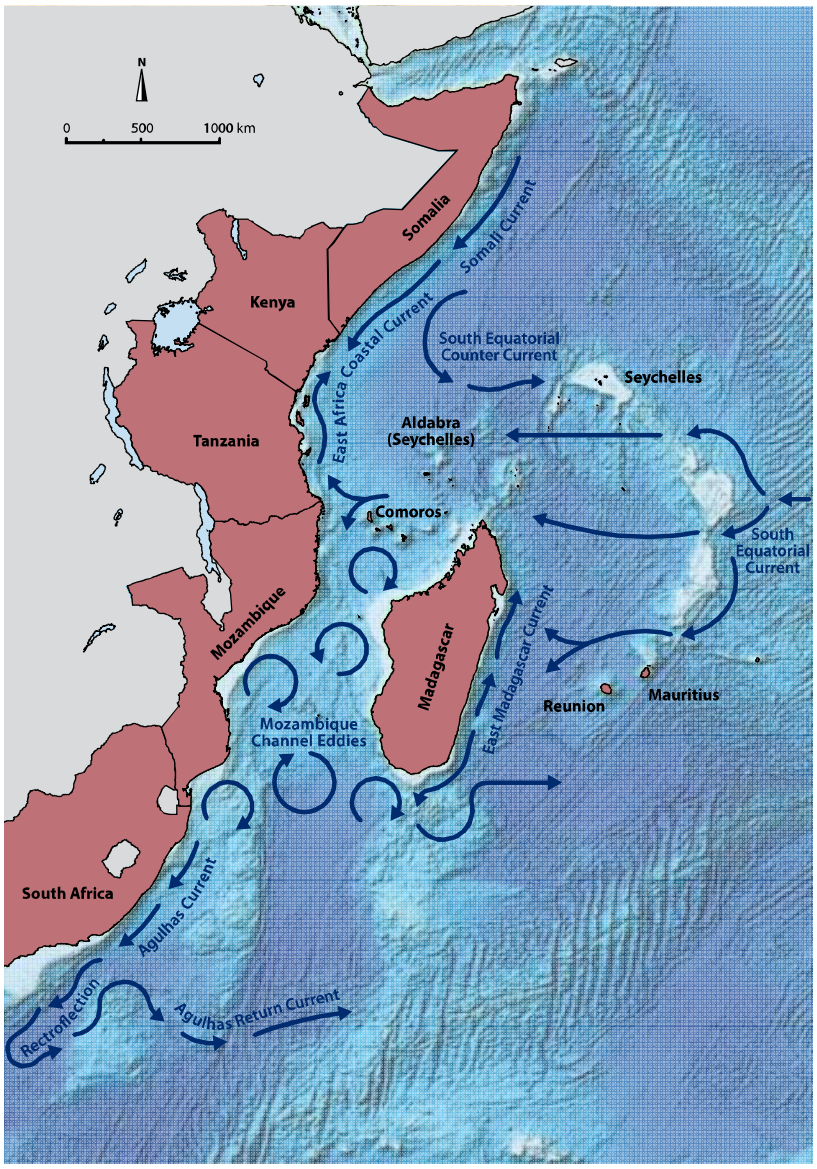



**Figure 36.1.** The WIO region, showing the countries, the bathymetric profile (adapted from Amante and Eakins 2009) and main current patterns (adapted from Lutjeharms and Bornman 2010).

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

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

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

### The mandate and methodology of the RSOCR for the WIO

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

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

## ASSESSMENT OF BIODIVERSITY

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

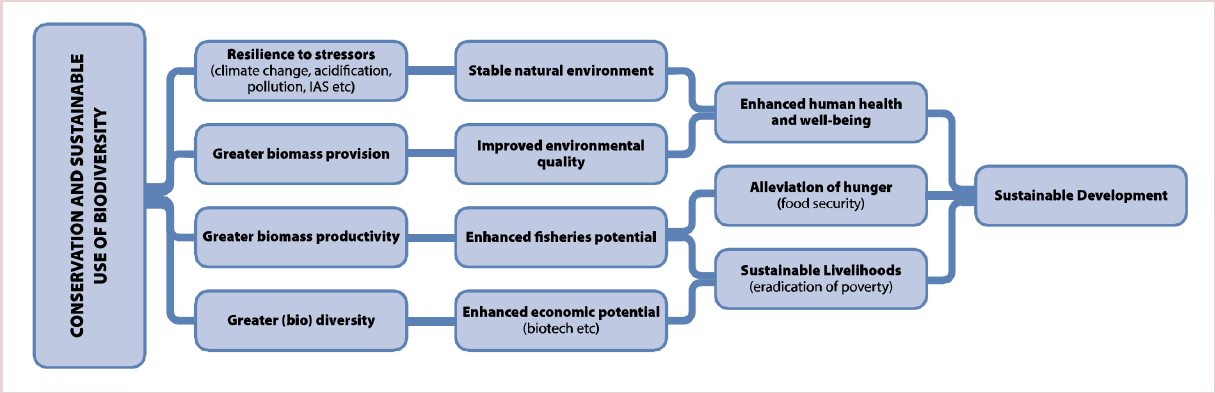
The assessment of biodiversity addressed the main ecosystems that constitute the major support for biodiversity and living resources, such as the nearshore habitats (see Chapter 4), mangroves, salt marshes and seagrass beds (see Chapter 5), coral reefs (see Chapter 6), rocky reefs (see Chapter 7), sediments (see Chapter 8) and pelagic and deep sea environments (see Chapter 9). The assessment further included a summary of threatened marine species (see Chapter 10), as well as the significant social and economic aspects of biodiversity conservation (see Chapter 11). For detailed descriptions, refer to these chapters and references therein. The overall assessment merges the biodiversity components (ecosystems, threatened species and socioeconomic aspects) into a single analysis. Figure 36.2 attempts to provide a summary of the RSOCR biodiversity assessments under a framework of DPSIR methodology. The term ''biodiversity" is used here in its holistic scientific meaning, ie, including all levels of organization of life, from genes and populations to species, habitats, ecosystems and ecoregions.

### Drivers of change

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

- **Increased extreme events,** such as storms and cyclones, affecting physically the coastal zone by erosion, sedimentation and destruction of habitats, but also through alteration of precipitation patterns leading to flood and drought events. Behaviour of river catchments in relation to these pressures will produce changes in sediment loads and estuarine discharges to the ocean.
- **Sea level rise** is considered to affect the WIO region in the mid term, with consequences to habitats by submersion and erosion, especially in low lying intertidal areas like tidal flats, mangrove forests and salt marshes. Additionally, sea level puts at risk the integrity of human settlements at the coast.
- **Temperature rise,** mainly SST, affects directly the biology of key organisms such as corals that are prone to bleaching. On the longer term, ocean warming will alter the distribution of organisms and will impact of species local extinctions and replacement, with unforeseen consequences for ecological patterns and resource availability.
- **Ocean circulation** may be altered, namely patterns of currents at mesoscales. This will affect dispersal of organisms and distribution of primary productivity, affecting biomass and biological communities. These shifts may not necessarily decrease productivity and biodiversity at a WIO region scale, but will certainly displace resources and affect the geography of traditional living resource extraction activities.
- **Changes in sediment dynamics** can occur via extreme events, as well as changes to coastal currents and sediment loads from river basins, affecting patterns of sedimentation and erosion in the coastal zone.
- **Acidification** is a consequence of the increasing

**BOX 36.1.** THE OCEAN OR BLUE ECONOMY by Louis Celliers




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

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

In providing food, oxygen and livelihoods, the world's oceans and coasts have the potential to perform a critical role in the move towards a green economy. In this coastal context, what can be called the 'Blue-Green Economy', results in a reduction in ecological impacts, while promoting the economic and social sustainability of traditional and emerging ocean-oriented economies (UNEP and others, 2012). The blue-green economy is related to a number of interrelated sectors, including, for example fisheries, tourism, maritime transport, energy generation, aquaculture, mining and nutrient Economy.

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

load of $CO_2$ in the oceans, albeit their effects more pronounced in cold and deep waters. It affects the calcification processes of organisms such as corals and certain phytoplankton. Scenarios predict that by 2100 all coral reefs will live in marginal conditions for survival under this threat.

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

• **Population growth** within the coastal zone, by either migration or high growth rates, impacts on urbanization and land reclamation, but also on pollution discharges and pressure over natural resources.

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

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

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

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

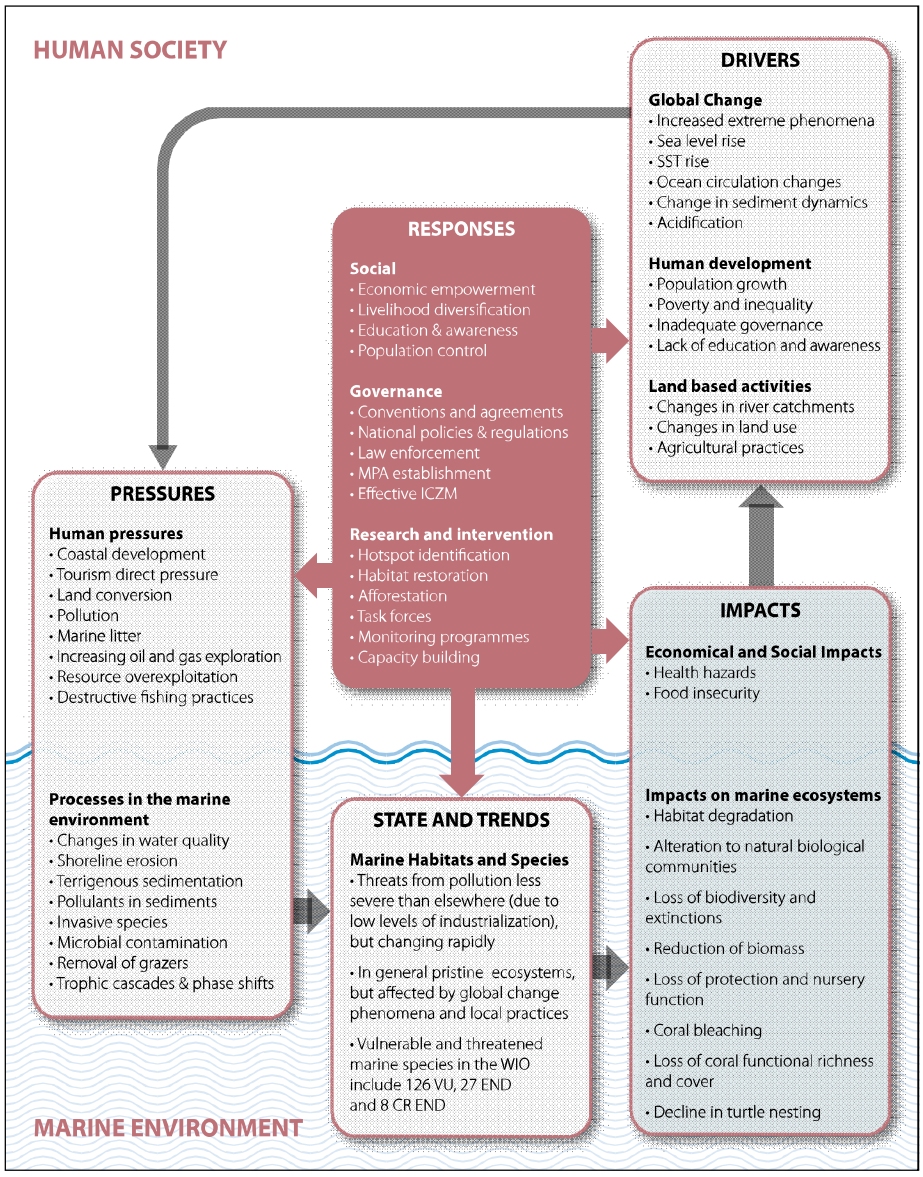



**Fig 36.2.** Diagrammatic summary of DPSIR analysis for marine biodiversity in the WIO.

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

• **Changes in river catchments** are increasing with economic development, namely damming for clean energy source and water subtraction for consumption and agriculture, with consequences for normal flood regimes and sediment transport, and potentially leading to salt intrusion processes near the coast.

• **Changes in land use,** namely reclamation of large portions of ecosystems such as mangroves and salt marshes for construction, aquaculture and salt ponds.

• **Agricultural practices** enhance nutrient load in rivers and estuaries, and provoke increased soil erosion.

### Pressures on marine ecosystems and species

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

• **Land conversion** diminishes the available ecosystem cover and associated biodiversity and resources (see Chapters 27-29).

• **Coastal development** leading to land reclamation and increasing overall impacts (see Chapter 29).

• **Pollution** arises from multiple sources and can be derived from industrialization, domestic load and other sources, such as aquaculture and agriculture, affecting biological and ecological processes (see chapters 25-29).

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

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

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

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

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

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

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

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

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

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

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

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

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

• **Trophic cascades** are processes that affect whole trophic networks, reaching their top organisms, frequently those that represent food security resources. An example being nutrient enhancement leading to red tides that impact filter-feeders consumed by humans.

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

### State and trends of the marine environment

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

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

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

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

### Impacts on the marine environment and related livelihoods

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

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

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

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

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

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

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

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

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

### Society responses

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

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

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

• **Education and awareness** are the basic frameworks for civil engagement on environmental issues, namely conservation and sustainable exploitation of resources.

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

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

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

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

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

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

• Strengthen **Integrated Coastal Zone Management**.

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

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

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

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

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

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

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

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

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

## ASSESSMENT OF SERVICES FROM THE MARINE ENVIRONMENT OTHER THAN PROVISIONING

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

### Climate regulation in the WIO

The exchange of mass and energy at the interface between the sea surface and the atmosphere results in a complex coupling (see Chapters 14 and 15 for details on biogeochemical processes, weather and climate regulation in the WIO region). The WIO region shows strong inter-annual climatic variability, due phenomena such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), as well as seasonal climatic variability derived from the monsoon circulation (Manyilizu and others, 2014). Main climatic *pressures* are:

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

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

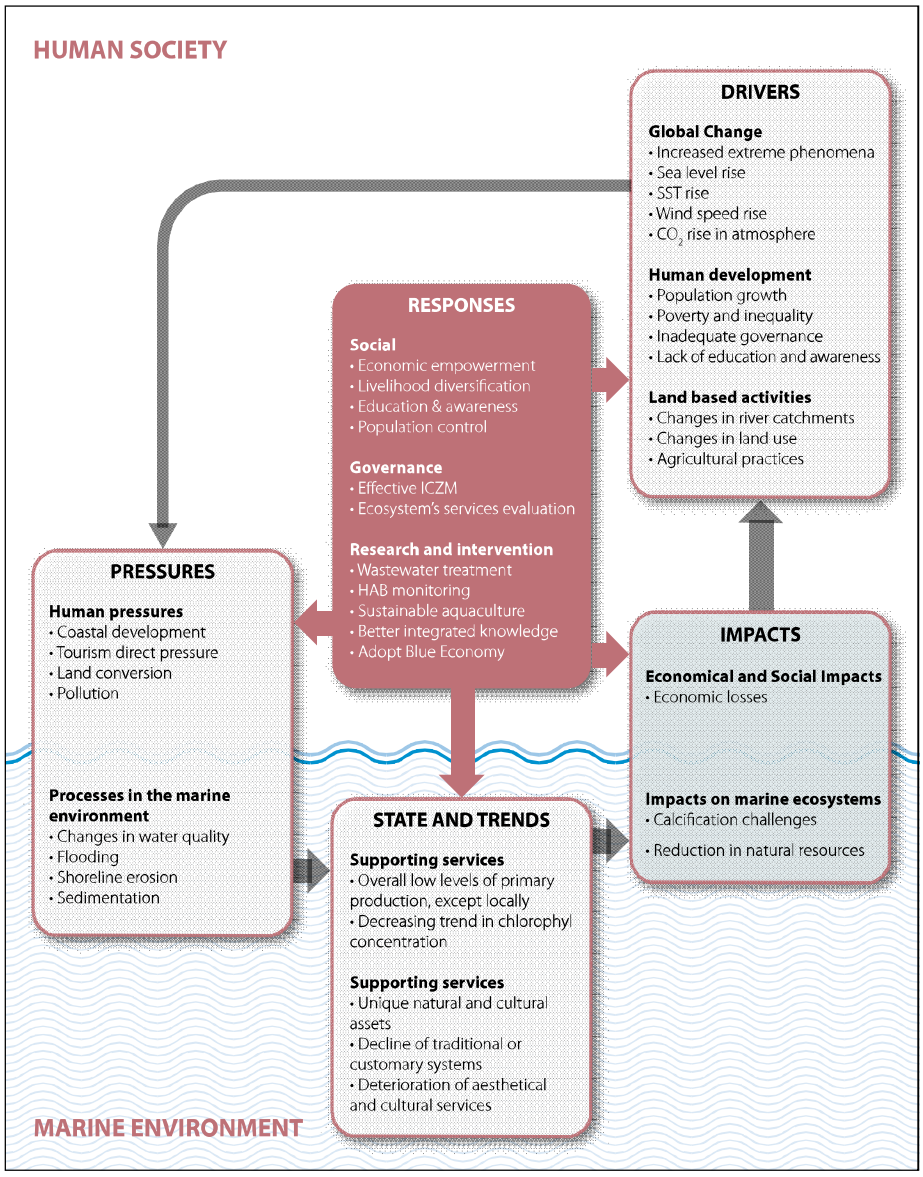



Fig 36.3. Diagrammatic summary of DPSIR analysis for services from the WIO marine environment other than provisioning.

Ocean along 20°S (which includes the southwestern Indian Ocean), anthropogenic $CO_2$ storage over an 8-year period (between 1995–2003/2004) is reported to have increased at an average rate of 7.1 mol $m^{-2}$ (Murata and others, 2010), almost two times higher than that reported during the previous decade (Sabine and others, 1999).

Over the last three decades, both the mean and maximum speeds of the monsoon winds have generally strengthened in some parts of the region such as in Tanzania (Mahongo and others, 2012), however it is not excluded that these changes could be derived from natural climatic cycles. Webster and others (2005) observed an increase in the annual frequency of cyclones in the South Indian Ocean within the period 1970 and 2004. The number of intense tropical cyclones also increased from 36 during the 1980-1993 period, to 56 during 1994-2007, comparable to a simultaneous but smaller decrease in the number of tropical storms (Mavume and others, 2009). Globally however, there is no sound indication that tropical cyclone frequency has increased over the past century (Christensen and others, 2013). According to Christensen and others (2013), tropical cyclone numbers are unlikely to increase, but cyclone maximum intensity is likely to increase on the global average, meaning increased maximum precipitation and winds. Mauritius, Reunion, Madagascar and Mozambique are the regional countries that are more prone to

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

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

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

**Support to primary production by the WIO**

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

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

*Responses*:

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

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

**Support to ocean-sourced carbonate production by the WIO**

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

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

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

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

### Cultural services of the WIO

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

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

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

**General recommendations regarding ecosystem services other 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**.

## ASSESSMENT OF FOOD SECURITY FROM MARINE RESOURCES

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

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

### Capture fisheries

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

Statistics on landings, that highlight contrasting figures, are considered as gross under-estimations, due widespread lack of reporting by the artisanal fisheries sector. Nevertheless, it is clear that landings have continued to increase over the past decade, showing growth of the fishing sector, as is the case of Mozambique and Madagascar (Benbow and Harris 2011). However, prawn landings have declined throughout the WIO. Seychelles experienced an increase in large pelagic fish landings after 1997 reflecting the development of its fishing port as a hub for the international tuna industry.

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

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

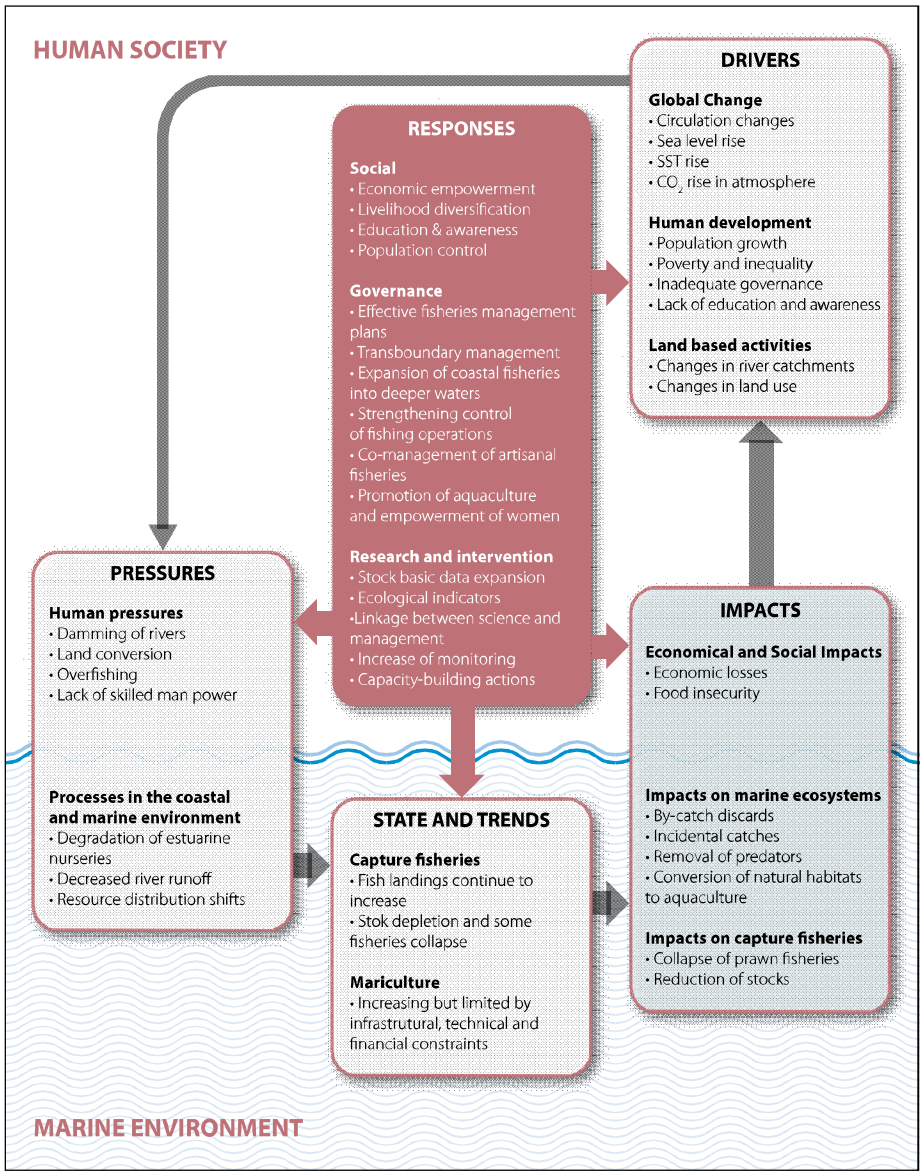



**Fig 36.4.** Diagrammatic summary of DPSIR analysis for food security from marine resources in the WIO.

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

## Mariculture

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

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

*Pressures and impacts*: Pond farming in Madagascar takes place behind mangrove areas along the northwest coasts where mangroves have come under threat through erosion, siltation and related effects from ponds constructed on salt flats. Limited success of mariculture is due economic isolation, insufficient training, and degraded road infrastructure, as is the case of Madagascar, but also Mozambique.

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

**General recommendations regarding food security from marine resources**

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

- Appropriate control should be acquired by authorities throughout the WIO region to address **overfishing of marine resources**; especially numbers of fishers, methods used, and harvest quantities.
- Governance and economic conditions should be developed to **expand coastal fisheries into deeper waters**, frequently tabled as an option to increase harvests from the sea.
- **Effective management plans** should be developed to include the majority of species and fisheries.
- **More basic data is required** to describe distribution patterns, biological characteristics and reference points, stock status, and the effects of fishing.
- **Strengthen the linkage between science and management** to pass messages from stock status, or to provide solutions to recent or longstanding management issues often not prioritized.
- **Increase monitoring, control and surveillance** (MCS) capacity, making enforcement of national and international laws and regulations more effective in most WIO countries.
- **Promote co-management of artisanal fisheries**, through Beach Management Units (BMUs) empowered to manage fisheries in specific areas on behalf of fisheries departments.
- Promote awareness and implementation of an **ecosystem approach to fisheries management** (EAF).
- Promote the use of **ecological indicators** for evaluating and comparing the status of exploited marine ecosystems.
- Promote cooperative **transboundary fish stock management** in the WIO.
- Promote **capacity-development initiatives** for the scarcity of skilled manpower (namely fisheries researchers, scientific observers, fisheries managers, surveillance technologists, hatchery and grow-out system operators) in the region.
- **Encourage mariculture** as an alternative activity to generate fish protein and wealth.
- A more **integrated approach** to mariculture is required.
- Promote **empowerment of women** in culture and business aspects of mariculture.

## ASSESSMENT OF OTHER HUMAN ACTIVITIES

Assessment of other human activities in the marine environment is developed under Part VI of the RSOCR. It includes a number of important sectorial issues such as maritime activities (see Chapter 25), oil, gas and renewable energy (see Chapter 26), coastal mining and coastline stability (see Chapter 27), tourism and recreation (see Chapter 28), urbanization, coastal development and vulnerability and catchments (see Chapter 29) and marine genetic resources and bio-prospecting (see Chapter 30). The adoption of Blue Economy agenda should drive development of human activities that promote economic development and poverty alleviation, at the same time ensuring sustainable use of resources and environmental quality maintenance. Some of the analysed emergent activities can turn into opportunities for human development in the WIO region. Figure 36.5 provides a summary of the RSOCR assessment of other human activities in the coastal and marine environment under a framework of DPSIR methodology.

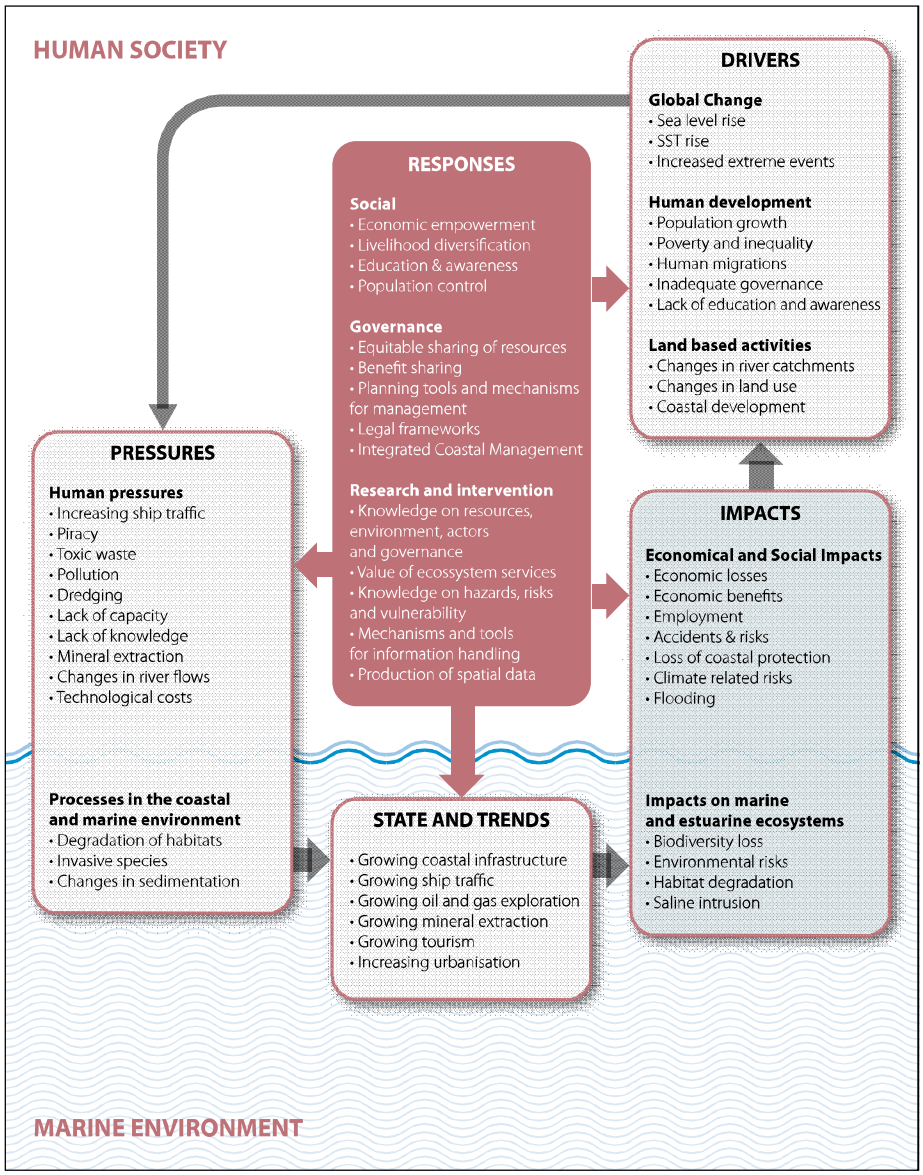



**Figure 36.5.** Diagrammatic summary of DPSIR analysis for other human activities in the coastal and marine environment in the WIO.

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

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

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

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

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

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

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

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

### Oil, gas and renewable energy

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

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

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

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

### Coastal mining and stability

*Status and trends*: The coastal regions of Sub-Saharan Africa are witnessing increasing non-renewable mineral resources extraction (UNEP/ Nairobi Convention Secretariat 2009a). Human development results in heavy dependence on natural resources, namely as building materials such as cement, sand and coarse aggregate (stones) for concrete and mortar, and clay for bricks (eg ASCLME 2012). The major types of materials and environments used are coral rock and limestone for cement manufacturing and course aggregates for concrete and road building by quarrying, artisanal sand mining from catchments, flood plains, river banks, estuaries and lagoons, informal removal of sand from beaches and fore dunes, and production of sea salt from saltpans located on estuary flood plains.

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

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

### Tourism and recreation

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

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

*Impacts and pressures*: The tourism and recreation sector is a major driver for socio-economic development, promotion of economic growth and alleviation of poverty (eg Richardson 2010) with direct and indirect economic impacts, promoting infrastructure development such as roads, airports and amenities in the coastal zone (eg Seetanah and others, 2011). The tourism industry is an important source of direct and indirect employment, creating multiple opportunities. Tourism often supports conservation through the promotion of private, communal and public conservation (Buckley 2008). Ecotourism is becoming popular among environmentally-conscious tourists, presenting opportunities for sustainable tourism development. Although tourism has great potential to contribute to socioeconomic development and to environmental rehabilitation, it also has a wide range of negative social and environmental impacts (Gössling 2006). The health status of the marine environment in the WIO is increasingly under threat and the additional pressure of tourism and recreation is a growing environmental concern.

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

### Coastal development and vulnerability

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

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

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

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

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

### Catchments

River catchments, which connect terrestrial and freshwater ecosystems to oceans, enable and modulate essential ecological processes in coastal and marine environments. Rivers transport freshwater, sediments, nutrients, biota and chemicals, which, along with oceanic forces, shape the coast and establish the availability of natural resources in estuaries and coastal environments (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a)

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

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

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

### Genetic resources and bio-prospecting

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

*Status and trends*: The countries of the WIO region have limited scientific and technical capabilities and consequently most research, development and commercialisation of marine genetic resources and their property rights are conducted outside the region. South Africa and, to a lesser extent, Kenya, are the only WIO countries engaged actively in international collaborative projects. Several areas in the WIO are however of major interest for the exploration of natural products. There is an increased interest in the WIO islands and East African coastline, and the presence of biodiversity hotspots in the region also suggests that the area is likely to be of increasing interest for marine natural products. Only a small fraction of this biodiversity has been explored for its commercial potential (Davies-Coleman and Sunassee 2012).

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

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

### General recommendations regarding other human activities

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

- Increase the **knowledge** about the resources, the environment, the people using and exploiting such resources, and the way in which they are governed.
- Understanding the **value of ecosystem services** and how it is influenced by environmental change.
- Promote **equitable access** to and **benefit sharing** of coastal and marine resources, preferably entrenched in all national policy and legislation.
- Promote the understanding and management of **hazards, vulnerability and risk**.
- Develop **mechanisms and tools** for the capture, exploration and archiving of data, information and knowledge.
- Develop **planning tools and mechanisms** for the management of coastal land-use and conversion at all scales (regional, national and sub-national) and human activities and their usage and exploitation of resources.
- Emphasize the production of **spatial data** that enables usage of scientific products for marine planning and other similar mechanisms.
- Establish relevant **legal frameworks** that enable rather than frustrate efforts to develop environmental management solutions for sustainable development.
- Prioritize **integrated coastal management** (ICM) for the management of coastal areas and associated human activities.

## SCENARIOS, POLICIES AND CAPACITY BUILDING NEEDS

### Future scenarios for the WIO region

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

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

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

### *The CWS scenario*

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

### *The SWS scenario*

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

### *The way forward*

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

## Governance and policy options

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

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

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

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

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

### Research and capacity-building

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

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

## OVERALL CONCLUSIONS

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

The Regional State of the Coast Report for the West-

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

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

Other human activities are increasing in the region, such as maritime trade and mineral extraction from the coast, oil and gas exploration, coastal tourism and bio-prospecting. While these sectors present enormous potential opportunities to contribute towards economic development, the potential impacts associated with each may challenge sustainability. Their development should be addressed and monitored with integrated sound management strategies.

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

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

## References


Amante, C. and Eakins, B.W. (2009). ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24. National Geophysical Data Center, NOAA. doi:10.7289/V5C8276M

Arrieta, J.M., Arnaud-Haond, S. and Duarte, C.M. (2010). What lies underneath: conserving the oceans' genetic resources. *PNAS* 107(43), 18318-18324

ASCLME (2012). National Marine Ecosystem Diagnostic Analysis. Tanzania. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by UNDP with GEF grant financing)

ASCLME/SWIOFP (2012). Transboundary Diagnostic Analysis for the Western Indian Ocean. vol. 1: Baseline. South Africa

Bakker, K.A. and Odendaal, F. (2008). Managing heritage in a contested space: the case of Le Morne Cultural Landscape in Mauritius. *South African Journal of Art History* 23(1), 225-244

Beatley, T., Brower, D.J. and Schwab, A.K. (1994). *An introduction to coastal zone management.* Island Press, Washington, D.C.

Benbow, S. and Harris, A. (2011). *Managing Madagascar's octopus fisheries*. Proceedings of the workshop on *Octopus cyanea* fisheries. BlueVentures. Aberdeen Centre, London

Boko, M, Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. and Yanda, P. (2007). Africa. In *Climate Change Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.) pp. 433–467. Cambridge University Press. Cambridge,UK

Brownfield, M.E., Schenk, C.J., Charpentier, R.R., Klett,

T.R., Cook, T.A., Pollastro, R.M. and Tennyson, M.E. (2012). Assessment of Undiscovered Oil and Gas Resources of Four East Africa Geologic Provinces . No 2012-3039. U.S. Geological Survey's (USGS). World Petroleum Resources Project

Buckley, R.C. (2008). Testing take-up of academic concepts in an influential commercial tourism publication. *Tour. Manag.* 29(4), 721–729

Caddy, J.F. and Bakun, A. (1994). A tentative classification of coastal marine ecosystems based on dominant processes of nutrient supply. *Ocean Coast. Manage.* 23(3), 201-211

Chassot, E., Bonhommeau, S., Dulvy, N.K., Melin, F., Watson, R., Gascuel, D. and Le Pape, O. (2010). Global marine primary production constrains fisheries catches. *Ecol. Lett.* 13, 495–505

Chislock, M.F., Doster, E., Zitomer, R.A. and Wilson, A.E. (2013). Eutrophication: causes, consequences, and controls in aquatic ecosystems. *Nat. Educ. Knowl.* 4(4), 10

Christensen, J.H., Krishna Kumar, K., Aldrian, E., An, S.-I., Cavalcanti, I.F.A., de Castro, M., Dong, W., Goswami, P., Hall, A., Kanyanga, J.K., Kitoh, A., Kossin, J., Lau, N.-C., Renwick, J., Stephenson, D.B., Xie, S.-P. and Zhou, T. (2013). Climate Phenomena and their Relevance for Future Regional Climate Change. In *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the IPCC . (eds. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley) pp. 1217-1308 Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Cinner, J.E (2007). The role of taboos in conserving coastal resources in Madagascar. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* 22, 15-23

Cinner, J.E. and Aswani, S. (2007). Integrating customary management into marine conservation. *Biol. Conserv.* 140(3), 201-216

Cochrane, K.L. and Japp, D. (2015). Pelagic fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Cooley, S.R., Kite-Powell, H.L. and Doney, S.C. (2009). Ocean acidification's potential to alter global marine ecosystem services. *Oceanography* 22, 172-181

Davies-Coleman, M.T and Sunassee, S.N. (2012). Marine bioprospecting in southern Africa. In *Drug discovery in Africa – impacts of geneomics, natural products, traditional medicines, insights into medicinal chemistry, and technology platforms in pursuit of new drugs* (eds. K. Chibale, M. Davies-Coleman, and C. Masimirembwa) pp. 193-209. Springer-Verlag, Berlim

De Mora, S. (2006). *An Assessment of the National Capabilities for Marine Pollution Monitoring in the Western Indian Ocean Region and Recommendations for Regional Capacity Building and Training Needs*. Report to UNEP and WIO-Lab by the International Atomic Energy Agency: Marine Environmental Laboratory. Monaco

DHI and Samaki (2014). Coastal Profile for Mainland Tanzania 2014 Thematic Volume – Draft 0. Investment Prioritization for Resilient Livelihoods and Ecosystems in Coastal Zones of Tanzania DHI and Samaki Consultants

Doney, S., Fabry, V., Feely, R. and Kleypas, J. (2009). Ocean Acidification: The other $CO_2$ problem. *Annu. Rev. Mar. Sci.* 1, 69–92

Duarte, R.T (2012). Maritime History in Mozambique and East Africa: The Urgent Need for the Proper Study and Preservation of Endangered Underwater Cultural Heritage. *Journal of Maritime Archaeology* 7(1), 63–86

Everett, B.I., Groeneveld, J.C., Fennessy, S.T., Dias, N., Filipe, O., Zacarias, L., Igulu, M., Kuguru, B., Kimani, E., Munga, C.N., Rabarison, G.A., Razafindrakoto, H. and Yemane, D. (2015). Composition and abundance of deep-water crustaceans in the Southwest Indian Ocean: Enough to support trawl fisheries? *Ocean Coast. Manage.* 111, 50-61

FAO (1995). Code of Conduct for Responsible Fisheries. Food and Agriculture Organization. http://www.fao.org/docrep/005/v9878e/v9878e00.htm

FAO (2010). *The state of world fisheries and aquaculture*. Food and Agriculture Organization of the United Nations, Rome

Fennessy, S.T. and Everett, B.I. (2015). Crustacean shallow-water trawl fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Global Ocean Commission (2013). Policy Options Paper No. 4: Bioprospecting and marine genetic resources in the high seas. A series of papers on policy options, prepared for the third meeting of the Global Ocean Commission. November 2013. Available at http://www.globaloceancommission.org/wp-content/uploads/GOC-paper04-bioprospecting.pdf

Gössling, S. (2006). Towards sustainable Tourism in the Western Indian Ocean. *Western Indian Ocean J. Mar. Sci.* 5(1), 55-70

Government of Mauritius (2013). The Ocean Economy. A Roadmap for Mauritius. Prime Minister's Office

Graham, N. McClanahan, T., MacNeil, M., Wilson, S., Polunin, N., Jennings, S., Chabanet, P., Clark, S., Spalding, M., Letourneur, Y., Bigot, L., Galzin, R., Ohman, M., Garpe, K., Edwards, A. and Sheppard, C. (2008). Climate Warming, Marine Protected Areas and the Ocean-Scale Integrity of Coral Reef Ecosystems. *PLoS ONE* 3(8): e3039

Hahs, A., McDonnell, M., McCarthy, M., Vesk, P., Corlett, R., Norton, B., Clemants, S.E., Duncan, R.P., Thompson, K., Schwartz, M.W. and Williams, N.S.G. (2009). A global synthesis of plant extinction rates in urban areas. *Ecol. Lett.* 12(11), 1165–1173

Hoegh-Guldberg, O. (Lead Author) (2015). Reviving the Ocean Economy: the case for action - 2015. WWF International, Gland, Switzerland, Geneva, 60 pp

IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds. V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastran drea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Jackson, J.B., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J. and Estes, J.A. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science* 293(5530), 629-637

Kangwe, J., Semesi, S., Beer, S., Mtolera, M. and Bjork, M. (2012). Carbonate production by calcareous algae in a seagrass dominated system: The example of Chwaka Bay. In *People, Nature and Research in Chwaka Bay, Zanzibar, Tanzania* (eds. De la Torre Castro, M. and Lyimo, T.) pp. 143–156

Levitus, S., Antonov, J.I., Boyer, T.P., Locarnini, R.A., Garcia, H.E. and Mishonov, A.V. (2009). Global ocean heat content 1955-2008 in light of recently revealed instrumentation problems. *Geophy. Res. Lett.* 36(7), L07608

Lutjeharms, J.R.E. (2006). *The Agulhas current*. Springer-Verlag, Heidelberg

Lutjeharms, J.R.E. and Bornman, T.G. (2010). The importance of the greater Agulhas Current is increasingly being recognised. *S. Afr. J. Sci.* (online) 106(3/4), 4 pp. DOI: 10.4102/sajs.v106i3/4.160

Mahongo, S.B., Francis, J. and Osima, S.E. (2012). Wind Patterns of Coastal Tanzania: Their Variability and Trends. *Western Indian Ocean J. Mar. Sci.* 10, 107-120

Maina, J., Moel, H., Zinke, J., Madin, J., McClanahan, T. and Vermaat, J. (2013). Human deforestation outweighs future climate change impacts of sedimentation on coral reefs. *Nat. Commun.* 4, 1986

Manyilizu, M., Dufois, F., Penven, P. and Reason, C. (2014). Interannual variability of sea surface temperature and circulation in the tropical western Indian Ocean. *Afri. J. Mar. Sci.* 36(2), 233-252

Masalu, D.C.P. (2002). Coastal Erosion and Its Social and Environmental Aspects in Tanzania: A Case Study in Illegal Sand Mining. *J. Coast. Manage.* 30 (4), 347-359

Masalu, D.C.P., Shalli, M. and Kitula, R. (2010). Customs and taboos: The role of indigenous knowledge in the management of fish stocks and coral reefs in Tanzania. Coral reef, targeted research and capacity building for Management Program, 2010. Currie Communications, Melbourne, Australia

Mavume, A.F., Rydberg, L., Rouault, M. and Lutjeharms, J.R.E. (2009). Climatology and landfall of tropical cyclones in the south-west Indian Ocean. *Western Indian Ocean J. Mar. Sci.* 8(1), 15-36

May, V. (1991). Tourism, environment and development. Values, sustainability and stewardship. *Tour. Manag.* 12(2), 112-118

MRAG (2005). Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries. Final Report, Department for International Development (DFID, UK), and Norwegian Agency for Development Cooperation (NORAD)

Murata, A., Kumamoto, Y., Sasaki, K., Watanabe, S. and Fukasawa, M. (2010). Decadal increases in anthropogenic $CO_2$ along 20°S in the South Indian Ocean. *J. Geophy. Res., Oceans* 115(C12)

Mwaluma, J. (2002). Pen culture of the mud crab *Scylla serrata* in Mtwapa mangrove system, Kenya. *Western Indian Ocean J. Mar. Sci.* 1(2), 127-133

Norse, E.A., Brooke, S., Cheung, W.W., Clark, M.R., Ekeland, I., Froese, R., Gjerde, K.M., Haedrich, R.L., Heppell, S.S., Morato, T., Morgan, L.E., Pauli, D., Sumaila, R. and Watson, R. (2012). Sustainability of deep-sea fisheries. *Marine Policy* 36 (2), 307-320

Obura, D.O., Church, J.E. and Gabrié, C. (2012). *Assessing Marine World Heritage from an Ecosystem Perspective: The Western Indian Ocean*. World Heritage Centre, United Nations Education, Science and Cultural Organization (UNESCO)

Parson, L.M. and Evans, A.J. (2005). Seafloor topography and tectonic elements of the Western Indian Ocean. *Phil. Trans. R. Soc. A* 363(1826), 15-24

Puppim de Oliveira, J.A. (2005). Tourism as a Force for Establishing Protected Areas: The Case of Bahia, Brazil. *J. Sustainable Tour.* 13(1), 24-49

Ribeiro, F. (2007). Inventory of Small-Scale Mariculture in Mozambique . WIOMSA SUCCESS Programme

Richardson, B. (2010). The Contribution of Tourism to Economic Growth and Food Security. USAID Mali, Office of Economic Growth. Michigan State University, USA

Robinson, G. (2011). Community Based Sea CucumberAquaculture in Madagascar. In *Mariculture in the WIO Region "Challenges and Prospects"* (eds. Troell, M., Hetcht, T., Beveridge, M., Stead, S., Bryceson, I., Kautsky,N., Ollevier, F. and Mmochi, A.) No 11, pp. 47-52. WIOMSA Book Series

Roger, H.C. (2002). Impact on the Coastal Environment of Marine Aggregates Mining. *Int. J. Environ. Stud.* 59(3), 297-322

Roxy, M.K., Ritika, K., Terray, P. and Masson, S. (2014). The Curious Case of Indian Ocean Warming. *J. Clim.* 27(22), 8501-8509

Sabine, C.L., Key, R.M., Johnson, K.M., Millero, F.J., Poisson, A., Sarmiento, J.L., Wallace, D.W. R. and Winn, C.D. (1999). Anthropogenic $CO_2$ inventory of the Indian Ocean. *Glob. Biogeochem. Cycles* 13(1), 179-198

Sadally, S.B., Taleb-Hossenkhan, N. and Bhagooli, R. (in press ). Spatial and temporal variations of micro-phytoplankton diversity and biomass in two tropical coral reefs. *Afr. J. Marine Sci.*

Seetanah, B., Juwaheer, T.D., Lamport, M,J., Rojid, S., Sannassee, R.V. and Subadar Agathee, U. (2011). Does Infrastructure Matter In Tourism Development? *University of Mauritius Research Journal* 17, 89-108

Semesi, I. (2009). Seawater pH as a controlling factor in macroalgal calcification and photosynthesis. PhD Thesis. Stockholm University

Shalli, M. (2011). Taditional Knowledge in the Management of Coastal and Marine Resources in Tanzania. PhD Thesis. Aquatic Sciences. University of Dar es Salaam

Spalding, M.D., Fox H.E., Allen, G.R., Davidson, N., Ferdana, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A.L. and Lourie, S.A. (2007). Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience* 57, 573–583

Spectrum (2014). New seismic agreement with Madagascar's OMNIS. Press Release 3 October 2014. http://www.spectrumasa.com/press-release/new-seismic-agreement-with-madagascars-omnis Accessed at 19 November2014

Sunde, J. (2013). *Living customary law along the South African coast: securing the rights of small-scale fishing communities*. Environmental Evaluation Unit, University of Cape Town

Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K. and Wetterberg, O. (2012). Cultural Ecosystem Services provided by Landscapes: Assessment of heritage values and identity. *Ecosystem Services* 2, 14-26

Tinley, K.L. (1985). *Coastal dunes of South Africa*. South African National Science Programme report 109. Pretoria: FRD-CSIR. South Africa

Troell, M., Hecht, T., Beveridge, M., Stead, S., Bryceson, I., Kautsky, N., Ollevier, F. and Mmochi, A. (2011). Mariculture in the WIO region – Introduction and some perspectives. In *Mariculture in the WIO region "Challenges and Prospects"* (eds. M. Troell, T. Hecht, M. Beveridge, S. Stead, I. Bryceson, N. Kautsky, F. Ollevier and A. Mmochi) WIOMSA Book Series No 11, Pp. 1-5. Jamana Printers Limited, Tanzania

UN (2012). United Nations Department of Economic and Social Affairs/Population Division. World Population Prospects: The 2012 Revision, Highlights and Advance Tables. Paper No. ESA/P/WP.228.

UNCTAD (2006). Review of Maritime Transport 2006. United Nations publication. NY. Geneva

UNEP (2003). Tourism and Local Agenda 21: The Role of Local Authorities in Sustainable Tourism. United Nations Environment Programme. The International

Council for Local Environmental Initiatives

UNEP (2010a). Africa Water Atlas. Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP). Nairobi, Kenya.

UNEP (2010b). Are you a green leader? Business and biodiversity: making the case for a lasting solution. Paris: United Nations Environment Programme.

UNEP (2011). Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. http://www.unep.org/greeneconomy/Portals/88/documents/ger/ger_final_dec_2011/Green%20EconomyReport_Final_Dec2011.pdf [Accessed December 19, 2012].

UNEP, FAO, IMO, UNDP, IUCN, World Fish Center, GRID-Arendal (2012). Green Economy in a Blue World. www.unep.org/greeneconomy and www.unep.org/regionalseas

UNEP, IOC-UNESCO (2009). An Assessment of Assessments, findings of the Group of Experts. Start-up phase of the Regular Process for Global Reporting and Assessment of the State of the Marine Environment including Socio-economic Aspects. Summary for Decision Makers. United Nations Environment Programme and Intergovernmental Oceanographic Commission/ United Nations Educational Scientific and Cultural Organization. Malta

UNEP, Nairobi Convention Secretariat, WIOMSA (2008). Marine Litter in the Eastern Africa Region: An Overview Assessment. United Nations Environmental Programme

UNEP/Nairobi Convention Secretariat and WIOMSA (2009). An assessment of hydrological and land use characteristics affecting river-coast interactions in the Western Indian Ocean region. UNEP/Nairobi Convention Secretariat and WIOMSA. Nairobi, Kenya

UNEP/Nairobi Convention Secretariat (2009a). Transboundary Diagnostic Analysis of Land-based Sources and Activities Affecting the Western Indian Ocean Coastal and Marine Environment. UNEP Nairobi, Kenya

UNEP/Nairobi Convention Secretariat (2009b). Strategic Action Programme for the Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities. Nairobi, Kenya

UNEP/Nairobi Convention Secretariat, CSIR and WIOMSA (2009). Regional Synthesis Report on the Status of Pollution in the Western Indian Ocean Region. UNEP. Nairobi, Kenya

UNESCO (2014). World Heritage in Africa Region: UNESCO WORLD HERITAGE CENTRE. June 2011. http://Whc.unesco.org/en/sessions/35COM

UNFPA (2002). UNFPA at work 2001. United Nations Population Fund, New York

UN-Habitat (2014). The State of African Cities 2014: Re-imagining sustainable urban transitions. UN-Habitat. Nairobi, Kenya

van der Elst, R., Everett, B., Jiddawi, N., Mwatha, G., Afonso, P. S. and Boulle, D. (2005). Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. *Phil. Trans. R. Soc.* A 363(1826), 263-284

Veron, J.E.N., Hoegh-Guldberg, O., Lenton, T.M., Lough, J.M., Obura, D.O., Pearce-Kelly, P., Sheppard, C.R.C., Spalding, M., Stafford-Smith, M.G. and Rogers, A.D. (2009). The coral reef crisis: The critical importance of <350 ppm CO2. *Mar. Pollut. Bull.* 58, 1428–1436

Vincent, L.A., Aguilar, E., Saindou, M., Hassane, A.F., Jumaux, G., Roy, D., Booneeady, P., Virasami, R., Randriamarolaza, L.Y.A., Faniriantsoa, F.R., Amelie, V., Seeward, H. and Montfraix, B. (2011). Observed trends in indices of daily and extreme temperature and precipitation for the countries of the western Indian Ocean, 1961–2008. *J. Geophys. Res.-Atmos.* 116(D10)

Webster, P.J., Holland, G.J., Curry, J.A. and Chang, H.R. (2005). Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. *Science* 309(5742), 1844-1846

WWF (2001). *Eastern African Marine Ecoregion*. Proceedings of the Vision Workshop. 23-27 April 2001. Mombasa, Kenya

Zinke, J., Pfeiffer, M., Timm, O., Dullo, W.C. and Davies, G.R. (2005). Atmosphere-ocean dynamics in the Western Indian Ocean recorded in corals. *Phil. Trans. R. Soc.* A 363(1826), 121-142