Mozambique marine ecosystems review

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Estudos e Advocacia Ambiental

Mozambique Marine Ecosystems Review

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Mozambique Marine Ecosystems Review

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From left to the right and clockwise: Ponta Dobela, Maputo Province (Marcos Pereira); Loggerhead turtle at Ponta do Ouro, Maputo Province (Marcos Pereira); Sand banks at the Bazaruto Archipelago, Inhambane Province (Jess Williams); Dhow at Muelé, Inhambane Province (Rodrigo Santos); Bowmouth guitar shark at Tofo, Inhambane Province (Jess Williams); Tridacna at Primeiras and Segundas Islands, Nampula Province (Marcos Pereira).

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EXECUTIVE SUMMARY

The purpose of the review was to analyse in detail the available information on the broad situation of the marine ecosystems of Mozambique, and highlight the critical gaps in available data or research. The report will enable Fondation Ensemble and its partner the Oak Foundation, or any other interested stakeholder, to deepen their understanding of the broad marine ecosystem situation in Mozambique and help establish intervention priorities for practical field initiatives and/or on research within the areas of marine biodiversity conservation, and/or sustainable fishing.

Mozambique is located along the southern coast of East Africa. The 2,470 km coastline and a diverse and productive continental shelf area of about 104,300 km^2 are of paramount importance for the country. The Mozambican coastline is characterized by a wide diversity of habitats including sandy and rocky beaches; sand dunes, coral reefs, estuaries, bays, seagrass beds and mangrove forests, which support pristine ecosystems, high biological diversity, high endemism, and endangered species. The coastline can broadly be classified into three regions from north to south, each supporting a variety of marine ecosystems; 1) the coral coast, 2) swamps and 3) parabolic coastal dunes. In addition to these three main regions, the deep-water pelagic and seabed ecosystems contribute to the majority of the country's exclusive economic zone (EEZ). The various natural resources therein, sustain about half the population of Mozambique living in the coastal zone, help support the country's economy through fisheries, tourism, industries and communications. There are more than 20 million people living in Mozambique with a growth rate of 2.5% per annum, the majority of which lives below the poverty line and has no access to improved water and sanitation. About two-thirds of the total population resides within the coastal region.

Legal and Institutional Framework

Mozambique is endowed with a comprehensive environmental and fisheries legal framework, including conventions and international agreements. The legal framework is widely recognized as sufficient and progressive; the major challenge being enforcement and compliance. Apart from local communities represented either by community-based organizations or fisheries community councils, the main coastal and marine stakeholders include Governmental institutions at various administrative levels dealing with fisheries (Ministry of Fisheries and subsidiary agencies), environment (Ministry for the Coordination of Environmental Affairs), conservation (Ministry of

Tourism), and safety, hydrography and navigation (Ministry of Transport and Communications and its agencies). Other important stakeholders include academia (Eduardo Mondlane University, UniLúrio and their departments and schools), the private sector (operating in tourism, fisheries and aquaculture, consulting), national and international non-governmental organizations and international bodies (including several United Nations agencies).

Climate

According to the classification of Köppen, the northern and coastal regions have a tropical rain savannah climate (Aw) and the southern sedimentary terrains a dry savannah climate (BSw). The coastal region has been divided in three climatic zones: a) north of the Zambezi River (Cabo Delgado, Nampula and Zambézia provinces), b) a transitional zone in the region of Zambezi River and c) southern region of Mozambique. Along the coast, mean temperature ranges are from 25 to 30° C during the warmer months. The average annual temperature is 23° C along the southern region and slightly higher in the northern region (26°C). The average relative humidity is 69%. The Inter ‐ Tropical Convergence Zone is positioned over the northern part of the country along the Zambezi River, to the north of Sofala province, bringing 150 ‐ 300mm of rainfall in the Cabo Delgado and Nampula provinces from November to April, which are the warmer months of the year. The transitional zone of the Zambezi River in Central Mozambique has the highest average annual rainfall, 1,200–1,600 mm, and is also mainly restricted to the warm season. South of the Zambezi River, climate of central and southern Mozambique is influenced by a subtropical anti-cyclonic zone. This area is dominated by the southeast trade winds and receives easterly prevailing winds throughout the year. Evaporation reaches about 1,650 mm per year, which exceeds the precipitation by about 500 mm per year.

Oceanography

Tides of the coast of Mozambique are semi-diurnal (two low waters and two high waters each day). The tidal range is about 2 m in the south, 3.1 m in the north and about 6.4 m in the centre. The higher range in the centre is caused by the broad shallow continental shelf fed by sediments of over 100 rivers, the major ones being the Rovuma, Lúrio and Zambezi in the north, Pungué, Buzi, Gorongosa and Save in the centre and Limpopo, Incomáti and Maputo in the south. These rivers drain about 208 km^3 of nutrient-rich water into the coastal waters each year. About 80% of this water enters the ocean in the vicinity of the Sofala Bank, central Mozambique. The Zambezi River, the largest river in eastern Africa, contributes approximately 67% of the total river discharge from Mozambique.

Biodiversity and Conservation

The wide latitudinal range of the Mozambican coastline, as well as the diversity of habitats and ecosystems, supports high biodiversity and an array of flagship species. Several ecological areas of regional and global importance (hotspots) have been identified along the coast. Almost 900 species of reef-associated fishes have been recorded, 122 species of sharks and rays, 400 species of molluscs, 27 species of marine mammals, including arguably the last viable population of dugongs in the western Indian Ocean, five species of marine turtles, 270 species of hard and soft corals, 14 species of seagrasses and ten species of mangroves.

The network of marine protected areas (MPAs) is comprised of five conservation areas (two national parks, one reserve, one total protection zone, and one environmental protection area). Currently, MPAs cover a total area of about 20,462 km^2 of which 8,633 km^2 encompass marine ecosystems. In Mozambique, conservation areas in general and MPAs in particular, are under-staffed and poorly equipped. Also lacking in most of the MPAs are management procedures and tools (including management, monitoring and research plans) as well as adequate science to support them. Several ecosystems and species such as seagrass beds, mangroves, the dugong, manta rays and the whale shark are still poorly represented in the current MPA network in Mozambique.

Major threats to the coastal and marine ecosystems of Mozambique include overfishing, industrial and coastal development, natural resources exploitation, unregulated and damaging tourism practices, pollution and weather extremes such and storms and cyclones.

Fisheries

There are three main types of fisheries: industrial, semi-industrial and artisanal. The fisheries sector plays an important role in the economy, contributing about 3% of the Gross Domestic Product (GDP), and 4% of the global national exports. The level of production in 2012 was 213,436 tons (t) of total products representing an estimated value of 526 million USD. Commercial fisheries (industrial and semi-industrial) exploit the most important and valuable resources such as shallow- and deep-water shrimp that occur on the Sofala Banks as well as pelagic fish species such tuna, billfishes, and sharks.

Artisanal fishery occurs along the entire coast and captures shallow water demersal and pelagic species using traditional gears. Artisanal landings are, on average, responsible for almost 90% of the total national production. This sub-sector has a high social importance since it is the most important source of food and employment for the coastal communities, which represent more than two-thirds of the population of Mozambique. Data from the last census of artisanal fisheries conducted in 2012, indicate that there were about 343,000 fishermen and other professionals involved in this sector, of which 18% were women, all depending directly or indirectly on activities related to fishing. At present, almost all fisheries are overexploited and facing crisis due to a declining production and increasing operating costs.

Available Data and Information Gaps

During the past decade, marine scientific research in Mozambique has grown with many authors paying special attention to corals and associated fishes, marine mammals, seagrasses, mangroves and associated fauna, and sea turtles. However, limited research has been done in other areas therefore knowledge on the biology of sharks, seaweeds, seabirds, molluscs, and echinoderms remains poor. Information relevant to fisheries is also lacking and represents a source of future challenges. For example, the migratory routes of tuna that recurrently travel to the Mozambican coast are unknown. Similarly, shark fishing, deep-sea fisheries, reproductive aspects of lobsters, sea cucumbers, mussels, fishing effort, and catches of the artisanal sub-sector have been poorly reported.

Additionally there is a need to assess: the use and conservation of coastal resources in the central region of the country; levels of trace metal pollutants in the coastal environment; effects of the discharge of untreated urban waste on nutrient dynamics and coastal marine ecosystems; variations in the spatial distribution of macrobenthos and nutrient dynamics in mangroves and seagrass; effects of climate change and movement of sediments; the condition of corals; characterization (to species level) of phytoplankton and zooplankton communities (both intertidal and deep-sea); migration and population genetics of whales, stingrays, mantas; rehabilitation of ecosystems degraded such as coastal dunes, reefs, mangroves and seagrass; distribution of sea turtles and their nesting along the Mozambican coast; the migration routes and nesting areas for seabirds; assessment of the impact of tourism on shore birds; and mapping of areas that may be ecologically sensitive to the development of oil and gas reserves recently found in the Rovuma basin.

Recommendations

Several recommendations are proposed and pertain essentially to research and monitoring; management and conservation; networking, dissemination of information and capacity building; legal and institutional framework; and funding. Ecological indicators for major ecosystems and flagship species as well as social indicators have also been proposed.

LIST OF ACRONYMS AND UNITS

AAIW – Antarctic Intermediate Water

ACCM – Association of Coastal Conservation of Mozambique

ACOPS – Advisory Committee on Problems of the Sea

ADNAP – Adminbistração Nacional das Pescas (National Administration of Fisheries)

AFD – Agence Française de Développment

AfDB – African Development Bank

AMAR – Associação de Mergulhadores Activos para os Recursos Marinhos

ASCLME – Agulhas and Somali Current Large Marine Ecosystem

BADEA – Arab Bank for Economic Development in Africa

BIOFUND – Foundation for the Conservation of Biodiversity

CBNRM – Community-Based Natural Resource Management

CI – Conservation International

CI-GCF – Conservation International Global Conservation Fund

CCP – Conselho Comunitário de Pesca (Fishing Community Council)

CONDES – Conselho Nacional para o Desenvolvimento Sustatável (National Council for Sustainable Development)

CTV – Centro Terra Viva

DANIDA – Danish International Development Agency

DDCA – Direcção Distrital para Coordenação Ambiental (District Directorates for Coordination of Environmental Affairs)

DFID – United Kingdom Department for International Development

DMI – Indian Ocean Dipole Mode Index

DNFP – Direcção Nacional de Fiscalização da Pesca (National Directorate for Fisheries Surveillance)

DPCA – Direcção Provincia para Coordenação Ambiental (Provincial Directorates for Coordination of Environmental Affairs)

EACC – East African Coastal Current

EC – European Commission

EIA – Environmental Impact Assessment

EMP – Environmental Management Plan

ENSO – El Niño Southern Oscillation

EOTH – Eyes on the Horizon

EP – Escola de Pesca (Fisheries School)

EU – European Union

FAO – Food and Agriculture Organization

FFP – Fundo de Fomento Pesqueiro (Fisheries Development Fund)

GEF – Global Environmental Facility

ha – hectares

ICEIDA – Icelandic International Development Agency

IDB – Islamic Development Bank

IDPPE – Instituto de Desenvolvimento da Pesca de Pequena Escala (Institute for Small Scale Fisheries Development)

IFAD – International Fund for Agricultural Development

IIP – Instituto Nacional de Investigação Pesqueira (National Institute for Fisheries Research)

INAQUA – Instituto Nacional de Desenvolvimento da Aquacultura (National Institute of Aquaculture Development)

INIP – Instituo Nacional de Inspecção de Pescado (National Institute of Fish Inspection)

IO – Indian Ocean

IOC – Intergovernmental Oceanographic Commission

IOD - Indian Ocean Dipole

IODM - Indian Ocean Dipole Mode

IOTC - Indian Ocean Tuna Commission

IPB – International Public Bodies

ISO – Intra-Seasonal Oscillations

ITCZ – Inter-Tropical Convergence Zone

ITF – Indonesian through Flow

IUCN – International Union for Conservation of Nature

JICA – Japan International Cooperation Agency

KfW – Kreditanstalt für Wiederaufbau (German Bank for Development)

km – kilometre(s)

km^2 – square kilometre(s)

m – meter(s)

MICOA – Ministério para Coordenação da Acção Ambiental (Ministry for the Co-ordination of Environmental Affairs)

MJO – Madden-Julian Oscillations

MMF - Marine Megafauna Foundation

MOZBIO – Conservation Areas for Biodiversity and Development Project

MPA – Marine Protected Area

MPR – Maputaland-Pondoland Region

NADW – North Atlantic Deep Water

NE - Northeast

NEMC – Northeast Madagascar Currents

nm – nautical mile(s)

NORAD – Norwegian Agency for Development Cooperation

ODINAFRICA - Ocean Data and Information Network for Africa

OFCF – Overseas Fishery Cooperation Foundation of Japan

OPEC – Organization of the Petroleum Exporting Countries

PPF – Peace Parks Foundation

RSW – Red Sea Water

SCUBA – Self Contained Underwater Breathing Apparatus

SEMC – Southeast Madagascar Current

SST – Sea Surface Temperature

Sv - Sverdrup

SW – Southwest

SWIOFP - The Southwest Indian Ocean Fisheries Project

TNC - The Nature Conservancy

TPRM – Tongaland-Pondoland Regional Mosaic

UN – United Nations

UNDP - United Nations Development Programme

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organisation

USAID – United States Aid

WCS – Wildlife Conservation Society

WIO – Western Indian Ocean

WHO – World Health Organization

WRI – World Resources Institute

WWF – World Wildlife Fund for Nature

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1. INTRODUCTION

1.1. PURPOSE AND BACKGROUND

The purpose of this review, as stated in the scope of work, is to analyse in detail the available information on the broad situation of marine ecosystems in Mozambique, and where necessary, to draw attention to the critical gaps in available data or research.

The review will help establish intervention priorities for practical field initiatives and/or on research within the areas of marine biodiversity conservation, and/or sustainable fishing, in order to enable Fondation Ensemble and its partner the Oak Foundation, or any other interested stakeholders, to deepen their understanding about the broad marine ecosystem situation in Mozambique, also taking into account the living conditions of coastal communities, which necessarily have an impact on the ecosystems.

1.1.1. Report Organization

This report consists of twelve sections. **Section 1** gives the reader an understanding of Mozambican marine ecosystems, fisheries and coastal communities, biological and oceanographic characteristics of the Mozambican coastal area, literature and data search conducted for this review, and the qualitative and quantitative data available as well as identified data gaps.

Sections 2 and **3** deliver information on the scientific community, national and local governments, companies and corporate federations operating in fisheries and aquaculture sectors, international public bodies, local and foreign NGOs, civil societies and private bodies, and main social indicators.

Section 4 highlights applicable legislation on the marine environment, fisheries and aquaculture sectors, the enforcement of main environmental laws and policies, the promulgation of new environmental and fisheries laws and the establishment of MPAs.

Section 5 summarizes the climate of Mozambique, and its physical and biological oceanography.

Section 6 focuses on the characteristics and condition of main coastal ecosystems, namely dunes and lagoons, mangroves, reefs, seagrass beds, estuaries and bays, rocky shores, and the seafloor.

Section 7 presents the Mozambican biodiversity hotspots as well as their location.

Section 8 presents the types of MPAs (existing and planned), their management and effectiveness and human induced impacts on coastal and marine environments focusing on urban, industrial and tourism impacts.

Section 9 discusses the main and potential threats to Mozambican marine environment.

Section 10 reports on fisheries with emphasis on production by fleet, target species, gear, management, catch information, local seafood market and trade flows, and illegal and regulated fishing.

Finally, **Section 11** presents conservation recommendations namely applied research and priorities, protection and restoration of marine ecosystems and fisheries, influence of coastal ecosystems on livelihood and indicators of condition of marine ecosystems and fisheries.

1.1.2. Background

Mozambique is located along the southern coast of East Africa, between latitudes 10°27’ S and 26°52’ and longitudes 30°12’ E and 40°51’E (ASCLME, 2012; Bandeira *et al*., 2002; Motta, 2002). The country occupies a total surface area of 784,032 km^2 and is divided in 10 provinces. The country is bordered by the Republic of Tanzania to the north, by Malawi, Zambia and Zimbabwe to the west, by South Africa and Swaziland to the south and by the Indian Ocean (Figure 1.1). The coastline is 2470 km long (CIA, 2013), making it the third longest coastline in the East African region. Total continental shelf area is about 104,300 km^2.

There are more than 20 million people living in Mozambique with a growth rate of 2.5% per annum. Most of the population is concentrated in the southern provinces of Maputo, Gaza and Inhambane and in central and Northern provinces of Zambézia and Nampula. About two-thirds of the total population resides within the coastal region (ASCLME, 2012; Barnes *et al*., 1998; Ruby *et al*., 2008). According to Motta (2002), the higher coastal population densities are recorded in Maputo (1,525 persons/km^2), Beira (625 persons/km^2), Nacala (409 Persons/km^2) and Mozambique Island (13,000 persons/km^2). The high coastal population density contributes to coastal erosion, sedimentation, water pollution, over-exploitation of resources, deforestation, and reduction and modification of biological diversity (Sete *et al*., 2002).

Figure 1.1 – Location of Mozambique and neighbouring countries of East Africa (source: GoogleEarth).

1.1.3. Marine and Coastal Ecosystems

The Mozambican coastline is characterized by a wide diversity of habitats including sandy and rocky beaches; sand dunes, coral reefs, estuaries, bays, seagrasses and mangrove forests (Bandeira *et al*., 2002; Duarte, 2012; Hoguane, 2007; SEA ALARM, 2009). The coastal area supports pristine ecosystems, high biological diversity, high endemism, and endangered species. There are various natural resources, which include fisheries, coastal and marine fauna, and flora that sustain about half the population of Mozambique living in these areas, and support the country's economy (Hoguane *et al*., 2012).

The coastline can broadly be classified into three regions from north to south, each supporting a variety of marine ecosystems; 1) the coral coast, 2) swamps and 3) parabolic coastal dunes. In addition to these three main regions, the deep-water pelagic and seabed ecosystems (200 nautical miles [nm] offshore) contribute to the majority of the country's exclusive economic zone (EEZ). Despite international recognition for its unique marine ecosystems (Nature Conservancy, Mission Blue & WWF, 2014a; Obura *et al*., 2012), only 3% of its territorial waters are contained within MPAs (World Bank, 2014).

Although the majority (86%, Pew 2014a) of Mozambique's EEZ comprises deep-water habitat, knowledge on this ecosystem type is really lacking (Marsac *et al*., 2014). Based upon oceanographic understanding of the Mozambican Channel, it is a highly productive ecosystem characterized by complex upwelling patterns and converging eddy dipoles (Marsac *et al*., 2014). This offshore ecosystem supports the commercial harvest of pelagic fish species such as tunas, mackerel, marlin and sailfish (Pew, 2014b).

1.1.4. Fisheries

Mozambique is a country with a great fishing potential along its coastline and within an EEZ with an area of 571,955 km^2. In this vast marine area there are three main types of fisheries: industrial, semi-industrial and artisanal.

These fisheries sectors became prominent during the early 1980s, after the independence in 1975. During the majority of the colonial period, artisanal fisheries remained largely subsistence-based and fish products were imported mainly from Angola. Only the industrial prawn fishery was developed. In 1977, a civil war erupted and fisheries remained far below their potential but still the most important economic sector generating exports. In 1990, the Constitution and first Fisheries Law Act were established. Peace was reached in 1992 and Mozambique began to rebuild its infrastructures and recover a steady economic growth. Recognizing the strategic importance of the fisheries sector the government created in 2000 a Ministry fully dedicated to fisheries (MIPE – Ministry of Fisheries; Blythe *et al*., 2013).

Actually the fisheries sector plays an important role in the economy, contributing for about 3% of the Gross Domestic Product (GDP), and 4% of the global national exports. The level of production in 2012 was 213,436 tons (t) of total products representing an estimated value of 526 million USD. Export of prawns to Europe is one of the most important sources of exportation with revenues of 18.5 million USD placing prawn 13th in the ranking of exports commodities (INE, 2013; MIPE, 2013).

Commercial fisheries (industrial and semi-industrial) are exploiting the most important and valuable resources such as prawn and deep shrimp (gamba) that occurs on Sofala Bank, located in the centre of the country. Other important offshore resources are tuna, billfish and sharks (Santana Afonso, 2006).

Artisanal fishery occurs along the entire coast and captures shallow water demersal and pelagic species using traditional gears. Artisanal landings support, on average, almost 90% of the total national production (MIPE, 2013). This sub-sector has a high social importance since it is the most important source of food and employment for the coastal communities, which represent more than two-thirds of the population of Mozambique (Figure 1.2). It is crucial for reducing vulnerability to food insecurity and poverty since fish products contribute to almost half of the animal protein source accessible for these communities (FAO, 2007). Data from the last census of artisanal fisheries, conducted in 2012, indicate that there were about 343,000 fishermen and other professionals involved in this sector, of which 18% were women, all depending directly or indirectly on activities related to fishing (IDPPE, 2013).

Figure 1.2 – Local fisherman at Pemba bay in wooden canoes, Cabo Delgado Province (Photo: Boris Atanassov)

Aquaculture industry is very young but growing very fast, primarily on small-scale production of freshwater species, and has been promoted throughout the country by the National Aquaculture Development Institute (INAQUA). Marine aquaculture is represented by some commercial enterprises dedicated to the farming of prawn, and some species of marine fish and algae in the provinces of Cabo Delgado, Nampula, Zambézia and Sofala. The total production in 2012 was 604 t representing only 0.3% of the national fish production (MIPE, 2013).

Currently, almost all fisheries are overexploited and facing crisis due to a declining of production and increasing operating costs. Industrial prawn fishery has been especially affected (USAID, 2010).

On the other hand there are offshore resources that are not being fully exploited or being exploited by foreign fleets. There is now a priority to maximize exploitation of the EEZ fish resources to support economic development. One very recent move was the acquisition of 24 fishing vessels by the government to develop a national industrial tuna fishery fleet (Portal do Governo, 2013).

This report includes a general characterization and overview of the different fisheries sectors in Mozambique, describing current production levels, trends, main species exploited, processing and market structure, trade flows, legislation, institutional framework, management and the state of local and external illegal, and unreported and unregulated fishing.

1.1.5. Coastal Communities

During the war, Mozambique had a large flux of population from inland to the coast (Gervásio & Lopes, 2003). Nowadays at least 40% of the population is living in coastal districts, including over half of the urban population (MICOA, 2002; 2007). Urban centres include Maputo, Matola, Inhambane, Beira, Nacala and Pemba. The majority of the coastal communities depend on marine resources either directly or indirectly. The level of this dependence is highly influenced by geographic and biological characteristics, such as the profile of the beach, distance from the reef, and the quality of the soil for other activities (Whittingham *et al*., 2003).

Particularly for rural communities, lack of basic needs such as potable water, health care and access to education are common (Virtanen, 2005). The main sources of income and subsistence are agriculture and small fisheries (Oceanic Development *et al*., 2006). However, tourism, harvest of tidal invertebrates and juvenile stages of fish, trading, charcoal production, seaweed farming and aquaculture may also play an important role in both community livelihoods and the economy, depending on the region (Carvalho & Gell, 1998; de Boer *et al*., 2002; Gervásio & Lopes, 2003).

The combination of declining fish catch, illegal fisheries, exploration of mineral resources, over-exploitation of tidal ecosystems, global changes and rapid coastal development has caused several socio-economic changes and challenges (Blythe *et al*., 2014; Whittingham *et al*., 2003).

Island communities, small communities, and communities inside protected areas are more likely to engage in traditional management and co-management of natural resources toward conservation (e.g. Garnier *et al*., 2008). Such a participatory approach is important to ensure sustainable development. However, lack of management is far more common in Mozambique and unfortunately due to coastal development, natural resources are being intensively harvested with little control. For example, in the Inhambane Province, the use of gill nets has increased dramatically in the last 5 years raising by-catch of protected or key species for tourism, such as manta rays, whale sharks, and dugongs (Pierce & Marshall, 2008). Now the population is facing a dilemma – attending to the demands of development without destroying the resources necessary to sustain such growth (Tibiriçá *et al*., 2011). Without controls, sustainable development seems unlikely to be achieved in the majority of coastal areas. In such areas local communities are tragically trapped in destructive development, in which the "needs of today" threaten the future viability of the coastal community (Figure 1.3).

Figure 1.3 – Local fishing community at Quirimbas; Cabo Delgado Province (Photo: Jacques Rousselot)

1.2. METHODOLOGY

1.2.1. Literature and Data Search

Historically, a small group of fisheries research scientists linked to Eduardo Mondlane University (EMU) Biological Sciences Department pioneered formal marine scientific studies in Mozambique following the independence of 1975.

Initially, the investigations carried out by the EMU focused on Inhaca Island given that the island was easily accessible and the Estação de Biologia Marinha da Inhaca was provided with well-equipped laboratories and boats. Alongside EMU, the Fisheries Research Institute also conducted scientific research, since it was receiving aid from Norway, Russia, and Iceland.

To conduct the review of marine ecosystems of Mozambique the project team searched databases available in electronic and print formats. However, although the country has an extensive coastline there are few formally published data on its marine ecosystems. There is, however, a relatively abundant grey literature containing information that should probably be published.

1.2.2. Quantitative and Qualitative State of Data Collection/Availability

The fishery biology field in Mozambique presents more specific information on marine sciences with special emphasis for deep sea fishing of shrimp and fish (Bamoi *et al*., 2007; Brito, 2010; Brito *et al*., 2007; Brycesson & Massinga, 2002; Cadima & Silva, 1998; Fischer *et al*., 1990; Gervásio & Lopes, 2003; Gislason & Sousa, 1985; Gjosaeter & Sousa, 1983; Halare, 2012; Hoguane, 2007; Hoguane *et al*., 2012; Machava *et al*., 2014; Pinto & Lopes, 2001) and some ecological aspects of commercial shrimps that recruit in mangroves creeks (Macia 2004a,b; Macia *et al*., 2003; Ronnback *et al*., 2002).

During the past decade, marine scientific research in Mozambique has grown with many authors paying special attention to corals and associated fishes[1], marine mammals[2], seagrasses[3], mangroves[4] with special attention on fauna[5], and marine turtles[6].

However, limited research has been done to document other marine resources. There are few data on the biological production of the shelf ecosystem (phyto-and zooplankton studies are virtually absent), as well on the biology of sharks (Pierce *et al*., 2008), cephalopods, tuna (Chacate & Mutombene, 2012; Palha de Sousa, 2011), seaweed (Bandeira, 1995, 1998; Bandeira *et al*., 2001; Frontier-Mozambique, 1997), seabirds (Le Corre & Jaquemet, 2005), barnacles (Litulo,

[1] (Barnes & Bell, 2002; Costa *et al*., 2005; Motta, 2000; Motta *et al*., 2000; Muthiga, 1998; Obura *et al*., 2002; Pereira, 2000a,b; 2002; Pereira *et al*., 2001; Pereira & Videira, 2005; Quod, 1999; Rodrigues *et al*., 1999; Schleyer, 1998; Schleyer *et al*., 1999; Souter, 2000).
[2] (Cockroft *et al*., 2008; Guissamulo, 1993; Guissamulo & Cockroft, 1996; Guissamulo *et al*., 2002; Hughes, 1969; Kiszka *et al*., 2007; Mendez *et al*., 2011; Overvest, 1997).
[3] (Almeida *et al*., 1995, 1999, 2001; Bandeira, 1995, 2000, 2002; Bandeira & Bjork, 2001; Bandeira & Nilsson, 2001; Barnes *et al*., 1998; Gell & Whittington 2002; Gullstrom & Dahlberg 2004; Gullstrom *et al*., 2002).
[4] (Bandeira *et al*., 2009; Barbosa *et al*., 2001; Brauer *et al*., 2002; Ferreira *et al*., 2009; Frontier-Mozambique, 1997; Hatton & Couto, 1992; Kalk, 1995; Macnae & Kalk, 1969).
[5] (Amaral *et al*., 2009; Barnes *et al*., 2011; Cannicci *et al*., 2009; Ferreira *et al*., 2009; Flores *et al*., 2002; Guerreiro *et al*., 1996; Hartnoll *et al*., 2002; Litulo, 2005a,b,c,d; 2006, 2007; Macia *et al*., 2001, 2004a,b; 2014a,b; Paula *et al*., 2001a,b; 2003; Penha-Lopes *et al*., 2010a,b,c; Silva *et al*., 2009; Torres *et al*., 2009a,b).
[6] (Brito, 2012; Costa *et al*., 2007; Fernandes *et al*., 2014; Frontier-Mozambique, 1997; Garnier *et al*., 2012; Gove & Magane, 1996; Louro *et al*., 2006).

2007), bryozoans (Barnes & Whittington, 1999), gastropods and bivalves (de Boer *et al*., 2000), and echinoderms (Walenkamp, 1990), which remains poorly known.

1.2.3. Data Gaps

Regarding fisheries, there are many data gaps that could be a source of future challenges. For example, the migratory routes of tuna that recurrently travel to the Mozambican coast are unknown. Similarly, shark fishing, deep-sea fisheries, reproductive aspects of lobsters, sea cucumbers, mussels, the number of fishermen involved in each gear as well as the specific composition and yield by fishing gear (Fernando *et al*., 2012) have been poorly reported.

There is a need to assess: the use and conservation of coastal resources in the central region of the country; levels of trace metal pollutants in the coastal environment; variations in the spatial distribution of macrobenthos and nutrient dynamics in mangroves and seagrass; effects of climate change and movement of sediments on mortality of corals; characterization (to species level) and production of the phytoplankton and zooplankton system; migration and population genetics of whales, stingrays, mantas; rehabilitation of ecosystems degraded such as coastal dunes, reefs, mangroves and seagrasses; distribution of sea turtles along the Mozambican coast (ASCME, 2012); the migration routes and nesting areas for seabirds; assessment of the impact of tourism on shore birds; and mapping of areas that may be ecologically sensitive to the development of oil and gas reserves recently found in the Rovuma basin.

2. KEY STAKEHOLDERS

2.1. SCIENTIFIC COMMUNITY

Research in marine sciences in Mozambique started in the 70s when the country gained its independence from the Portuguese rule. Soon after independence, research activities were concentrated on fisheries as the country received financial aid to support this sector from the Soviet Union and Norway (Bandeira *et al*., 2002). As mentioned earlier, pioneering marine research in Mozambique took place at the Marine Biological Station at Inhaca Island, an institution attached to the Department of Biological Sciences of Eduardo Mondlane University, the oldest and leading Mozambican university founded in 1962. Sweden has been a key, long-term partner of the Department as well as the Biological Station at Inhaca, sponsoring high-level human resources capacity building and equipment.

There are currently five technical institutions operating in marine sciences in Mozambique: INAHINA – National Institute for Hydrography and Navigation, IIP- National Fisheries Research Institute, CDS_ZONAS COSTEIRAS - Centre for Sustainable development of Coastal Zones, CEPAM – Centre for Marine And Coastal Research of Pemba and UEM Eduardo Mondlane University with the Natural History Museum and the Inhaca Island Marine Biology Research Station. In addition, the Eduardo Mondlane University also carries out research and teaching in marine sciences through two institutions: the Superior School of Marine and Coastal Sciences of Quelimane, and the Department of Biological Sciences, Faculty of Science.

The aim of INAHINA is to conduct technical and scientific activities in Mozambican waters under national legislation ensuring navigation safety and to provide assistance to research and protection of marine resources. The Fisheries Research Institute was founded in the 60s and conducts research on fisheries and provides advice on fisheries management.

The CDS-Zonas Costeiras is a public institution created by the Mozambican Ministry of Environmental Affairs (MICOA). Its main mission is to coordinate and promote studies and their dissemination: provide technical advice, training and develop pilot activities to manage marine, coastal and inland (lake) environments; and contribute to the design of policies and legislation, which promotes the development of the coastal zone.

CEPAM (full name in Portuguese: Centro de Pesquisa do Ambiente Marinho e Costeiro) was created by the Ministry for Coordination of Environmental Affairs to carry out programs of applied research on marine and coastal ecosystems to improve the understanding of their capacity; contribute to the implementation of the integrated planned actions and good practices of the management of marine and coastal areas; conduct monitoring activities and regular evaluation of the marine and coastal ecosystems; reinforce the protection of the marine and coastal environment; promote environmental training programs and promote scientific exchange with national and foreign institutions which carry out research activities of the marine and coastal environment.

The School of Marine and Coastal Sciences of Quelimane (ESCMC) was created under the Faculty of Sciences of University Eduardo Mondlane in 2005. The ESCMC conducts multidisciplinary research on marine ecosystems for a better use and management of marine resources; contributes to an improved knowledge of the marine ecosystems; designs teaching programmes directed at meeting the country's needs in the many fields of marine sciences; and promotes communication and collaboration between institutions and individual marine science researchers (Hoguane, 1998).

The Department of Biological Sciences (DBS) is a teaching department of the Eduardo Mondlane University, which has been active for more than 25 years. It began its activities in 1986 as the Faculty of Biology and in 1999 it became a Department of Biological Sciences when it merged with the large Faculty of Science. Since 2010, the DBS teaches four undergraduate courses (to the Licenciatura level), one of which focuses on Marine and Aquatic Biology. Since 2008 this department also teaches a Master of Science Course in Aquatic Biology and Coastal Ecosystems offering postgraduate training opportunities in Mozambique. Marine research of this institution includes the ecology of commercial shrimps (nursery grounds), marine botany (mangroves, seagrasses and taxonomy), ecology and utilization of intertidal resources, marine mammal biology and ecology, coral reef research, and mariculture of marine invertebrates and aquaculture.

2.2. NATIONAL AND LOCAL GOVERNMENTS

There are seven Provinces and ten main cities along the coast. These are Pemba (Cabo Delgado), Angoche, Nacala (Nampula), Pebane, Quelimane (Zambezia), Beira (Sofala), Vilankulos, Maxixe, Inhambane (Inhambane) and Maputo (Figure 2.1). The National Environmental Policy is the main policy that governs environmental management in Mozambique. The Environmental Law (Decree 20/97, of 1 October) recognizes the need to control the increasing environmental degradation. The law also establishes specific regulations for sound management and use of coastal resources. It integrates socio-economic aspects with environmental issues.

Figure 2.1 – Administrative division of Mozambique, showing the Provinces and location of main coastal cities (from http://www.portaldogoverno.gov.mz).

MICOA's main responsibility is the preparation of environmental policies and strategies and coordinating their implementation in the field. It operates at central and provincial level. The Provincial Directorates of MICOA (DPCA) main activities are inter-sectorial coordination, provincial planning and management of exploitation of natural resources (ASCLME, 2012; Wingqvist, 2011).

Other authorities in Mozambique that are relevant in the management of coastal and marine environment include the Mozambique Maritime Authority, which is responsible for overseeing, monitoring and controlling activities within the marine waters of Mozambique in order to maintain law and order and territorial integrity. In case of a threat to territorial integrity, the armed forces would step in.

With regard to ports, the Mozambique Port Authority is responsible for their administration and management. This includes supervision of port operations and ensuring that port services are efficient, safe, and environmentally sound.

2.3. COMPANIES AND CORPORATE FEDERATIONS IN FISHERIES/AQUACULTURE SECTORS

Currently, the fisheries sector in Mozambique is focused on exports as driven by companies fishing at semi-industrial and industrial levels. Consequently, this sector has received more attention from the Mozambican government, providing assistance either in terms of access to funds for the acquisition of equipment and refrigerating systems or assisting with the development of the fisheries market.

Most companies operating in the fisheries sector in Mozambique focus their efforts on shrimp and demersal fish that have great commercial value in Asia and European markets. Among the various companies operating in this sector there are: Sulpesca - Sociedade de Pescas do Sul Lda, Gambeira - Sociedade de Pesca de Gamba Lda, Krustamoz - Crustáceos de Moçambique, Lda., Pescamar - Sociedade de Pescas de Mariscos Lda, Pescas do Sul Lda, Zambézia Pescas Lda., Boa Hora Comercio e Industria de Productos Alimentares Lda, Companhia de Pesca Industrial Lda, Efripel - Entreposto Frigorífico de Pescas de Moçambique Lda, Finage Mar Mocambique Lda, Indicus Pesca Lda, Indicopesca Lda, Mavimbi Lda, Marbar Lda , Moza Fisheries Lda, Pecabom Lda, Pestrai - Pescaria Transporte Inhassoro Lda, Prapesca - Companhia de Pesca de Moçambique Lda and Wing Koon, Lda. Up to 90% of the employees of these companies are Mozambicans. In order to access the EU market, the companies need to adhere to international regulations with regards to sanitary and public health issues. However, there has been some resistance in applying ecofriendly technology (e.g. by-catch reduction devices such as turtle exclusion devices). In general, the companies grant access to technicians from the National Institute for Fisheries Research (IIP) to conduct research and monitoring activities aboard their vessels.

The aquaculture sector in Mozambique was initially more focused on the commercial production of Penaeid shrimps for Asia as the primary export destination. There are currently three commercial shrimp aquaculture enterprises operating in three Mozambican provinces: Beira (Sol & Mar, 500 ha), Quelimane (Aquapesca, 1,000 ha) and Pemba (Indian Ocean Aquaculture, 980 ha). All use a semi-intensive farming system in earthen ponds (size range from 5-10 ha) and import feed from the region (South Africa and Seychelles) or from Asia. Current production is at 4.8 tonnes/ha/year. Water quality is permanently monitored and investment is high. The species produced are *Penaeus monodon*, the giant tiger prawn and *Penaeus indicus*, the Indian white prawn. All farms use their effluent ponds and mangroves as biofilters. The INAQUA has been promoting aquaculture projects throughout the country, including the building of ponds in mangroves. This, without a master plan can prove deleterious for mangroves in Mozambique, as similarly to what happened in other countries such as Indonesia and Ecuador.

In recent years, there have been a large number of companies producing seaweed in the Cabo Delgado province with the purpose of exporting carrageenan (linear sulphated polysaccharides extracted from red algae) to Asian markets (Bandeira *et al*, 2002; Brycesson & Massinga, 2002). More recently, fish farming has become an alternate source of animal protein for the whole country (Figure 2.2). Currently, the largest firms dedicated to large scale aquaculture in the country are: Aquaquel Lda, Aquapesca Lda, Aquapemba Lda, Mozambi Fisheries & Aquaculture S.A, Nhangu Lda, Sol e Mar Lda, Peixe Bela-Vista Lda, MozTilapia Lda, Chicoa Fish Farm Lda, Agropecua-Sumbanini Lda, Xibaha Lda, Aquase Lda, Chicamba Pesca Lda and Ada Verde Lda. The aquaculture sector can generate an income of about USD $ 6.7 million per year (ASCLME, 2012). Moreover, it is believed that in general, the sector faces some problems such as poor planning, inadequate site selection, inappropriate management procedures and lack of attention to environmental friendly practices. However, information on the environmental impacts of these projects is scarce.

Figure 2.2 – MozTilapia, an aquaculture project based in Machavenga between Tofo and Inhambane, Inhambane Province (Photo: Dave Charley)

2.4. INTERNATIONAL PUBLIC BODIES

The United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP), as well as other major UN bodies, such as the Food and Agriculture Organization (FAO), and the World Bank (e.g. South-west Indian Ocean Fisheries project), have all undertaken coastal/marine/oceanographic programs in Mozambique. FAO has been particularly active in the assessment of marine ecosystems of Mozambique through the EAF-Nansen project "Strengthening the Knowledge Base for Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries", which is a project the FAO conducted in close collaboration with the Institute of Marine Research of Bergen (Norway) and funded by the Norwegian Agency for Development Cooperation (NORAD).

UNESCO also has a specific programme associated with the marine environment – Intergovernmental Oceanographic Commission (IOC) – that has been particularly active in integrated coastal management in Mozambique (www.ioc-cd.org). An important program of the IOC is the Ocean Data and Information Network for Africa (ODINAFRICA), as well as the joint program between the IOC and the Advisory Committee on Problems of the Sea (ACOPS) on development and protection of the coastal and marine environment in sub-Saharan Africa.

The presence of the International Maritime Organisation (IMO) is also key to African countries, particularly in the field of governmental regulation and practices that are, among others, associated with protection of the marine environment. Additionally, the Global Environmental Facility (GEF) is the funding agency of the Agulhas and Somali Current Large Marine Ecosystem (ASCLME), which is part of a multi-project, multi-agency programme to institutionalize cooperative management in the region. The implementing agency of ASCLME is UNDP and the executing agency is the UN Office for Project Services.

2.5. NATIONAL AND INTERNATIONAL NGOs

Pereira (2008a) conducted a national review of the capacity and needs of Non-Governmental Organizations (NGOs), dealing with marine and coastal issues in Mozambique, including fishermen associations. Twenty-four organizations out of a total of 43 distributed throughout the country were assessed. The study revealed that in general NGOs in Mozambique were relatively young, understaffed, under-funded, and poorly equipped. Also, it highlighted that whilst an enabling environment and legal framework for NGO establishment and functioning was established, there were several procedural difficulties. There was still a lot to be accomplished with regards to training, communications and networking, and general institutional capacity building in order to enable the NGOs to perform their roles. In a more recent study focused on fishermen associations targeting tuna, Pereira *et al*. (2013), showed that associativism is still a “novelty” in Mozambique as the majority of the fishermen interviewed (83.0%) were not engaged or anyway associated with any organization that manages or is part of any decision-making processes.

Prominent national NGOs in the country that deal with marine and coastal issues, including research, monitoring, conservation and/or lobbying advocacy, include Centro Terra Viva (CTV), Eyes on the Horizon (EOTH), Associação de Mergulhadores Activos para os Recursos Marinhos (AMAR), Associação Ambiental Ocean Revolution Moçambique, Associação Bitonga Divers and the Association of Coastal Conservation of Mozambique (ACCM). In general, NGOs in Mozambique are primarily funded by foreign aid (both Governmental and private donors), with European countries and the United States being the most relevant. International NGOs and bodies that operate in Mozambique include the World Wildlife Fund for Nature (WWF), the International Union for Conservation of Nature (IUCN), Peace Parks Foundation (PPF), the Marine Megafauna Foundation (MMF), All Out Africa, Friends of Vamizi Trust, and the Wildlife Conservation Society (WCS). Some of these organizations work mainly as donors whilst others implement projects in the field or provide technical assistance to local partners. Table 2.1 presents further information on these organizations.

Table 2.1 – Summary of main NGOs working on marine and coastal issues in Mozambique

NGO and Focus	Current Projects	Weak Points	Strong points
National NGOs			
CTV	Monitoring of good governance, community land use rights, marine turtle conservation and technical support to conservation areas	Based in Maputo with regional offices in Pemba and Maxixe. Marine/coastal issues not an institutional priority	Advocacy, intervention and technical capacity
EOTH - to assist on illegal fishing	Newsletter, lobbying on illegal fisheries	Under funded, few staff	Networking
AMAR – divers association for marine conservation	Project COAST - Tofo, Tofinho and Barra	National level but focused mainly on Tofo/Barra region	Support from dive industry and networking
ACCM – research and conservation mainly on Zavora region	Research: Manta ray population, humpback whale, marine invertebrates (nudibranchs). Conservation: environmental education and sea turtle patrolling	Under funded, dependent on volunteers to fund, few staff and lack of networking	Field laboratory infra-structure that could partner with other organizations, support from local industry and schools
Associação Ambiental Ocean Revolution Moçambique	Train people from local community to become dive leader and environmental educators	Mainly focused on Tofo area	International donors. Networking
Associação Bitonga Divers	Sponsors SCUBA dive training courses, (open water, dive master and instructor training), boat skipper and swim teacher training courses Marine conservation awareness presentations with local communities	Sponsorship/ traineeship opportunities are quite selective/limited/exclusive Limited opportunity for beneficiaries to seek stable permanent employment post training (dive industry and employment is small)	Provides an avenue for Mozambicans to become involved in dive industry; Strong links to local fishing communities; Facilitates employment opportunities with local dive operators for members who complete their dive/skipper training; Provides beneficiaries with equipment (dive gear and computers)
International NGOs			
Istituto Oikos – conservation and development	Protection of marine and coastal habitats and food security at the Quirimbas National Park	Restricted to Cabo Delgado province	Credibility, integrated approach
WWF – fund and support protected	Vilankulos-Bazaruto seascape, Primeiras and		International recognition, funding

NGO and Focus	Current Projects	Weak Points	Strong points
areas	Segundas, Quirimbas National Park		
IUCN – fund and protected endangered animals	Dugong Research and conservation, Vamizi island		International recognition
PPF – management and conservation of transfrontier parks	Ponta do Ouro Partial Marine Reserve	Only supports transfrontier areas	International recognition and credibility
MMF – research and conservation of megafauna	Research: manta ray, whale shark and sea turtle. Conservation: environmental education	Lack of networking with local organizations	Funded by international donors. Partnership with international universities and researchers
All out Africa – research and conservation of megafauna	Research: whale shark and manta ray monitoring. Conservation: environmental education	Highly depend on tourism and few qualified staff	Experience on Tofo area
Friends of Vamizi Trust – funding projects in Vamizi	Research: coral colonization, reef sharks, effects of MPA. Conservation: Community sanctuary, environmental education	Partial dependence on private sector	International donors. Partnership with IUCN. Long-term work with local community through the CCP

Several other prominent international NGOs (e.g. Blue Ventures, the Wildlife Conservation Society) have shown interest in starting projects in Mozambique and in some cases are in the process of seeking funds for their implementation. Rare's Mozambique program is guided by the Fish Forever alliance objectives and aims at supporting sustainable coastal fisheries in collaboration with the IDPPE. The establishment of a National Forum for Marine and Coastal NGOs is currently being promoted by the WWF. It will initially include five NGOs based in Maputo (Livaningo, CTV, WWF, Kuwuka JDA, and ABIODES), and will hopefully expand its membership to other NGOs in the country.

2.6. PRIVATE SECTOR

Several private companies throughout the country, especially those involved in coastal and marine tourism, closely collaborate with MPAs in data collection, monitoring and conservation activities. A good example of this collaborative effort is the annual marine turtle monitoring programme at the Ponta do Ouro Partial Marine Reserve, where companies from a diverse range of backgrounds (i.e. marine activities - Dolphin Encounters, accommodations - White Pearl Resorts - Ponta Mamoli and real state - Machangulo SA), contribute either through supervision of local monitors, salaries or with materials for the success of the monitoring. A number of consulting companies involved in the preparation of Environmental Impact Assessments (EIAs), Environmental Management Plans (EMPs), research, monitoring and similar projects deal one way or another with marine and coastal issues. The main ones are based in Maputo and amongst other include Impacto Lda., Golder Associates Lda., Cowi Moçambique, Consultec Lda., VerdeAzul Lda., and Biodinâmica S.A.

Several large-scale projects are currently taking place along the coastal zone in Mozambique and include amongst other oil and gas exploration, mining and other mega-projects (Table 2.2). These encompass large investments from multinational companies, which potentially could boost socio-economic development for the country in general, and for local communities in particular. This has not been the case so far and community involvement and benefit has been at best marginal, with several authors (Castel-Branco, 2010; Nhamire, 2014) questioning the real benefits of such projects for the country's economy. Oil & Gas projects in the Cabo Delgado province, where the main natural gas reserves have been found, can potentially cause direct and indirect significant changes in a considerable part of the coastal area of this province. Further Oil & Gas projects are expected to happen in other provinces of Mozambique within the next decades.

Apart from the socio-economic issues, environmental concerns have raised with regards to the non-compliance by large companies of environmental and public safety standards. A recent case in point, Justiça Ambiental and a coalition of Mozambican NGOs, filed a complaint against BHP Billiton regarding its decision to operate its Mozal aluminum smelter under a bypass authorised by the Mozambican Ministry for Environmental Coordination. The bypass allowed the smelter to operate without exhaust filters for a period of 6 months. The company claims the bypass caused no damage to the environment and not public health issues. However, this has not been verified by independent entities.

Table 2.2 – Main development areas in each of Mozambique's coastal provinces that might have influence on the coastal districts

Province	Type of development	Key companies operating in the area
Cabo Delgado	Mueda Corridor*, North-South corridor, Oil & Gas Offshore and Onshore (Areas 1 and 4)**, Logistics, Ports, Mining, Tourism, Aquaculture	Anadarko, ENI, Petronas, ENH, ENHILS, Triton Minerals, Rovuma Resources, Indian Ocean Aquaculture
Nampula	Nacala Corridor, North-South corridor, Ports, Logistics, Mining, Industry, Aquaculture, Tourism	Vale, Kenmare, Aquapesca, Cimentos de Moçambique
Zambezia	Zambezia Corridor, North-South Corridor, Ports, Agriculture, Industry, Mining, Logging, Aquaculture, Industrial Fishing	Aquapesca, EOZ, Grupo Madal
Sofala	Beira Corridor, North-South Corridor, Ports, Logistics, Industry, Agriculture, Aquaculture,	Pescamar, Aquapesca, Krustamoz, Pescabom

Province	Type of development	Key companies operating in the area
	Industrial fishing	
Inhambane	North South-Corridor, Oil & Gas Onshore and Offshore, Tourism, Agriculture, Aquaculture	SASOL
Gaza	North-South Corridor, Agriculture, Aquaculture, Heavy sands in Chibuto	Anhui Foreign Economic Construction Group and Yunnan XinLi Non-ferrous Metals Co. Ltd
Maputo	Maputo Corridor, Libombos Corridor, North-South Corridor, Industry, Ports, Logistics, Industrial fishing	MOZAL, CIM, Cimentos de Moçambique, MPDC

* "Corridors" mean development corridors that are planned for the country
** A new bidding process for Oil & Gas exploration concessions in Mozambique has been released during the last trimester of 2014, therefore, new Oil & Gas areas are expected in Rovuma (East), Angoche, Zambeze Delta (Sofala's Bank region), and near the Pande-Temane and Palmeira concession

3. COASTAL POPULATIONS

3.1. MAIN SOCIAL INDICATORS

Two thirds of the 20.8 million Mozambicans live along the coastline (Table 3.1). Fishing, agriculture, trade and tourism are the largest income generating activities for such communities. Fishing however is the largest contributor to the livelihoods of such societies. The biggest concentration of fishing villages is in Zambézia, Nampula, and Cabo Delgado provinces. These have the largest number of households and inhabitants respectively.

Table 3.1 – Main socio-economic indicators for Mozambique

Indicator	Figure	Source
Population size (2013)	20.8 Million	UNDP 2014
Urban population ratio	31%	UNDP 2014
GDP per capita	971 USD	UNDP 2014
Population below poverty line (1.25USD/day)	59.58%	UNDP 2014
Adult literacy rate	50.6%	UNDP 2014
Unemployment rate	22.5%	UNDP 2014
Electrification rate (2010)	15%	UNDP 2014
Access to improved water	43%	UNICEF 2014
Access to improved sanitation	19%	UNICEF 2014

There are 53,000 registered artisanal fishing units in 1,586 fishing centres spread throughout the country that account for 400,000 jobs. These contribute to poverty relief and food security. Men own 98.9% of fishing units. Fishing is the main source of income for 87% of unit owners, followed by agriculture. The most common vessels used by these units are canoes (88%) and their biggest concentration is in the Nampula and Sofala provinces (Jone *et al*., 2013).

Artisanal fishing is carried out either from a vessel or by foot, and is confined to the coastal regions and lakes. The gear used includes manual fishing trawls, gillnets, handlines, traps, and harpoons. Subsistence and artisanal fishers, catch almost 200 t or 91% of all fish caught in national waters (Ministério das Pescas, 2013). Most of the catch is for local consumption and is sold in local and regional markets. Fish makes up 50% of the population’s protein consumption in Mozambique (FAO, 2001). Sixty percent of artisanal fishing takes place in maritime waters, in beaches and the open sea, while the remaining 40% is carried out in inland waters primarily in Niassa and Tete Province (Jone *et al*., 2013).

Artisanal fishing has increased three times its production between 2005 and 2012 reaching over 200,000 t. This increase has contributed to an exponential increase in the living conditions of fishing communities. Purchasing power has increase by 51.6%, living conditions have improved by 19.7%, 41.9% of fishing communities have access to drinking water, fishing revenue can cover household expenditures, and 43% of fishing communities have access to latrines (Ministério das Pescas, 2013).

Electricity is only available in major urban centres, hence only nearby communities have access to fresh fish. For that reason several conservation methods have been developed: sun drying which is most common in Nampula, smoking which is most common in Zambézia, Nampula and Cabo Delgado, and salting and drying which is most common in Sofala, Nampula and Cabo Delgado. In Maputo and Gaza, 17% and 32% respectively of fish is frozen. Conserved fish is then transported and sold to inland communities (Degnbol, 2002; IDPPE, 2009).

Women play a very marginal role in the fishing industry, mainly picking shellfish for household consumption and selling the surplus. For cultural reasons, in the more conservative North and Centre of the country, women sell any surplus fish locally but are rarely allowed by their husbands to participate in more formal marketing of fish, as it is believed that this would bring them in to close contact with other men. In the South women engage in the commercialization of fish, however it is the men who generally control the money they earn (Degnbol *et al*., 2002).

Fishing communities along the Mozambican coast (Figure 3.1) witness migration patterns due to the seasonal fluctuation of resources (Lopes *et al*., 1997). In the North, shoal movements in the Quirimbas Archipelago attract fishermen and traders from Tanzania and Nampula (Johnstone, 2004; Santos, 2008), while in the Centre and South, fishermen rotate from one fishing camp to another (SAL, 2006). Another factor that has influenced the migration patterns in fishing communities is new protected areas in national parks such as the Bazaruto Archipelago National Park (SAL, 2006).

These fishing-induced migrations have also had adverse social consequences including the increased dissemination of HIV/AIDS and communal conflict (Ministério das Pescas, 2007). For instance, migrant fishermen staying for longer periods of time in certain areas such as the Quirimbas Archipelago have increased the pressure on fishing resources (SAL, 2006). The seasonal closing of shrimp fishery has also been met with resistance by some fishermen (Johnstone, 2004). Another source of conflict is the company fleets invading exclusive marine zones for artisanal fishing (Santos, 2008). Local conflicts are typically resolved at the fishing centres without the interference of local authorities. However, local authorities are sometimes requested to intervene when conflicts include migrants.

Figure 3.1 – Local fisherman at Inhambane Bay, Inhambane Province (Photo: Rodrigo Santos)

Several socio-economic problems have exerted increasing pressure on fishing communities resulting in the disruption of the native ecosystems including: inappropriate fishing practices that make use of mosquito nets; fishing during the closed season and of protected species; cutting of mangrove trees; overlapping authority; inefficient application of resource management policy; increasing population density in coastal areas; increasing fishery related conflicts; and weak control of fisheries (Pereira, 2011).

4. APPLICABLE LEGISLATION

4.1. POLITICAL AND POLICY CONTEXT

4.1.1. Environment at Large

The Constitution of Mozambique establishes the right to live in a well-balanced environment and the right to protect and defend that environment. The state and local authorities are required to adopt policies to protect the environment and ensure rational and sustainable use of natural resources. To guarantee the right to a favourable environment while recognising the need for sustainable development, the state has adopted policies which prevent and control pollution and erosion, which support integrated environmental objectives in sectorial policies and promote the integration of environmental values in the education system policy and programmes (Wingqvist, 2011).

The Ministry for Coordination of Environmental Affairs (MICOA) is the government institution responsible for ensuring the preservation and sustainable use of natural resources, the coordination of environmental activities including licensing. Provincial Directorates for Coordination of Environmental Affairs (DPCA) and in some cases District Directorates for Coordination of Environmental Affairs (DDCA) are the local representatives of MICOA.

In 1997 the Environmental Law was approved by the Parliament (Law 20/97, of 1 October). This law regulates the use and management of the environment with a vision of promoting sustainable development. It also includes a number of definitions and establishes principles based on the constitutional right to a favourable environment. The principles include:

- The principle of use and rational management of natural resources;
- The principle of recognition and value of community knowledge and traditions;
- The principle of environmental management based on preventive systems;
- The principle of integrative management;
- The principle of citizen participation; and
- The principle of responsibility

In addition, the laws urge all stakeholders involved in the environmental activities to:

- Prevent and control pollution and erosion;
- Integrate the environment objectives in sector policies;

- Promote the integration of environmental values in educational policies and programs,
- Ensure the rational use of natural resources within their capacity to regenerate and bearing mind the rights of future generations (Legal Framework, 2009).

4.1.2. Marine Environment

The Decree 5/2003 of 18 February created the Centre for Sustainable Development of Coastal Zones established in the Gaza province. This is an institution subordinated to the Ministry of Coordination of Environmental Affairs. The essential mandate of the Centre is to coordinate and promote studies, technical assistance, capacity and development of microenvironment coastal, marine and lacustrine management activities which contribute to elaborate policies, and to formulate legislation that promotes the development of coastal zones.

The fishery sector in particular contributes significantly to national exports. This sector is regulated by Law 22/2003 of 1 November (Fisheries Law). The fisheries sector is both nationally and regionally important. Some aspects of the law are not in conformity with international law such as delimitation of fishing boundaries and continental shelfs, prohibition of over-night fishing, the compulsory need to get migration permits for foreign crews fishing in Mozambican waters. The other pressing issues are over-fishing and the protection of the marine environment.

Aquaculture is a relatively new activity in Mozambique and the industry may be divided into two broad categories. Namely freshwater aquaculture and coastal aquaculture, which are each subdivided in subsistence and commercial aquaculture. The national strategy for the development of aquaculture has three principal objectives:

- Increase the supply of fish to the internal market to address the shortage of food in the country;
- Improve the level of employment and increase the fish man yield as well as small scale producers; and
- Increase fish production to enhance exports.

There is a general Aquaculture Regulation that defines all rights and obligations of all stakeholders. The legislation defines specific norms and requirements for aquaculture farms and establishes procedures for licensing and parameters for each farming system.

For the offshore oil and gas industry, the National Institute of Petroleum is the institution responsible for the regulation and funding of all activities related with research, production and transportation of petroleum, as well as all the adoption of necessary policy in the field. National Institute of Petroleum manages the petroleum resources of Mozambique and administers the related operations. This Institution was established by the Decree 25/2004 of 20 August three years after enacting the Petroleum Law (Law 3/2001 of 21 February), which defines the granting of rights for oil and gas operations in the Republic of Mozambique.

Article 23 of the Petroleum Law is particularly relevant as it relates to environmental protection and safety. This law clearly recognizes in article 21, the Law 4/96 of 4 January, Law of the Sea, which regulates the maritime jurisdiction of petroleum sites located in national waters. The geology of parts of Mozambique suggests that geological formations could contain both oil and gas.

Finally, with the new Biodiversity Conservation Law (Law 16/2014 of 20 June), the country has harmonized the categories of Conservation Areas (including Marine Protected Areas [MPAs]), which are divided in 2 types and several sub-types:

i) Total Conservation Areas include 3 sub-types – a) the Integral Natural Reserve, b) the National Park and c) the Cultural and Natural Monument;
ii) ii) Sustainable Use Conservation Areas include 7 sub-types – a) Special Reserve, b) Environmental Protection Area, c) Official Game Reserve, d) Community Conservation Area, e) Sanctuary, f) Game Farm, g) Municipal Ecological Park.

The first type corresponds to the areas of public domain that are aimed to the conservation of ecosystems and species without the extraction of resources. Only indirect use of natural resources is allowed with the exceptions considered in the Law. The second type corresponds to the areas of public and private domain, aimed to conservation, subject to an integrated management with permission of resource extraction but respecting sustainable limits according to the approved Management Plan. In this type, areas can be of National, Province, District and Municipality level. This law is yet to be regulated and until that has not happened, the former Conservation Areas cannot be reclassified according to the new categories.

4.1.3. Fisheries and Aquaculture

The fisheries sector is administered by the Ministry of Fisheries (MIPE), created by the Government in 2000. Prior to this, Fisheries and Agriculture was housed under a single ministry. MIPE is the institution responsible for granting licenses, inspection and management of all fishing activities. The structure of the Ministry comprises several dependent institutions: the National Administration of Fisheries (ADNAP), the National Institute of Aquaculture Development (INAQUA), the National Institute of Fish Inspection (INIP) and Fisheries Development Fund (FFP), a financial institution with the mandate to provide credit mechanisms for the development of fisheries. As subordinated institutions: Fisheries Research Institute (IIP), Institute for Small Scale Fisheries Development (IDPPE) and Fisheries School (EP).

The Fisheries Research Institute is responsible for collecting and processing statistical data on yield and effort, the periodic assessment of the most important stocks, and provides recommendations on management measures necessary for appropriate use of resources. The IDPPE is responsible for promoting the development of small-scale fisheries through development activities and projects related to socio-economic aspects and fishing technology.

At the local level, the MIPE is represented by Provincial Directorates and delegations of the institutes in each Province. At the district level, the involvement of the communities through the co-management of the fisheries is encouraged (MIPE, 2013; Santana Afonso, 2006).

The current development policy is documented in several strategy papers, including the Five-Year Programme for Government 2010-2014, the Action Plan for the Reduction of Poverty (PARP) for 2011-2014, the Fisheries Master Plan II 2010-2019, and the yearly Economic and Social Plan (PES). The legal basis of the Mozambican fisheries is given by the Fisheries Law, Law of Sea, and by the several regulations listed in Table 4.1. The National Directorate for Fisheries Surveillance (DNFP) is responsible for the compliance of all fishing sectors with the national laws and regulations.

Some of the most important rules are the definition of the mesh minimum size, the duration of the closed seasons, and the determination of the three-mile zone from the coast exclusively for artisanal fishing.

Table 4.1 – List of fisheries-related national legislation currently in force in Mozambique.

Law / Decree	Description
Law 22/2013	**Fisheries Law**: defines the legal framework regarding the management and regulation of fisheries, defines the granting of fishing licenses, defines measurements to conserve the fisheries resources, and plans the surveillance actions of fishing, including quality of fishery products intended for export
Ministerial Decree 62/90	Creates the Fishery School
Law 4/96	**Law of Sea:** redefines the rights of jurisdiction over the sea along the Mozambican coast and provides regulation and management of maritime activities in the country
Resolution 11/96	National Fisheries Policy and Implementation Strategies: was adopted and framed within the overall development objectives of national economy, which are to provide food security, sustainable growth, poverty alleviation, increase the net foreign exchange earnings and reduce unemployment rate.
Decree 62/98	Creates the Institute for Small Scale Fisheries Development (IDPPE)
Decree 63/98	Creates the Fisheries Research Institute (IIP)
Decree 10/98	Defines the Regulation of Inspection and Quality Assurance for Fishery Products (Replaced by Decree 17/2001)
Decree 51/99	**Regulation for Recreational and Sport Fishing**: determines what types of fishing gears and vessels are permitted in the practice of recreational and sport fishing. Defines the periods and areas for this activity. Defines the species and allowed quotas. Provides various types of licenses and the rights and duties of fishermen.
Presidential Decree 01/2000	Creates the Ministry of Fisheries (**MIPE**)
Decree 17/2001	Approves the Inspection and Quality Assurance for Fishery Products (replaces the Decree 10/98)
Decree 35/01	**General Regulation of Aquaculture** determines rules of management and planning of the activity establishing requirements for local installation and specific production systems. Creates several types of licenses for the activity and establishes the minimum conditions of quality of the products. Defines a set of standards for the protection of the environment and natural resources.
Decree 43/03	**General Regulation of Maritime Fisheries (REPMAR)** establishes the rules to be followed while fishing in marine waters of Mozambique. Defines a system of co-management in fisheries management and for the implementation of management measures. Sets the fishing gear and the type of requirements of vessels allowed in maritime waters, as well as surveillance actions of the activity. Addresses the creation of areas for the preservation of fishery resources (marine parks, marine reserves and marine protected areas). Sets the obligatory use of devices to protect endangered species (Turtle Exclusion Devices) and to reduce the by-catch. Addresses the possibility to create artificial reefs.
Decree 18/05	Creates the National Institute of Fish Inspection (INIP)
Ministerial Decree 139/06	Integrates the European Commission Regulations for Quality Control of Fish Products
Decree 28/2008	Creates the INAQUA
Decree 57/2008	Approves the **Inland Fisheries Regulation (REPAI)**
Resolution 26/2008	Monitoring, Control and Surveillance Fisheries Policy and Implementation Strategy
Decree 58/2009	National Action Plan to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishery
Decree 76/2009	Approves the **General Regulation for the Hygiene Control on Food of Aquatic Origin**
Decree 04/2010	Creates the ADNAP

Besides national laws, there are several international and regional agreements regarding fisheries. Table 4.2 shows the most important ones ratified by Mozambique.

Table 4.2 – International and regional agreements regarding fisheries ratified by Mozambique

Institution and year of implementation	**Description**
UN, 1982 (ratified in 1997)	United Nations Convention on the Law of the Sea (**UNCLOS**)
UNEP, 1985 (ratified in 1996)	United Nations Environmental Programme Convention For the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African.
FAO, 1993 (ratified in 2009)	Food and Agriculture Organization of United Nations Agreement to promote the compliance with International Conservation and Management Measures by fishing vessels on the high seas
UN, 1995 (ratified in 2008)	United Nations Fish Stocks Agreement
FAO, 1995	Food and Agriculture Organization of United Nations Code of Conduct for Responsible Fisheries
FAO, 1999	International Plans of Action (IPOA) for Reducing Incidental Catch of Seabirds in Longline Fisheries International Plans of Action (IPOA) for the Conservation and Management of Sharks International Plans of Action (IPOA) for the Management of Fishing Capacity
FAO, 2001	International Plans of Action (IPOA) to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
SADC, 2002	Southern African Development Community Treaty Protocol on Fisheries
NEPAD, 2005	**Abuja Declaration:** The New Partnership for Africa's Development Action Plan for Sustainable Development of Fisheries and Aquaculture in Africa
FAO, 2006	South Indian Ocean Fisheries Agreement (SIOFA)
UN 2001, ratified in 2008	The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (**UNFSA**)
SADC, 2008	Declaration of Commitment of the Ministers of Fisheries of Southern African Development Community in the fight against IUU Fishing
NEPAD, 2009	International Partnership for African Fisheries Governance and Trade (PAF)
IOTC, 2011	The Indian Ocean Tuna Commission Resolution 10/11 on Port State Measures to Prevent, Deter and Eliminate IUU Fishing

Institution and year of implementation	Description
IOTC, 2013	The Indian Ocean Tuna Commission (IOTC) Resolutions: Resolution 13/04 on the conservation of cetaceans Resolution 13/05 on the conservation of whale sharks Resolution 13/06 on a scientific and management framework on the conservation of shark species caught in association with IOTC managed Fisheries
FAO, 2014	Food and Agriculture Organization of United Nations Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing

In the Southwestern Indian Ocean Region there are several regional fishery bodies of which Mozambique is a member. One body is the Southwest Indian Ocean Fisheries Commission (SWIOFC) established in 2004 by the FAO to promote the sustainable use of live marine resources in the region. Another body, specialized in tuna and tuna-like fisheries, is the Indian Ocean Tuna Commission (IOTC), established in 1996.

The fisheries sector has several aid partners including cooperating countries and international agencies such as the Norwegian Agency for Development (NORAD), Danish International Development Agency (DANIDA), Icelandic International Development Agency (ICEIDA), Agence Française de Développement (AFD), Japan International Cooperation Agency (JICA), Overseas Fishery Cooperation Foundation of Japan (OFCF), European Commission (EC), United States Aid (USAID), United Kingdom Department for International Development (DFID), International Fund for Agricultural Development (IFAD), Organization of the Petroleum Exporting Countries (OPEC), African Development Bank (AfDB), Islamic Development Bank (IDB), Arab Bank for Economic Development in Africa (BADEA), and the World Bank.

4.2. ENFORCEMENT OF MAIN ENVIRONMENTAL LAWS AND POLICIES

The National Directorate for Fisheries Surveillance (DNFP) is the structure within the Ministry of Fisheries which is responsible for the enforcement of the national laws and regulations for all fishing sectors and aquaculture. Within the framework of the priorities set out in the Government Five Year Programme, the Monitoring, Control and Surveillance (MCS) Fisheries Policy and the Implementation Strategy (Resolution 26/08) was approved in 2008.

Industrial fisheries are the most regulated. All licensed fishing vessels are controlled by the VMS Centre (Satellite Vessel Monitoring System) which monitors in real time the position, direction and velocity of each vessel. Foreign vessels are inspected at ports as a condition to get the license. Surveillance of the entire EEZ is also done with two patrol vessels.

Artisanal Fisheries are difficult to control so the approach that has been used is the involvement of local communities in the co-management of fisheries, mainly through the Fishing Community Councils (CCP).

Despite the existing legal and institutional framework, law enforcement has been widely recognized as poor throughout the country. This is dealt with more details in Chapter 11.

4.3. LEGISLATIVE AND/OR EXECUTIVE PROCESSES

4.3.1. Promulgation of new environmental/fisheries laws

Traditionally, the process of promulgating general environmental laws and regulations has been spearheaded by MICOA. Drafts are produced internally or by consultants, and circulated for comments. A recent case where civil society played a very important role in drafting and leading the process was the promulgation of the "Beach Regulation" (Decree 45/2006 of 30 November). Processes regarding fisheries laws and regulations are usually driven by the Ministry of Fisheries, and tend to be participatory in nature. Good examples include the recently approved Fisheries Law, and the current revision of the Recreational and Sport Fisheries Regulation and the Regulation on General Maritime Fisheries.

Regulations and Laws are then submitted to the National Council for Sustainable Development (CONDES) and then to the Council of Ministers. Regulations are approved at the Council of Ministers level. Laws are then submitted to the Parliament, for discussion and approval.

4.3.2. Establishment of MPAs or other protected status

Until very recently, the proclamation of MPAs was based on several different legislations: the Land Law (Law 19/97 of 1 October), the Forest and Wildlife Law (Law 10/99 of 7 July), and the Regulation for General Maritime Fisheries (Decree 43/2003 of 10 December). This created discrepancies and redundancy, especially regarding categories and protection rulings. In 2009, the Conservation Policy and Implementation Strategy (Resolution 63/2009 of 2 November) was approved by the Council of Ministers, and very recently, the Biodiversity Conservation Law (Law 16/2014 of 20 June) was also approved. These two instruments are deemed fundamental for biodiversity conservation in Mozambique. The classification of conservation areas (including

MPAs), mechanisms of funding and management, as well as procedures for their proclamation, were defined and standardised. There is also a provision for several stakeholders (Governmental institutions, academia, private sector, NGOs, local communities or municipalities) to submit proposals of new conservation areas.

5. PHYSICAL ENVIRONMENT

5.1. CLIMATE AND WEATHER

Climate in the western Indian Ocean (WIO) is mainly controlled by the African and Indian monsoon systems, which can be separated into northern and southern hemisphere components. Analysis of daily satellite sea surface wind images near Mozambique, within the period from 2003 to 2007, evidence two distinct regimes, the southwesterly (SW) and the northeasterly (NE) monsoons (Malauene *et al*., 2014; van Rampelbergh *et al*., 2013) that correspond to the southern extension of the East African monsoon (Biastoch & Krauss, 1999; Saetre & da Silva, 1982 cited by Malauene *et al*., 2014).

The SW monsoon occurs during austral autumn-winter from the end of April to July/August and is characterized by a persistent and strong (14 m/s) SW wind regime, while the NE monsoon occurs during the austral spring-summer from August to March/April and has a low speed NE wind regime (10 m/s) (Malauene *et al*., 2014; van Rampelbergh *et al*., 2013). The East African Monsoon System in the north and the Indian Ocean Sub- tropical Anticyclone System in the south influence rainfall. The annual average rainfall is about 1,100 mm, with about 20 to 40% year-to-year variability.

The classification of Köppen (Cuamba *et al*., 2006) is widely used for the identification of homogeneous climate zones as it considers only rainfall and temperature as the meteorological variables. According to this classification, the northern and coastal regions have a tropical rain savannah climate (Aw) and the southern sedimentary terrains have a dry savannah climate (BSw) (Cuamba *et al*., 2006). But due to slightly differences in precipitation and temperatures amounts, Cuamba *et al*. (2006) subdivided Mozambique coastal region in three climatic zones: a) *north of the Zambezi River* (Cabo Delgado, Nampula and Zambézia provinces), b) a transitional zone in the region of Zambezi River and c) southern region of Mozambique (Figure 5.1).

Along the coast, mean temperature ranges are from 25° to 30° C during the warmer months (Cuamba *et al*., 2006). The average annual temperature is 23° C along the southern region and slightly higher in the northern region (26°C). The average relative humidity is 69% (Sete *et al*., 2002).

The Inter-Tropical Convergence Zone (ITCZ) is positioned over the north of the country along the Zambezi River, to the north of Sofala province, bringing 150-300mm of rainfall in the Cabo

Delgado and Nampula provinces from November to April, the warmer months of the year (Cuamba *et al*., 2006). Saetre & Silva (1979) showed that the transitional zone of the Zambezi River in Central Mozambique has the highest average annual rainfall, 1200–1600 mm, and is also mainly restricted to the warm season.

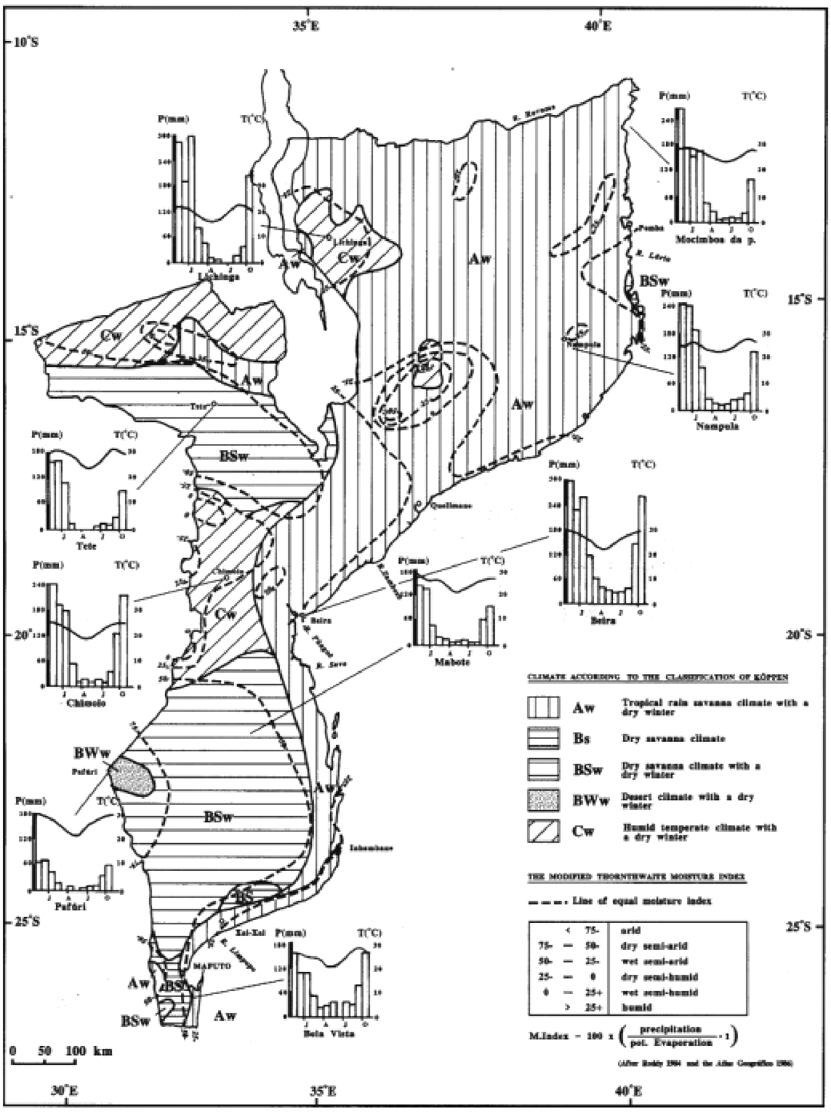

Figure 5.1 – The climate of Mozambique after Köppen (source: Cuamba *et al.*, 2006)

South of the Zambezi River, climate of central and southern Mozambique is influenced by a subtropical anti-cyclonic zone (Cuamba *et al*., 2006). This area is dominated by the SE trade winds and receives easterly prevailing winds throughout the year. Evaporation reaches about 1650 mm per year, which exceeds the precipitation by about 500 mm per year.

The coastal climate in Mozambique is influenced by several types of intra-seasonal oscillations (Schott *et al*., 2009). Extreme weather events that are associated with inter-annual climatic variability, namely the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole Mode (IODM; also called the Indian Ocean Zonal Mode) are reason for concern. Strong IODM events produce enhanced equatorial and southern-central East African rainfall during September, October, and November. However, the relationship between the IODM and East African rainfall is nonlinear. Only IODM extreme events that reverse the zonal SST gradient for several months trigger high rainfall, suggesting that it is a response to perturbations in the eastern Indian Ocean (Schott *et al*., 2009).

Sea level rise has been a great concern during the twentieth century. The mean rate of sea level rise has been on the order of 1.6–1.8 mm/year and is associated with land ice melt (~55%), followed by ocean thermal expansion (~30%; Church & White, 2006; Wenzel & Schroeter, 2010). While the regional sea level trends are mostly of steric origin (i.e. due to thermal expansion and salinity changes; Levitus *et al*., 2005) related to ocean circulation changes, deformations of ocean basins and self-gravitational changes are other causes for seal level changes (Milne *et al*., 2009; Mitrovica *et al*., 2009 cited by Meyssignac *et al*., 2012; Peltier, 2004). In Mozambique coastal sea level trend patterns, based on satellite altimetry (1993–2009), show an increase of 2-4 mm/year (Meyssignac *et al*., 2012).

5.2. PHYSICAL OCEANOGRAPHY

The Mozambique Channel, which is 400 km wide at its narrowest point, separates Mozambique from Madagascar Island. Madagascar Island is a barrier to some of the Indian Ocean dynamics such as the gyres, except at its southern tip (south of latitude 25°S; Massinga & Hatton, 1997) and northern tip, where Cabo-Delgado is exposed to the direct influence of the Indian Ocean.

The south Indian Ocean is characterized by the westward flowing South Equatorial Current (SEC) to a large part supplied by the Indonesian Through Flow (ITF; Figure 5.2). SEC splits near the east coast of Madagascar into northward and southward branches, the Northeast and Southeast Madagascar Currents (NEMC and SEMC). The NEMC transports about 30 Sv (Schott & McCreary, 2001), supplying water to the Mozambique Channel flow and the East African Coastal Current (EACC). The SEMC transports about 20 Sv to the southern tip of Madagascar, where it develops a sequence of eddies and dipoles that migrate to the African coast (De Ruijter *et al*., 2004; Quartly *et al*., 2006). It is likely that these volumes are also subject to seasonal variations. Part of the SEMC may also retroflect to supply the northeastward flow east of Madagascar.

Along the Mozambique large latitudinal gradient (10°20'S and 26°50'S), two superficial water masses (upper 100-150 meters depth) are usually identified: the tropical surface water that is influenced by the warm equatorial branch of the SEC (salinity equal to 35.5) in the northern region, and the subtropical surface water (with salinity greater than 35.5) derived from the centre of the subtropical anti-cyclonic vortex of the Indian Ocean in the southern region (Saetre & da Silva, 1982). This follows Sete *et al*. (2002) who analysed survey data from 1977 to 1980 and reported that annual SST was higher in northern part of Mozambique compared to the southern part.

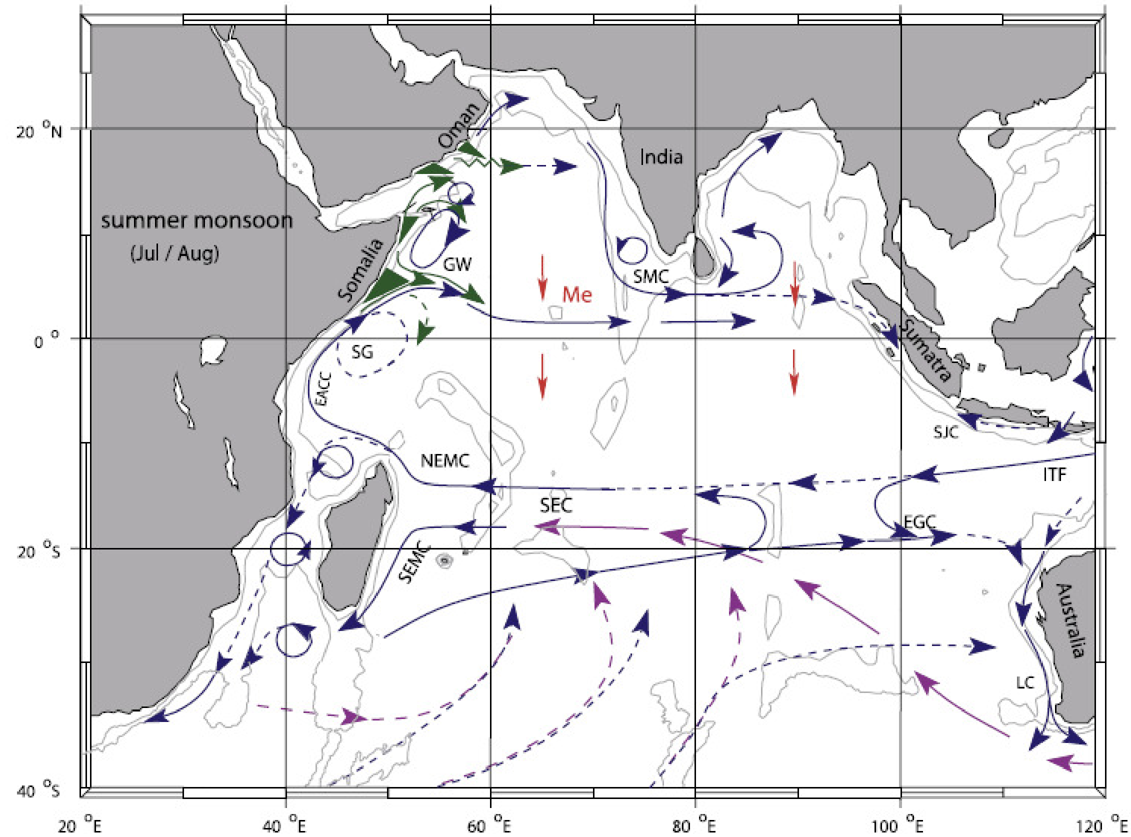

Figure 5.2 – Schematic representation of current branches during the summer (southwest) monsoon: South Equatorial Current (SEC), South Equatorial Countercurrent (SECC), Northeast and Southeast Madagascar Current (NEMC and SEMC), East African Coastal Current (EACC), Somali Current (SC), Southern Gyre (SG) and Great Whirl (GW) and associated upwelling wedges (green shades), Southwest and Northeast Monsoon Currents (SMC and NMC), South Java Current (SJC), East Gyral Current (EGC), and Leeuwin Current (LC). The subsurface return flow of the supergyre is shown in magenta. Depth contours shown are for 1000 m and 3000 m (grey). Red vectors (Me) show directions of meridional Ekman transports. ITF indicates Indonesian Throughflow (From Schott *et al*., 2009).

Sub-surface water is characterized by maximum salinity between 150 and 300 meters depth (Sete *et al*., 2002). The central water layer stays between 300 and 600 meters depth with a core corresponding to an oxygen maximum coinciding with a temperature of 11^{o} C and a salinity of 35.0 ppt isohaline (Sete *et al*., 2002).

Two different waters masses can be found below the thermocline, the low salinity Antarctic Intermediate Water (AAIW) and the relatively salty and low oxygen Red Sea Water (RSW) from the northern Indian Ocean, (Sete *et al*., 2002). At 24°S AAIW stands out by a marked salinity minimum and velocity weakens, ranging between 0.1 and 0.2 m/s, while carrying northward along the continental slope (Sete *et al*., 2002).

The deep water core is below 2000 m, where it has maximum equatorward speeds near 0.2 m/s. This narrow jet carries North Atlantic Deep Water (NADW) northward, as assessed from its relatively high salinity and oxygen concentrations, together with low silica levels (De Ruijter *et al*., 2002). The deep undercurrent is still observed in the narrow section of the Channel around 2500 m, but it is much weaker. De Ruijter *et al*., (2002) estimated the total equatorward transport in the Mozambique Undercurrent to be about 5 Sv at 24˚S, of which some 2 Sv is in the NADW-core.

Several recent studies have focused on the Mozambique Channel (e.g. De Ruijter *et al*., 2002; Donohue & Toole, 2003; Lutjerharm, 2006; Lutjerhams *et al*., 2012; Ternon *et al*., 2013) and showed that the current within the channel flows southward, and is connected upstream to monsoon-driven circulation in tropical regions and downstream to the interocean exchange system around South Africa, the Agulhas Current System. The mean volume transport through the Mozambique Channel has been estimated at 17 Sv from a multiyear moored array (De Ruijter *et al*., 2002), hydrographic section analysis (Donohue & Toole, 2003) and in agreement with earlier inverse model results of 15 ± 5 Sv (Ganachaud *et al*., 2000). The transport is not carried by a quasi-laminar boundary current but rather by migrating anticyclonic eddies (Biastoch & Krauss, 1999; de Ruijter *et al*., 2002; Lutjerharm, 2006; Saetre & da Silva, 1984; Ternon *et al*., 2013). The Mozambique Current, with warm surface water, passes close to the shore near Mossuril and Cabo das Correntes, attaining its greatest speed during the north-east monsoon (October to November). Large counter currents occur in the Bights of Sofala and Maputo, forming, in the later case, the characteristically northward-orientated peninsulas, most notably the Machangulo (Santa Maria), Inhambane and São Sebastiao (Bazaruto Peninsulas) (ASCLM, 2012; Lutjeharms, 2006; Saetre & Paula, 1979; Sete *et al*., 2002).

The anticyclonic eddies have 300 to 350 km diameters and there are on average of 5 to 6 eddies per year (Backeberg *et al*., 2008; De Ruijter *et al*., 2002). The eddies propagate southward at approximately 3–6 km per day with current speeds reaching up to 2 m/s at their edges (Schouten *et al*., 2002; 2003), producing a rectified southward current at the Mozambique side of the Channel and northward towards the Madagascar side (de Ruijter *et al*., 2002). According to de Ruijter *et al*. (2002), Mozambique eddies may be effective transporters of RSW and its associated salt towards the Agulhas Current.

Lutjerhams *et al*. (2012), reported the very short-lived event of a continuous current that was characterized as atypical, intermittent and highly irregular, with an average duration of 9 days (± 5 days) and a mode of less than 5 days per year (25 year data set; Lutjerhams *et al*., 2012).

Tides of the coast of Mozambique are semi-diurnal (two low waters and two high waters each day) with a daily variation of about 10-20 cm in Maputo, Inhambane, Chinde, Quelimane and Angoche, and about 30-40 cm in Beira, Pebane, Ilha de Moçambique, Nacala, Pemba and Mocímboa da Praia (Sete *et al*., 2002). The tidal range is about 2 m in the south, 3.1 m in the north and about 6.4 m in the centre. The higher range in the centre is caused by the broad (140 km wide) shallow continental shelf (Massinga & Hatton, 1997). Flood tides entering the Mozambique Channel from the south would, due to the Coriolis force, induce an increment in the tidal range on the adjacent Mozambican coast.

Mozambique has over 100 rivers, the major ones being the Rovuma, Lúrio and Zambezi in the north, Pungué, Buzi, Gorongosa and Save in the centre and Limpopo, Incomati and Maputo in the south. These rivers drain about 208 km^3 of nutrient rich water into the coastal waters each year. About 80% of this water enters the ocean in the vicinity of the Sofala Banks, central Mozambique. The Zambezi River, the largest river in eastern Africa, contributes approximately 67% of the total river discharge from Mozambique (Saetre & da Silva, 1982).

5.3. BIOLOGICAL OCEANOGRAPHY

Phytoplankton communities are essential to the majority of marine ecological processes and affect the structure of food webs (e.g., primary production), nutrient cycling and the flux of particles to deep waters. The principal factors that affect horizontal distribution (i.e. latitudinal and longitudinal) of phytoplankton communities are temperature, salinity and currents, while vertical distribution (i.e. with depth) is mostly affected by irradiance, nutrients and water column stability (Barlow *et al*., 2007; Leal *et al*., 2009). Therefore, phytoplankton abundance and community structure vary among worldwide regions, from tropical to temperate ecosystems (Leal *et al*., 2009; 2010; Longhurst, 1998). Some phenomena such as upwelling, that is defined as the uplift of deeper nutrient richer waters (Quartly & Srokosz, 2004), tides and river runoff are extremely important to explain nutrient dispersion and concentration.

In Mozambique the more productive waters are found near the coast, due to the influence of river discharges and upwelling while the warmer offshore waters support a lower plankton biomass dominated by picoplankton, namely Prochlorococcus (Sá *et al*., 2013). This group is adapted to survive in oceanic nutrient-poor waters (Bouman *et al*., 2011). Sá *et al*. (2013) also showed a latitudinal gradient increase in biomass from North to South that was associated with water temperature. Warmer water in the North is dominated by pico-sized-community and cooler water dominated by micro-phytoplankton (diatoms). While there is a seasonal signal of productivity (Tew-Kai & Marsac, 2009), in both northern (10°S–16°S) and southern (24°S–30°S) regions the variability in the central region (16°S–24°S) is driven by mesoscale dynamics.

The Angoche wind-driven Ekman-type coastal upwelling occurs in the northern region, during the southward passage of anticyclonic eddies. These eddies form as a response to northeasterly (NE) monsoon winds that blow poleward, alongshore and parallel to the coast off Angoche, and prevail between August and March (Sá *et al*., 2013). In this area the nanoplankton community was more representative (90%), with the most abundant organisms being the coccolithophores, *Discosphaera tubifera* and *Acanthoica quattrospina*. No diatoms were present.

While in the central region, Sofala Bank (16◦–24◦S) productivity is closely related to rainfall events, the Zambezi River runoff (Saetre & da Silva, 1982) and the heterogeneity of currents on the mid-continental shelf waters (Leal *et al*., 2009). In fact, salinity is known to vary seasonally in this area, from 20 in the rainy season (Lutjeharms, 2006b) to 34 ppt in the dry season (Sá *et al*., 2013). In this study Sá *et al*. (2013) shows that micro-sized plankton (20µm - 200µm) dominate this region and through the microscopic analysis confirmed a diatom-dominated assemblage (70% contribution), where *Chaetoceros* spp. and *Proboscia alata* were the most abundant species, with 20% and 16% respectively of all diatom population. The presence of diatoms and dinoflagellates are usually indicative of mature upwelled waters and water column stability. This study (Sá *et al*., 2013) also indicates that *Prochlorococcus* are not expected to be part of the pico-sized phytoplankton community present in this coastal shallow region. Tew-Kai & Marsac (2009), who applied statistical models to satellite data (1997–2004), subdivide the central portion of the Mozambique Channel (16°S–24°S) in three sub-systems. The first one occupies the northern part, more specifically the narrow part of the channel, where eddies are at early life stages and the spin-up process of cyclonic eddies is associated with nutrient inflow. The second sub-system stretches out in the median part characterized by eddies becoming mature as they move along the west coast. The third subsystem is located in the southern part, where eddies enter a spinoff process with decreasing energy and phytoplankton growth is greatly reduced.

Delagoa Bight is a shallow shelf centered on 34°E, 26°S where a poleward flow passing this bight generates a cyclonic eddy in the region throughout most of the year inducing upwellings (Lutjeharms & da Silva, 1988). Incomáti, Umbeluzi, Tembe, Matola and Maputo rivers discharge in the Delagoa Bight is estimated to vary from 10 m^3/s to 800 m^3/s (Sete *et al*., 2002), having a major influence on primary productivity (Quartly & Srokosz, 2004; Sá *et al*., 2013). Therefore, phytoplankton production is a concomitant result of upwelling, rivers discharge, and current flows that supply nutrients to the surface layers. Sá *et al*. (2013) estimates that upwelling contributes to an increase in silica, which has an average concentration of 8,857 µmol/L in inner shore stations, favouring the growth of diatoms. This concentration is similar to that reported by other authors for the western Indian Ocean (WIO) (Barlow *et al*., 2008; Leal *et al*., 2009; Paula *et al*., 1998). Sá *et al*. (2013) and Barlow *et al*. (2008) reported very small nitrate values for Delagoa Bight and associated this depletion to the prompt consumption of nutrients by diatoms.

Due to the influence of AAIW, it is worth mentioning that the region between 35˚S and 40˚S in the south-western Indian Ocean is a transitional zone bordered by the Agulhas Frontal system and its associated return flow with oligotrophic warm waters of the subtropics. The sub-Antarctic front contributes with more productive waters of the sub-Antarctic zone (e.g. Belkin & Gordon, 1996 cited by Metzl, 2009; Lutjeharms & Valentine, 1984), which is extremely important for some migratory animals such as whales (blue, fin and humpback) and birds.

6. MAIN COASTAL AND OFF-SHORE ECOSYSTEMS: CHARACTERISTICS AND HEALTH

6.1. COAST TYPES

Mozambique has a high diversity of coastal ecosystems including mangroves, coral reefs, swamps, subtropical rocky reefs and seagrass banks. Coral reefs are more abundant in the north of Mozambique, while subtropical rocky reefs occur in the south. Seagrass banks and mangroves occur along the entire coast of Mozambique but are more abundant in the central area. The main coastal and offshore ecosystems can be divided in three large Ecoregions (Figure 6.1) (Ministry for the Coordination of Environmental Affairs, 1997).

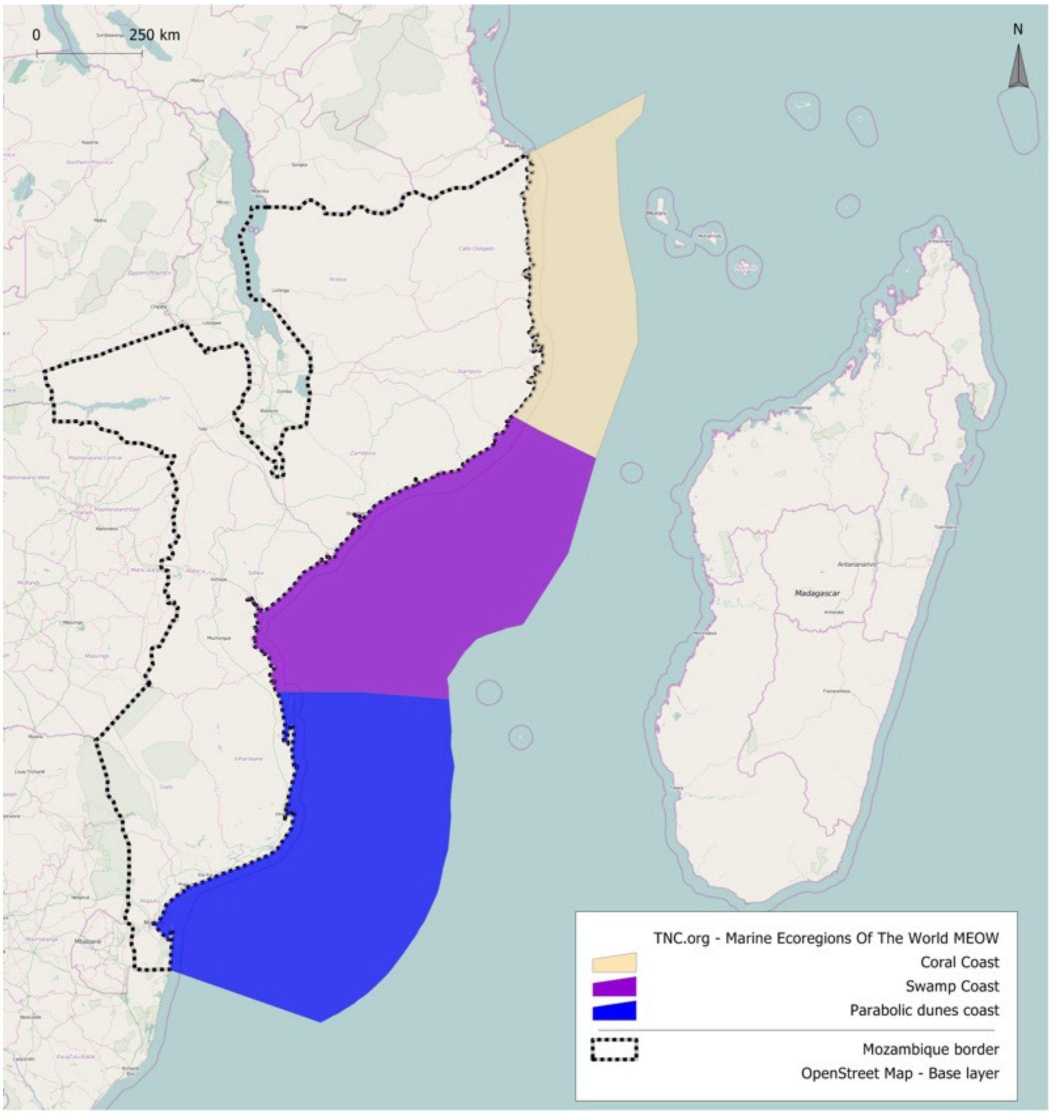

Figure 6.1 – Mozambique's coast types

a) Coral coast – From the Rovuma River to Pebane (17°20'), it encompasses the protected areas of Quirimbas Archipelago and the Primeiras and Segundas Archipelagos. This region is characterized by fringing reefs and island reefs, clear and warm waters (Benayahu *et al*., 2003; Ministério para Coordenação de Acção Ambiental, 2002; Obura *et al*., 2002). These reefs are mainly formed by calcium carbonate-secreting organisms (including corals) and are extremely important for the biodiversity and physical protection of the coast (Figure 6.2). They are one of most diverse ecosystems of the world and have recently been declared as the second most biodiverse area for coral species in the Indo-Pacific (Obura, 2012). In the most conserved reefs of Mozambique (e.g. Neptuno Reef, Vamizi), the vulnerable green humphead parrotfish (*Bolbometopon muricatum*), several reef sharks and the endangered Napoleon wrasse (*Cheilinus undulatus*) are relatively common. Strongly associated with coral reefs and mangroves systems, are seagrass ecosystems with eight of the 12 Western Indian Ocean (WIO) seagrass species occurring in Mozambican waters. Seagrass meadows can be mono or multi specific and often found in waters <12 meters (m) deep (Milchakova *et al*., 2005). Seagrass meadows are important nursery grounds for many juvenile reef fish and critical habitat for dugongs, marine turtles and commercial fisheries species (e.g. sea cucumbers). The Quirimbas Archipelago (~2000 hectares [ha]) is the most significant example of mangrove ecosystems within this region, although extensive mangrove areas occur along the swamp coast (Harari, 2005).

Figure 6.2 – Example of a coral coast, an aerial view of Pemba, Cabo Delgado Province (Photo: Hugo Costa)

b) Swamp coast – Central part of Mozambique, from Angoche (16°14S) to Bazaruto Archipelago (21°14'S) – in this region, 24 rivers discharge to the ocean, supporting extensive mangroves, soft-sediment intertidal habitats, large swamps and estuaries. Mozambique contains the second highest areal coverage of mangrove habitat in the WIO with 2,910 km^2 (Spalding *et al*., 2010) and all ten species of the WIO occur in Mozambique (Hatton & Couto, 1992). Often associated around river mouths, mangroves are essential for retaining and stabilizing marine sediments and coastlines (LeMarie *et al*., 2006). The continental shelf is very wide reaching up to 140 km around Beira (Ministério para Coordenação de Acção Ambiental, 2002). High turbidity limits extensive coral reefs formations along this section of the coast. This region is most well known for the Sofala Bank, the country's most important shallow water shrimp fishery (Sumale, 2005). The swamp coast includes the only two deltas on the Mozambique coast: the Zambezi Delta and Rio Save Delta. Deltas are characterized by wide and flat areas with many channels that branch out. Because of the low gradient in the area, the slow water flow induces the accumulation of sand at the mouth of the river. This has generated a number of habitats that might be permanently or seasonally inundated. The dynamics of the delta is fundamental to keep the ecological process functional. The construction of dams has changed the water flux in the Zambezi Delta. Careful management is needed to avoid further ecological impacts (da Silva, 1986; Ministério para Coordenação de Acção Ambiental, 2002). The swamp coast is particularly important for more than 73 species of waterbirds, including several vulnerable and threatened species and the fishery industry, particularly prawn fisheries (Bento & Beilfuss, 2000).

c) Parabolic dunes coast – The parabolic dune coast (Figure 6.3) stretches from Bazaruto Island down to the country's southern boundary at Ponta do Ouro (Louro, 2005). This region is characterized by steep and tall (up to 120 m high), vegetated parabolic dune systems backed by salt lakes and closed salt lagoons (Hatton, 1995; Momade & Achimo, 2004). Where lagoons are open to the ocean, large estuary areas occur which support seagrass meadows. Seagrass meadows of Bazaruto Archipelago are known to support the largest remaining populations of dugongs in the WIO (Findlay *et al*., 2011). The Bazaruto Archipelago is a transitional ecosystem, which presents both typical tropical coral reefs and submerged rocky reefs. Coral banks (e.g. Africa Banks) and patchy reef formations are scattered along the dune coast. Corals colonizing sandstone reef formations are typical, and soft coral species are more predominant than hard reef building species, the latter being found further north in the coral coast region. Rocky reefs and intertidal areas are also dispersed throughout. Extensive intertidal reef harvesting occurs, where local communities collect gastropods, bivalves and other macro-invertebrate species (de Boer & Longamane, 1996). Sandy beaches throughout this coast provide optimal nesting habitat for loggerhead and leatherback marine turtles (Louro *et al*., 2006). Inland of the dunes, there is a complex of salt and fresh water lakes. The unique oceanographic characteristics between Závora and Vilanculos make this area favourable to aggregations of whale sharks (*Rhincodon typus*) and manta rays (*Manta alfredi* and *Manta birostris*; Rohner *et al*., 2013).

Figure 6.3 – Beach and high dunes in the Manhiça District, Maputo Province (Photo: Marcos Pereira)

6.2. COASTAL DUNES AND BARRIER LAKES

Coastal dunes occur throughout the Mozambican coastal zone, but are more prominent in the southern region (Louro, 2005). Coastal dunes provide essential habitats for plants and invertebrates, as well as feeding and nesting sites for birds and marine turtles (Groom *et al*., 2007).

Coastal dunes are divided into two major groups: (1) the inner dunes (secondary) of old oxidation that in most cases have a red and/or yellow colour (Momade & Achimo, 2004) and (2) the outer coastal dunes (primary) that occur as a continuous, narrow coastal strand, exposed directly to the beach except at the mouth of the Limpopo and Incomati rivers (Hatton, 1995; Momade & Achimo, 2004). Depressions sometimes occur behind these dunes, forming coastal lagoons and adjacent dunes (Hatton, 1995). The dunes are formed by ancient and recent sands, carried by the wind over the past regressions (Kalk, 1995; Momade & Achimo, 2004). The unconsolidated dune and plain sand are from recent quaternary sediments and exposed to hydromorphic changes while near the mouth of large rivers sediments are mixed with soils of higher textures (alluvium) (Hatton, 1995; Tinley, 1971).

In the north and central regions of Mozambique, from Mocambo Bay to Sofala province, sandy beaches and some low parabolic dunes are formed by storm winds occasionally overlying with the barrier or marshy coast (Hatton, 1995; Tinley, 1971).

The southern coastal region dunes stretch over approximately 850 km from Bazaruto Island (35^{o} E, 21^{o} S) southward to Ponta de Ouro and beyond to Kwazulo-Natal at Mlalazi River in South Africa (28° 57'S). This section is characterised by high parabolic dunes, but barchanoids and longitudinal dunes are also present. Dunes have a dominant SE-NW orientation, consistent with the dominant wind regime (Kalk, 1995) and some dunes also show blowouts.

Dunes of the Bazaruto Archipelago are more abundant on the east side of Bazaruto Island, covering 27% of the island. The other islands of the archipelago have vegetated primary dunes (Nuvunga *et al*., 1998). Bazaruto dunes can reach 90 m in elevation and are sparsely vegetated (Cooper & Pilkey, 2002). In the district of Xai-Xai (33^{o} 19'E, 25 ^{o} 18'S), between Praia Velha and Praia do Chonguene region, primary dunes are smaller in height and width than secondary dunes (Nuvunga *et al*., 1998). In the region of Bilene-Macia (33^{o} E, 25^{o} S), secondary dunes reach heights of 100 m and are characterized by poorly consolidated red sands and covered by dense vegetation and the primary coastal dunes reach several tens of meters and are formed by white sands (Momade & Achimo, 2004). Along the southern coastal region, the dunes have become quite consolidated, sometimes forming scarps resulting from erosion, particularly in the mouth of the Bilene Lagoon. Tinley (1971), Hatton (1995) and Massinga & Hatton (1997) reported that the Ponta do Ouro-Inhaca dune systems attain heights of 120 m and are considered to be the highest vegetated dunes in the world (Figure 6.4).

Many studies in the southern region (Bandeira *et al*., 2007; Short, 1999, cited by Schlacher *et al*., 2011) show the importance of vegetated dunes in controlling coastal erosion. The vegetation is mainly classified in four plant communities, including pioneer dune vegetation (eg. *Phylohydrax carnosa*, *Scaevola plumieri*, *Ipomoea pes-caprae*, *Sophora inhambanensis*, *Canavalia rosea*, *Cyperus crassipes*, *Asystasia gangetica*, *Launea sarmentosa*, *Tephrosia* sp. and *Tragia* sp.), young shrub (e.g. *Sideroxylon inerme*, *Rhoicissus revoilii*, *Pavetta revoluta*, *Mimusops caffra* and *Diospyros rotundifolia*), shaggy dunes (e.g. *Diospyros rotundifolia*) and forest dunes (e.g. *Ochna natalitia*, *Mimusops caffra*, *Rhoicissus revoilii*, *Psydrax locuples* and *Gymnosporia* sp.), with smaller vegetation with less than 2.5 cm (eg. *Cissus quadrangulares*, *Sansiviera concinna*, *Rhus* sp., *Tricalisia sonderana*, *Ochna natalitia*, *Rhoicissus revoilii*, *Mimusops caffra*, *Scadoxos* sp., *Erythroxylum* sp., *Microsseleus scolopendrum*, *Carissa bispinosa* and *Deinbollia oblongifolia*; Bandeira *et al*., 2007; Koning & Balkwill, 1995; Nuvunga *et al*., 1998; Weisser, 1980).

Figure 6.4 – Lake Mwandle, Gaza Province (Photo: Marcos Pereira)

Dune ecosystems are protected by law in Mozambique, through the Regulation for the Prevention of Pollution and Protection of the Marine and Coastal Environment (Decree 45/2006, of 30 November), forbidding driving and building on the primary dunes and the beach. Unfortunately this still occurs where there is no enforcement (Louro *et al*., 2006). In the past, *Casuariana equisitifolia*, an exotic species, was planted in the coastal zone of Mozambique, in Inhaca island, Barra Falsa, Ponta Caldeira, Bazaruto, Ponta do Ouro, Cabo da Boa Paz, Barra and Závora (Cruz *et al*., 2003; Tinley, 1971), in order to erect fences tangent to the wind and the slope of pioneering exotic plants, to induce natural succession (Cardoso, 1954; Cruz *et al*., 2003; Gülçur, 1979). Yet, this exotic species, unlike pioneer vegetation, does not contribute to dune formation and also damages local biodiversity (Cardoso, 1954; Tinley, 1971).

Coastal barrier lakes, swamps, and temporarily-filled basins that occur behind the coastal dunes are a conspicuous feature of the coastal zone of southern Mozambique (Hatton, 1995; Massinga & Hatton, 1997). They occur from Vilankulos to Ponta do Ouro, but extend as far south as Durban in South Africa (Hart, 1995; Hill, 1975). Hill (1975) described three categories of such areas:

(i) Drowned valley lakes – which originated from the flooding of river valleys deeply incised during the last Pleistocene glaciation. These are the largest and most prominent features behind coastal dunes. Connectivity to the sea varies widely. Examples in Mozambique include Lake Poelela and Lake Nhambavale (Hart & Boane, 2004; Hill, 1975);

(ii) Inundation lakes – generally not associated with rivers, these originated by the flooding of low-lying depressions behind long-shore coastal barrier dunes. Known as "barrier lakes", they are generally shallow and lack direct surface links with the sea. Most lakes in southern Mozambique fall in this category. Lake Bilene is somehow a combination of the two (Hill, 1975);

(iii) Wind-eroded "deflation basin lakes" (Hart & Boane, 2004; Hill, 1975).

André (2012) Hart & Boane (2004) and Hill (1975) described the limnology of the southern Mozambique lakes (Figure 6.5), with brief accounts of the physico-chemical parameters and socio-economic uses of the Quissico lakes by Pereira *et al*. (2010). The lakes are important for subsistence-level farming, fishing, and salt production (e.g. Lakes Bilene, Quissico, Massava, Poelela) (Pereira *et al*., 2010a), as well as the booming tourism industry (Lakes Bilene, Chidenguele and Nhambavale being prime examples) (Hatton, 1995; Hatton *et al*., 1997; Massinga & Hatton, 1997).

Figure 6.5 – Quissico lakes, Inhambane Province (Photo: Marcos Pereira)

6.3. MANGROVES

Mangroves can be defined as woody plants that grow at the interface between land and sea in subtropical and tropical tidal environments where they exist in conditions of high salinity, extreme tides, strong winds, adverse temperatures, and muddy/sandy substrates. There is no other group of plants with such highly developed morphological and physiological adaptation to extreme conditions on Earth (Elisson & Farnsworth, 2001; Hogarth, 1999; Kathiresan & Bingham, 2001; Omodei Zorini *et al*., 2004). There is, in addition, a loosely defined group of species often described as "mangrove associates", or non-exclusive mangroves species. These comprise a large number of species typically occurring on the landward margin of the mangrove, and often in non-mangrove habitats such as rain forests, salt marshes, or lowland freshwater swamps (Hogarth, 1999). Many epiphytes also grow on mangrove trees. Among these, creepers, orchids, ferns, and other plants, many of which cannot tolerate salt and therefore grow only in the mangrove canopy (Lugo, 1989).

The muddy or sandy sediments of mangroves are home to a huge variety of epibenthic infaunal or meiofaunal invertebrates (Cannicci *et al*., 2008; Olafsson & Ndaro, 1997; Penha-lopes *et al*., 2010; Svavarson *et al*., 2002). These macrofauna form an important link between mangrove detritus at the base of the mangrove food web and consumers at higher trophic levels, which include birds and commercial fish species. In addition, channels within the mangrove support communities of phytoplankton, zooplankton, juvenile fish and shrimps (Macia, 2004a; Macia *et al*., 2003; Ronnback *et al*., 2002), which in turn occupy coral reefs, seagrass beds and the offshore as adults.

African mangrove forests cover an area of approximately 350,000 km^2 of which the greatest part is located along the west coast with 15 species distributed among 6 families. The Meliaceae are represented by three species: one species of *Conocarpus* and two of *Xylocarpus*; the Avicenniaceae - often included in Verbenaceae - are represented by two *Avicennia* species. The best represented is the order Myrtales with one *Sonneratia* (Sonneratiaceae), four *Rhizophora*, one *Bruguiera* and one *Ceriops* (Rhizophoraceae), one *Laguncularia* and one *Lumnitzera* (Combretaceae) species (Bosire *et al*., 2012; Chavellier, 2012; Hatton & Couto, 1992; Kairo *et al*., 2001).

The current estimate of mangrove forest area in Mozambique varies from 368,000 ha (MICOA, 2009) to 290,000 ha depending on the year of assessment and source of information. Based on a recent assessment, 28% of these mangroves occur in the Zambezi Delta (Fatoyimbo *et al*., 2008), which also represents the single largest area of mangrove forests in Africa. Globally, Mozambique ranks 13th in terms of mangrove coverage which is equivalent to approximately 2.3% of the global mangrove forest area (Giri *et al*., 2011). The largest mangroves areas are found within central Mozambique, and in protected deltas and large rivers estuaries (Barbosa *et al*., 2001; Sitoi *et al*., 2014), such as in Beira and the Save Rivers where the mangrove cover extends up to 50 km inland. They are scarce in the southern coast due to large dunes except Save River, Incomáti, and Maputo River as well as around larger bays such as Inhambane and Maputo (especially at Inhaca Island).

Avicennia marina is the most widespread species. It colonizes both inner and outer margins of the forests. Yet, towards higher latitudes some inner parts are dominated by *Sonneratia alba* and *Rhizophora mucronata*, less tolerant to changes in salinity.

The northern coast is predominantly coraline, with coral reefs normally bordering the clear water subtidal areas. Mangroves are common in this region of Mozambique and grow in estuaries, embayments, and some areas protected from direct ocean currents. Extensive mangrove areas occur in the extensive Quirimbas Archipelago and several embayments near the archipelago (viz Palma, Ulombi, Mocimboa, Quiretajo; Frontier, 1997; GNBR, 2010). Other important mangrove areas are Pemba Bay with 33,600 ha (Ferreira *et al*., 2009) and the coastline of Nampula. In southern areas mangrove cover is patchy (Sitoi *et al*., 2014).

In Mozambique, mangrove forests provide numerous goods and services to the communities living along the coast. They are critical habitats, particularly since they are crucial to the functioning and integrity of coastal and marine habitats, provide a nutrient-rich environment and shelter for juvenile fish and marine invertebrates, in particular for commercial prawns that are harvested in open waters. In addition, mangrove trees are used as construction material, firewood, and as a source of tannins used to preserve and camouflage fishing gear, stabilize the coastline by preventing erosion, contribute to detoxification and depuration of waste waters, and protect inland areas from weather extremes such as storm surge and extreme high tide events (Bandeira *et al*., 2009; Paula *et al*., 2014).

Mangroves are a charismatic habitat of the Mozambican coastline, and there is a considerable amount of data available. Early descriptions of flora and associated fauna were done by Kalk (1959) and McNae & Kalk (1969). In contrast, after independence (1975) some researchers centered their investigations on mangroves of Inhaca Island and associated fauna (e.g. Barbosa *et al*., 2001; Cannicci *et al*., 2009; de Boer, 2002; Flores *et al*., 2003; Hatton & Couto, 1992; Litulo *et al*., 2005, 2010; Litulo, 2004, 2005a,b,c,d; 2006; 2007; MacNae & Kalk, 1995; Paula *et al*., 2001a, 2003, 2014; Penha-Lopes *et al*.; 2009, 2010, 2013; Silva *et al*., 2009, 2013; Torres *et al*., 2008a,b, 2009). However, a more accurate account of the recent status of Mozambican mangrove forests is given by Barnes *et al*. (2011), Fatoyimbo & Simard (2013), Fatoyimbo *et al.*(2008), and Ferreira *et al*. (2009) using satellite imagery. The total area of mangroves in Mozambique was reduced from 408,000 ha in 1972 to 357,000 ha in 2004 (Marzoli, 2007 cited by Sitoe *et al*., 2012). Resource use is not only cause of loss of mangroves in Mozambique: the effects of floods in 2000 also contributed to a loss of more than half of the mangrove area in the mouth of the Limpopo River (Sitoe *et al*., 2012).

The majority of the Mozambican population lives in coastal areas. Moreover, several large cities – including Maputo, Beira, Quelimane and Pemba – are located in the coastal zone. Urbanization of the coastal area has caused a high rate of mangrove destruction and degradation in Mozambique in and around developing cities, where mangrove wood products such as charcoal, firewood and timber are in high demand. These ecosystems are also cleared for agricultural purposes and salt extraction, and will probably be affected by the extraction of hydrocarbons and heavy mineral sands. Mangroves are also diminishing as a result of upstream dam construction (Chavellier, 2013). For example, the Cahora-Bassa Dam has significantly reduced the flow of water in the Zambezi River, altering water conditions and causing mangrove cover to shrink (UNEP, 2007). Also, high volumes of crude oil are being shipped through the Mozambique Channel, resulting in accidental oil spills that have affected mangroves along the coastline. The Maputo Bay area is also affected by the shipping traffic and resultant pollution.

In Maputo and northern bays, mangroves are also used for boat and house construction and to produce various household utensils. Those forests located close to major human settlements are prone to rather heavy anthropogenic pressure (Figure 6.6), while the most remote mangroves (e.g. Maputo River Estuary, Maputo Special Reserve and Saco forests) are kept in a good, although not pristine, condition. Land use changes were also responsible for the loss of several hectares of mangroves. Conversion of mangroves to saltpans (most of them concentrated in the Matola region) and to shrimp aquaculture ponds have reduced the cover of mangroves. The forest is also being cleared for urban development. At Costa do Sol, for example, a new upmarket neighbourhood continues to encroach vital mangroves forests that would otherwise help counter floods and surge. Mangroves are also exposed to waterborne pollutants discharged in municipal waters, as well as agricultural and industrial effluents (Maputo Bay holds the biggest industrial park of Mozambique) (Bandeira *et al*., 2009; Paula *et al*., 2014).

Figure 6.6 – Mangroves at Barra, Inhambane Province (Photo: Rodrigo Santos)

There is a need to conduct the following tasks in order to ensure the long-term services mangroves provide in Mozambique and support good resource management practices:

- Analyse and evaluate the range of services and functions mangrove forests provide
- Examine the ecological and economic values of mangrove ecosystems and compare them with the sum of the products they generate.
- Study the complex functional linkages and interactions between mangroves and other ecosystems as well as biophysical processes both upstream and downstream of the mangrove forest area.
- Prevent degradation of the mangrove ecosystems in order to prevent irreversible changes of local physico-chemical, biological and ecological properties
- Document/model coastal currents and sediment transport as a decision-making tool that supports the prevention of chemical and physical impacts potentially caused by onshore and offshore commercial shipping and oil and gas activities (e.g. accidental spills, construction of shore facilities such as terminals and docks).

6.4. REEFS

Coral reefs have considerable socio-economic importance in Mozambique (Bjerner & Johansson, 2001; Pereira, 2003; Schleyer *et al*., 1999), supporting tourism and local fisheries throughout the country. Research on corals and coral reefs dates back to the early 50s although the first published papers dealing with reef fish and fisheries appeared in 1925 (Fowler, 1925). Two major reviews have been published (Rodrigues *et al*., 2000 and Schleyer & Pereira, 2014).

Coral reefs of Mozambique cover an estimated area of 1,890 km^2 (Spalding *et al*., 2001). These are found almost continuously in northern Mozambique as far south as the Primeiras islands, located north of the Sofala Bank (Rodrigues *et al*., 2000). These are mainly fringing reefs and result from biogenic accretion, thus are considered true coral reefs (Schleyer *et al*., 1999). In general the reefs occur within a wide depth range (5-40 m) and are dominated by hard corals (Order Scleractinia) with *Acropora*, *Porites*, *Pocillopora*, *Echinopora* and *Favites* as the dominant genera. However, in some locations, soft corals (Order Alcyonacea) are very abundant and dominate the reef benthos (e.g. Benayahu *et al*., 2003; Schleyer, 1999a; Videira & Pereira, 2007), with *Sinularia* and *Lobophytum* (Family Alcyoniidae), nephtids (Family Nephtiidae), and xenids (Family Xenidae) being particularly conspicuous.

Within the Sofala Bank, no coral reefs are found given the high turbidity and low salinity, resulting from the discharge of about 28 rivers (Rodrigues *et al*., 2000). From the Bazaruto archipelago to Ponta do Ouro, coral communities grow as a thin veneer on late Pleistocene sandstone, which originated from submerged coastal sand dunes (Ramsay, 1994, 1996); fully formed reefs originated by biogenic accretion do not occur here. These incipient reefs run parallel to the coastline 1 to 2 km offshore and can be classified as patch reefs. Coral colonies occur more sparsely at depths usually greater than 12 m to about 40 m (Pereira, 2003).

In Mozambique, reefs occur in a wide latitudinal range (10^o 30 S – 26^o 50 S), which confers to the country high levels of biodiversity (Figure 6.7). More than 900 species of reef fish have been identified (Pereira, 2000a) in 97 families (Tupper *et al*., 2008 see section 7.2). Although the coral taxonomy is poorly known and in need of urgent work, at least 149 species of hard corals (in 59 genera) (Sheppard, 1987; Veron, 1993) and more than 50 species of soft corals (belonging to 15 genera) have been identified (Benayahu *et al*., 2003; Schleyer, 1999; Schleyer & Celliers, 2000). Recent work (Obura, 2012) identified 220 species of hard corals in Nacala and suggested that the maximum species richness could be as high as 297 species. These results highlight once again the need for in-depth taxonomic and ecological work on Mozambican reefs.

Figure 6.7 – Coral reef at Northern Quirimbas, Cabo Delgado Province (Photo: Marcos Pereira)

While the exposure of reefs of Mozambique to the elements and to human impacts (especially artisanal/subsistence fishing) may vary, if one considers reefs that are similar in nature (Table 6.1), available data suggests that reefs located within MPAs or in relatively remote areas, appear to be in better condition. This is even more pronounced if one looks at the fish community, where protected reefs support considerably higher fish abundance (density and biomass) and diversity (Motta *et al*., 2002; Pereira & Videira, in prep).

Table 6.1 – Summary data on reef conditions of selected reefs along the Mozambican coast. Reefs marked with * are located within MPAs

Location	Reef	Total live coral cover	Dominant benthos	Reference
Palma	Quionga1	36.6%	Hard coral (35.6%) Sand, rock and algae, rubble (36.5%) Fleshy macroalgae (31.0%)	Pereira & Videira (in prep)
Quirimbas National Park	Ibo lighthouse*	39.9%	Sand, rock and algae, rubble (51.8%) Total hard coral (25.1%) Massive hard coral (15.8%)	Pereira & Videira (in prep)
Quirimbas National Park	Sencar channel*	37.4%	Sand, rock and algae, rubble (53.1%) Soft coral (27.1%) Total hard coral (7.6%)	Pereira & Videira (in prep)
Quirimbas National Park	Matemo Is.*	39.8%	Sand, rock and algae, rubble (35.2%) Total hard coral (34.2%) Massive hard coral (10.7%)	Pereira & Videira (in prep)
Primeiras and Segundas	Epidendron Is.	54.5%	Rock and algae (38.9%) Hard coral (38.6%)	Pereira & Rodrigues (in prep)

Location	Reef	Total live coral cover	Dominant benthos	Reference
archipelago			Branching hard coral (18.1%)	
Primeiras and Segundas archipelago	Mafamede Is.	51.8%	Hard coral (40.6%) Rock and algae (40.6%) Branching hard coral (18.9%)	Pereira & Rodrigues (in prep)
Bazaruto Archipelago National Park	Two-mile reef*	44.0%	Hard coral (42.7%) Bare reef, sand, rubble (34.5%) Coralline algae (8.5%)	Schleyer & Maggs (2007)
Bazaruto Archipelago National Park	Lighthouse reef*	50.2%	Hard coral (43.4%) Bare reef, sand, rubble (32.3%) Dead coral (9.0%)	Schleyer & Maggs (2007)
Inhambane	Anchor bay	10.6%	Rock and algae (74.3%) Sand (11.4%) Hard coral (9.8%)	Motta *et al*. (2002)
Inhambane	Mike's Cupboard	17.2%	Rock and algae (77.1%) Hard coral (7.4%) Sand (3.8%)	Motta *et al*. (2002)
Inhaca Is.	Baixo Danae	38.2%	Rock and algae (55.5%) Hard coral (30.8%) Soft coral (7.4%)	Motta *et al*. (2002)
Inhaca Is.	Barreira Vermelha*	42.3%	Hard coral (41.9%) Rock and algae (33.3%) Dead coral and algae (19.7%)	Motta *et al*. (2002)
Inhaca Is.	Ponta Torres*	36.1%	Hard coral (36.1) Dead coral and algae (18.9%) Sand (17.4%)	Motta *et al*. (2002)
Ponta do Ouro Partial Marine Reserve	Techobanine 1*	33.3%	Rock and algae (40.8%) Soft coral (26.7%) Turf macroalgae (12.3%)	Pereira & Fernandes (2014a)
Ponta do Ouro Partial Marine Reserve	Texas*	35.5%	Rock and algae (54.3%) Soft coral (31.9%) Fleshy macroalgae (6.2%)	Pereira & Fernandes (2014a)

Reefs of Mozambique are mainly impacted by overfishing, bleaching due to high irradiance and temperature in summer, coastal erosion, and in selected locations, the ravages of the predatory crown-of-thorns starfish, *Acanthaster planci* (Rodrigues *et al*., 2000; Schleyer, 1998; Schleyer *et al*., 1999). The collection of invertebrates (Figure 6.8) and reef fish for the curio trade is also impacting coral reefs in Mozambique (Whittington *et al*., 2000; Pereira, 2008b), as well as coral mining, especially in northern Mozambique, where there is a long tradition of its use as building material. Irresponsible tourism (anchoring, trampling) has taken its toll on the Two-Mile Reef in Bazaruto, with a drastic reduction of hard coral cover over the years (M. H. Schleyer, pers. com.).

Recreational SCUBA diving has grown tremendously in southern Mozambique and was seen as potentially detrimental to reef communities (Bjerner & Johansson, 2001), but this was not the case in Ponta do Ouro (Pereira & Schleyer, 2005), where both reef fish and coral communities, were largely unaffected by SCUBA diving at the time. The sustainable diving capacity was estimated at about 6000 dives per site dive and year (Pereira, 2003), and this figure was proposed as applicable to typical reefs found in southern Mozambique.

Figure 6.8 – Nudibranch (*Aegires villosus*) in a coral reef at Závora, Inhambane Province (Photo: Yara Tibiriçá)

6.5. SEAGRASS BEDS

Seagrasses are marine angiosperms, monocotyledons that are adapted to live permanently submerged in seawater (den Hartog & Kuo, 2006). Most are entirely marine although some species can survive in a range of conditions encompassing freshwater and estuarine conditions. There are relatively few species worldwide, about 60 known species are grouped in 13 genera and 5 families (Short *et al*., 2001).

The distribution of seagrasses ranges from high intertidal to shallow subtidal soft bottoms, i.e. sandy bays, mud flats, lagoons and estuaries, where they often form extensive mono- and multispecific meadows. In the tropics it is common to find seagrass meadows adjacent to other key ecosystems such as coral reefs and mangroves (Gullströom & Dahlberg, 2004; Ngusaru, 2011).

Of the about 60 species of seagrasses reported worldwide Short *et al*. (2001), 13 seagrass species were reported in the Western Indian Ocean (WIO) region (Bandeira & Bjork, 2001), and an additional species was recently identified (Duarte *et al*., 2012) totalling 14 species occurring along the coastal zone of Mozambique. One species (*Zostera capensis*) is listed as vulnerable (Bandeira, 2014). According to Ngusaru (2011) the most common genera are *Thalassia*, *Halodule*, *Syringodium*, *Halophila*, *Cymodoceae,* and *Thalassodendron*. In Mozambique the largest seagrass beds can be found at Inhaca and Bazaruto islands in the southern part of Mozambique and in many parts of Cabo Delgado province (Figure 6.9).

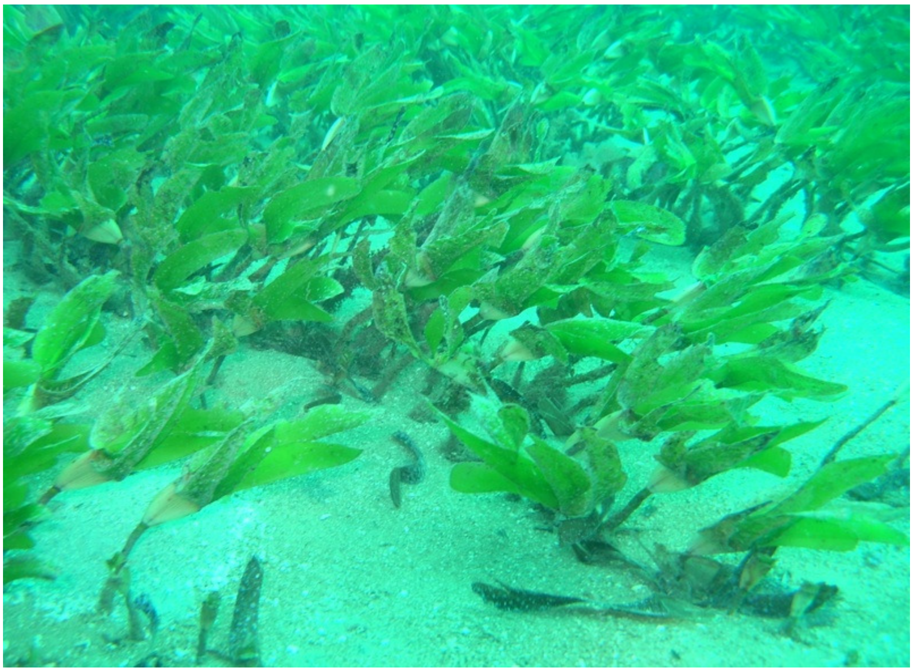

Figure 6.9 – Seagrass bed at Northern Quirimbas, Cabo Delgado Province (Photo: Marcos Pereira)

Seagrasses beds play a unique role in enhancing marine ecosystem process and marine biodiversity. They have a stabilising effect on shorelines, and provide food and shelter for numerous juvenile organisms. In addition seagrass beds mixed with some algal species (Halimeda sp.) are vital to carbonate sand production. They also harbour nitrogen-fixing bacteria and facilitate mineral circulation between the water and the sediments (Oliveira *et al*., 2005).

Habitats of seagrasses are known to be highly productive and play an important ecological role as nursery grounds, foraging areas, as well as refuges from predation for numerous fishes, invertebrates and other animals (Gell & Whittington 2002; Gullström *et al*., 2002; Orth *et al*., 1984;). They provide economic goods such as an extensive number of fish and invertebrates harvested by many of coastal communities (Gullströom & Dahlberg, 2004).

As a consequence of the high primary productivity and habitat complexity, the secondary productivity in seagrass beds is significant (Figure 6.10). Many of the species using seagrasses during their life stages have a high commercial value. Various species of fish and invertebrates that are associated with seagrasses are collected by local people as sources of food.

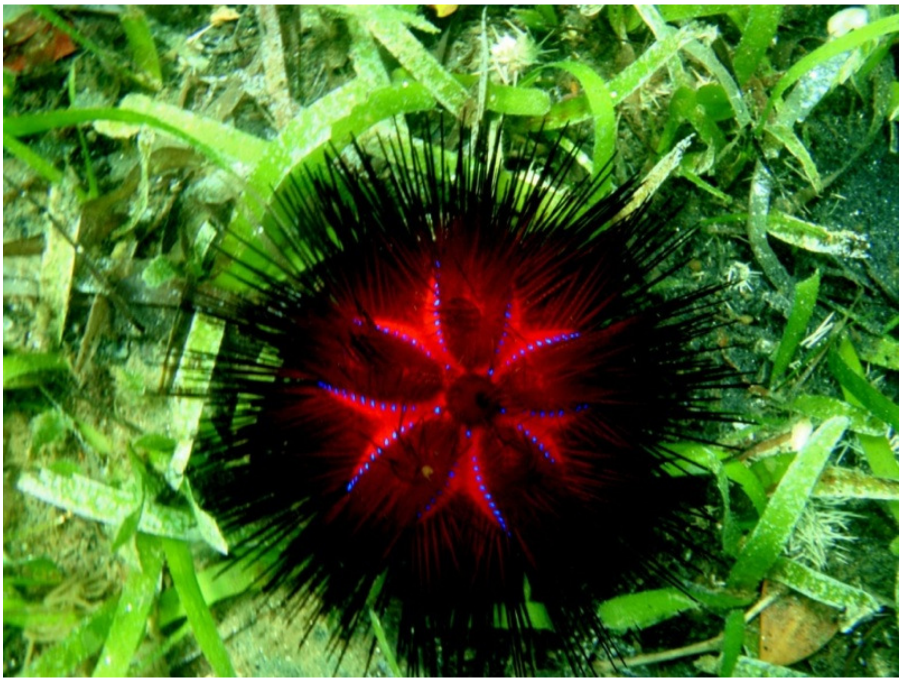

Figure 6.10 – Urchin in seagrass, Inhambane Bay, Inhambane Province (Photo: Jess Williams)

Vicente & Bandeira (2014) reported that the most collected invertebrates as a food source in Maputo Bay include gastropods, bivalves, crabs, and sea urchins. Seagrasses are valuable at local levels as they contribute to the provision of protein and cash income to the different human populations (Scarlet, 2005).

6.6. ESTUARIES AND BAYS

An estuary is an inlet reaching into a river while a bay is an inlet bordered by the coastline (Kaiser *et al*., 2011). Mozambique has an extensive drainage network that includes about 100 main river basins and a number of rivers, such as the Rovuma, Zambezi, Save, Limpopo and Incomáti Rivers (ASCLME, 2012). These rivers end in estuaries, mostly with funnel shape or delta-front topographies as described in Kaiser *et al*. (2011). Some estuaries of Mozambique create inlets due to the surrounding topography, thus creating bays, such as the Lúrio Bay associated with Lúrio River (approximately 50 km south of Pemba) and the Memba Bay associated with Moculumba River (located near Mazimingi, Nampula).

North of Pemba is the Rovuma River and Delta which borders Tanzania. This is an important coastal area with high mangrove cover and biodiversity (TRANSMAP, 2008) that has been relatively stable, probably due to the preventive effect of the Mnazi Bay-Rovuma Estuary Marine Park.

Pemba Bay is an important Mozambican bay and it is located on the northeastern coast around the city of Pemba. Pemba Bay has an area of 150 km^2 and is among the largest bays in the world. Due to its proximity to the city of Pemba and to shrimp aquaculture, mangrove cover surrounding the Pemba Bay has been decreasing over time (TRANSMAP, 2008). The Lúrio River flows into the sea south of Pemba Bay. This river is among the largest of Mozambique.

While the rivers leading to the Mozambique coast drain about 141 km^3/year of nutrient-rich water into coastal waters, about 67% of the total river discharge is delivered by the Zambezi River, which is the largest river in eastern Africa. The water flow from this river is strongly determined by the Cahora Bassa Dam (Ridderinkhof *et al*., 2001), which is one of the three major dams on the Zambezi River system and the largest hydroelectric scheme in southern Africa. This structure also affects the freshwater input to the coastal area known as Sofala Bank.

The Sofala Bank is the largest shelf area along East Africa and is located off central Mozambique within the 16^o S and 21^o S latitudinal range. Sofala Bank receives 80% of the Mozambique river runoff (Lutjeharms, 2006a; Sete *et al*., 2002). Here the continental shelf extends to 140 km offshore and is one of the most productive shelf regions of East Africa. The morphology of the coastal zone of Sofala Bank is characterized by flat land fringed by almost continuous mangrove swamps. These swamps are associated with rivers and with tidal creeks.

The coastal waters of Sofala Bank are estuarine in nature as influenced by the Zambezi, Pungué, Buzí and Save rivers (Leal *et al*., 2009, 2010; Saetre & Silva, 1979; Sete *et al*., 2002). The Sofala Bank is highly productive given the regional nutrient-rich runoff. Consequently, it is one of the most important fishery grounds of Eastern Africa, particularly for shallow water shrimp (Bandeira *et al*., 2002).

Approximately 500 km south of Beira (Sofala) and 470 km northeast of Maputo is Inhambane Bay, and the town of Maxixe. This bay is associated with the Morrumbene estuary (Figure 6.11), which has an area of 193 km^2 and is 20 km long with well-developed mangrove swamps draining into a broad lagoon (Day, 1974). Other bays of the Mozambican coast include the Fernão Veloso Bay, Conducia Bay, and Memba Bay near Nacala. However, scientific literature on these coastal systems is scarce.

Figure 6.11 – View of the Morrumbene estuary and Inhambane bay, Inhambane Province (Photo: Hugo Costa)

One of the most notable bays in Mozambique is Maputo Bay, which together with the Sofala Bank, is one of the main fishery areas that significantly contribute to the economy of Mozambique. The Maputo Bay is located in the southern part of Mozambique. It is 40 km long and 30 km wide, thus covering a 1,200 km^2 area (Sete *et al*., 2002). Five rivers drain into Maputo Bay: Incomáti River, Umbeluzi River, Tembe River and Matola River. Main features of this bay are the Espírito Santo Estuary to the west and Maputo River on the southwest side. Main rivers in this region are the Incomáti, Maputo and Umbeluzi (Sengo *et al*., 2005).

The areas surrounding these rivers produce substantial agricultural, which runs off into Maputo Bay (Sete *et al*., 2002; TRANSMAP, 2008). In addition, the Maputo Bay is next to the city of Maputo with over 1 million people generating substantial untreated domestic waste. Further, the main industries of Mozambique are located in Maputo and Matola and industrial runoff drains directly into the bay. The domestic, industrial and agricultural waste draining into the bay probably affects water quality, which in turn probably impacts local marine ecosystems.

Adjacent to Maputo bay is Delagoa Bight, one of the largest coastline indentations along the east coast of Africa (Lamont *et al*., 2010; Lutjeharms, 2006a). This is a very dynamic region as influenced by the Agulhas Current and the drainage by the Limpopo River, which sometimes floods the coastal area during heavy rainfalls (Kyewalyanga *et al*., 2007). Further, Delagoa Bight is also one of the most productive areas in the southern shelf of Mozambique (Kyewalyanga *et al*., 2007).

While the condition of Maputo Bay and the Sofala Bank has been examined over the past decades, little is known about the health of estuaries and bays of Mozambique. However, it is known that the river runoff has decreased over the years due to damming, water obstruction and irrigation in neighbouring countries, as well as modification of stream flow leading to either freshwater shortage/reduction or excessive runoff during certain periods of the year (ASCLME, 2012). This has lead to physico-chemical changes in the natural systems that may have dramatic consequences to the health of these coastal systems.

6.7. ROCKY SHORES

Rocky shores are mainly distributed along the coral coast (old intertidal reef formations) and the parabolic dune coast (Pleistocene sandstone, which originated from submerged coastal sand dunes; Ramsay 1994, 1996). Apart from a few localized studies, not much attention has been paid to rocky shores in Mozambique. Margaret Kalk's work at Inhaca Island (Kalk, 1958; 1995) and in northern Mozambique (Kalk, 1959), is still the basis for the current general knowledge on rocky shores of Mozambique. Studies of macroalgae of southern Mozambique and Mécufi include those by Isaac (1956; 1957) and Bandeira and colleagues (Bandeira, 1995; Bandeira & António, 1996; Bandeira *et al*., 2001).

Rocky shores are important for coastal protection. They also function as nursery areas for important fish species such as the potato bass (*Epinephelus tukula*; Fennessy *et al*., 2008; Kalk, 1958) and are permanent habitat for a number of species with commercial importance such as oysters (*Saccostrea cucullata*), mussels (*Perna perna*) and redbait (*Pyura stolonifera*). In certain areas such as Xai-Xai and the Ponta do Ouro Partial Marine Reserve, rocky shores are important resources for the livelihoods of local communities (e.g. Ribeiro, 2002; Robertson *et al*., 1996).

Apart from the macroalgae, not much is known about the biodiversity, exploitation and conservation status of rocky shores in Mozambique (Figure 6.12).

Figure 6.12 – Rocky shore at Palma, Cabo Delgado Province (Photo: Marcos Pereira)

6.8. SEAFLOOR

The continental shelf, between 10 and 200 m isobaths, covers an area of about 70,000 km^2 (Saetre & Silva, 1979). Seventy percent of the sediments were deposited during the last ice age, when sea level was 100 m below the current level (Impacto, 2012).

The continental shelf can be divided into two main regions, a northern region and a southern region, on either side of the 15° latitude line (Sætre & Silva, 1979). The northern region, is characterized by a very narrow continental shelf, deeply scarred with submarine canyons and bordered by coral reefs (Saetre & Silva, 1979). The southern region is much wider, extending several kilometres at its widest point with the Sofala Bank off Beira. Fischer *et al*. (1990) subdivided the regions in 4 areas:

1) Rovuma River (10° 28' S) to Ponta Namalunga (15° 30' S)

The continental shelf is very narrow, just a few kilometres at its widest part, and is bordered by coral reefs with high biodiversity (Massinga & Hatton, 1997). This area includes 32 islands, 11 of which are coralline and make up the Quirimbas Archipelago (Fischer *et al*., 1990). The Rovuma basin contains hydrocarbon reserves, some of them being explored (Gove & Mechisso, 2011). In most cases, rocks surround the river mouths.

2) Ponta Namalunga (15° 30' S) to Bazaruto (21° 30' S)

The continental shelf widens considerably up to the area south of Beira, at which point it starts to become narrow again reaching less than a 2 km width around Bazaruto. The Sofala Bank stands out in this area, as it is more than 100 km wide (Fischer *et al*., 1990).

Between Quelimane and the Zambezi Delta, an area of corals at depths between 40 and 100 m has been reported (Saetre & da Silva, 1979). The continental shelf is very steep in this area, with pointed edges (Fischer *et al*., 1990). The deltas of the Zambezi and Save Rivers generate a wide fluvial-marine plain and contribute to the deposition of large volumes of sediments, especially silt, on the continental shelf and sandbanks. Here, the seabed is sandy-muddy and waters are turbid, affecting life forms far beyond the sandbanks and the mangrove swamps. However, the dams built along these waterways interfere with the river flow and retain some of the sediments.

South of Beira, between 19° 30’ S and 21° 30’ S, the seabed is composed of “sand waves” generated by strong tidal currents in the area, with a wavelength between 200 and 400 m and an amplitude of about 10 to 15 m. Therefore, the continental slope is very steep and partially uneven (Saetre & da Silva, 1979).

3) Bazaruto (21° 30' S) to Cabo das Correntes (24° 06' S)

Between Bazaruto Island and Ponta Zavora the continental shelf is narrow and sprinkled with coral reefs (Fischer *et al*., 1990). In deeper water of the shelf there are rocky outcrops and canyons and muddier substrates beyond the shelf break (Saetre & da Silva, 1979).

4) Cabo das Correntes (24°06' S) to Ponta do Ouro (26°51' S)

The continental shelf widens considerably in this area, up to the latitude of Maputo. The area close to the shoreline is sandy with some silt near the Maputo estuary. It is generally shallow and flat with some coral patches along the Delagoa and Inhaca shores. From Ponta do Ouro to Inhaca, corals can be found at depths up to 100 m with some rocky outcrops and canyons present in deeper waters (Fischer *et al*., 1990).

7. BIODIVERSITY

7.1. LOCATION OF BIODIVERSITY HOTSPOTS

Several initiatives of the World Conservation Union (IUCN), World Resources Institute (WRI), The Nature Conservancy (TNC), Conservation International (CI) and UNEP funded the search for biodiversity hotspots in Mozambique (EAME, 2004). Table 7.1 shows MPAs and areas of high biological value.

Table 7.1 – Biodiversity hotspots in Mozambique.

Region	North of Mozambique
Location	Quirimbas Archipelago & Nacala-Mossuril (EcoRegion importance)
Conservation Status	Quirimbas National Park (partial protection of the Archipelago since 2002 – 1,430km²; Decree 14/2002).
Biological Value	Coral reefs, mangroves and savannahs. Highest diversity of corals and fish, aggregation of sharks, Bumphead parrotfish (*Bolbometopon muricatum*) and Napoleon wrasse (*Cheilinus undulatus*). Nesting area for Green and Hawksbill turtles and foraging ground for Olive Ridleys, Loggerheads and Leatherbacks (Garnier *et al*., 2008).
Remarks	Some important biological areas such as Neptuno reef, which is a remarkable nursery area for sharks, are located outside the park´s borders (Silva, pers. comm.). Other areas might be protected by local initiatives such as Vamizi Island which has its own community sanctuary (Garnier *et al*., 2008).
Region	North of Mozambique
Location	Primeiras and Segundas Archipelago (10,411 km²)
Conservation Status	Environmental Protected Area since 2012 (Decree 42/2012) EcoRegion importance
Biological Value	Coral reefs. Important nesting grounds for green and hawksbill marine turtles, highly diverse coral reefs, home to migratory whales, dolphins and bird species.
Remarks	The protected area was created as a joint effort of CARE, WWF, and the government to protect the environment and improve fisheries and people livelihoods.
Region	Mozambique central regional
Location	Zambezi Delta & Marromeu Complex
Conservation Status	Partially protected by the Marromeu Special Reserve (1,500 km²) Decree 1994 of July 23, 1960. Marromeu Complex of the Zambezi Delta was declared Wetland of International Importance in the Ramsar Convention in 2003. Global importance
Biological Value	Mangroves and swamp. Part of the largest mangrove complex in the Western Indian Ocean (2,800 km²) and a nursery area for fish and prawns. Concentrations of Risso's Dolphin, Humpback Dolphins and whales including breeding Humpback Whales (EAME, 2004). Highest density of waterbirds in Mozambique including Great White and Pinkbacked Pelicans, Glossy Ibis, Spuwing Geese and Whitebreasted Cormorants and the endangered Wattled Cranes (Bento & Beilfuss, 2000) and African Skimmer (EAME, 2004). The area is also habitat for other wildlife including elephants, wild dogs, leopards and lions (Bento & Beilfuss, 2000).
Remarks	There is an urgent need to restore seasonal flood flows of the Zambezi River to sustain ecological processes (Beilfuss & Santos, 2001). The Zambezi Delta regulates the recruitment of prawns, one of the biggest industries in Mozambique. Protection of the area is important for both the economy of the country and the ecology of the area (da Silva, 1986).

Region	Southern
Location	Bazaruto Archipelago and Cabo São Sebastião
Conservation Status	Protected by the Bazaruto National Park since 1971 limits expanded in 2001 (1,430 km²; Decree 39/2001 of 27 November) Globally important Cabo São Sebastião - Total Protect Zone since 2003
Biological Value	Coral reefs, rocky reefs, seagrass banks, mangrove, sand dunes Biggest Dugong (*Dugong dugon*) population in the Western Indian Ocean, 4 marine turtles, shark aggregation, 5 dolphin and 3 whale species (United Nations & World Heritage Convention, 2014), 6 endemic gastropod mollusc species. Populations of six bird species regularly exceeds 1% of the global population (EAME, 2004).
Remarks	Approximately 3500 people are living within the park. Barrier to cyclones and barrier lakes.
Region	Southern
Location	Pomene Estuary
Conservation Status	Partially protected by Pomene Reserve (Decree 2496 of 4 July 1964)
Biological Value	Mangroves, seagrass banks, coastal forest and rocky reefs. Large estuary important as nurse area for a great variety of fish, seagrass banks and sea horses.
Remarks	Seahorse population massively declined in the last 5 years (Y. Tibiriçá, pers. obs.)
Region	Southern
Location	Inhambane-Zavora (including Inharrime Complex)
Conservation Status	Not protected
Biological Value	Rocky reefs, tidal reefs, mangroves, lake systems and sand dunes Aggregation of manta rays (*Manta birostris* and *Manta alfredi)*, and whale sharks (*Rhincodon typus*), especially from Tofo to Zavora. Mating and reproduction area for a large population of Humpback whales during winter months. Leatherback turtles and Loggerhead turtles nesting area.
Remarks	United Nations & World Heritage Convention (2014) suggest Tofo-Bazaruto as a potential World Heritage marine site differentiated into two units: Bazaruto and Tofo. We agree that this area is a hotspot for conservation. However, we suggest that the Tofo-Bazaruto hotspot be extended to Zavora-Bazaruto to guarantee the integrity for protection of manta rays and whale sharks, since several scientific studies (Marshall, 2008; Marshall & Bennett, 2010; Pierce & Marshall, 2008; Pierce *et al*., 2010; Rohner *et al*., 2013) show that these large animals aggregate from Zavora to Vilanculos. There are only a few reefs in each zone where these animals aggregate often. Failure to protect part of this area could affect the successful protection of these species. Therefore small but effective protection for those reefs as part of a network would be the most effective way to protected these endangered species
Region	South - Maputo Bay-Machangulo Complex
Location	Ponta do Ouro to Inhaca
Conservation Status	Inhaca (DL 2620 of 25 July 1965) Ponta do Ouro Partial Marine Reserve established in 2009 (Decree 43/2009 of 21 August). Belongs to Maputaland-Pondoland-Albany Hotspot (CEPF, 2010) Global importance
Biological Value	Subtropical rocky reefs, marshes, seagrass banks, savannahs and grasslands. High diversity of fish, invertebrates, sharks, rays and skates (the elasmobranch fishes). Aggregation of sharks especially bull sharks (*Carcharhinus leucas*). Particularly important as a nesting area for loggerhead turtles (*Caretta caretta*) and leatherback marine turtles (*Dermochelys coriacea*) (Hughes, 1971). Important feeding area for turtles, dugong and migratory birds such as whimbrels and flamingos. Northern limit of migration for Southern Right Whale, migratory route for humpback whales and resident dolphins
Remarks	The area is part of a transboundary conservation project jointly funded by the Mozambican and South African Government.

7.2. FAUNA

7.2.1. Sharks and Rays

Many sharks and rays (elasmobranchs) are top predators crucial for the equilibrium of ecological processes (Daly *et al*., 2013). Most of these species have reduced reproduction rates and when commercially exploited they trend to become locally/regionally extinct. The worldwide increase in shark finning, including off Mozambique, is one of the biggest threats to the survival of these important species. In Mozambique there are approximately 122 species of sharks and rays, 20% of which are listed on the IUCN Red List of Threatened Species (Pierce *et al*., 2008). Sharks and rays are important for the health of ecosystems, and have economic value for tourism. For example, manta rays (*Manta birostris* and *M. alfredi*; Figure 7.1) and whale sharks (*Rhincodon typus*) are iconic species for diving tourism in Inhambane Province (Tibiriçá *et al*., 2011). Bull sharks (*Carcharhinus leucas*) are one of the main attractions at Ponta do Ouro and grey reef sharks (*Carcharhinus amblyrhynchos*) at the Neptuno Reef close to Vamizi Island. Yet, little protection is afforded to these species and there are very few scientific data on them.

Figure 7.1 – Manta ray (*Manta* sp.) at Závora, Inhambane Province (Photo: Yara Tibiriçá)

In Tofo (southern Mozambique), sightings of reef mantas have declined by 88% and those of whale sharks by 79% during the last eight years (Rohner *et al*., 2013). In the northern part of Mozambique, no sharks were observed during a rapid assessment of the coral reefs at Metundo Island (Samoilys *et al*., 2011). There is no validated data on the current status of the population of sharks and rays, yet anecdotal data point to a dramatic increase in the demand for elasmobranch products, particularly for the Asian market (Pierce *et al*., 2008). Therefore, there is an urgent need to enhance knowledge, management, law, protection and conservation of sharks and rays in Mozambique.

7.2.2. Reef Fish

There is a need for a comprehensive list of reef fish of Mozambique (Figure 7.2). Pereira (2000a) compiled all available information in a preliminary checklist, which includes 794 species in 93 families. Tibiriçá (2010) added another 18 species, yet the census is still far from complete.

Several species deserve special attention as they can be easily affected by human exploitation. Bumphead parrotfish *(Bolbometopon muricatum*) and napoleon wrasse (*Cheilinus undulatus*) are both listed in the IUCN red list as vulnerable and endangered, respectively. In Mozambique they are mainly seen on the healthiest coral reefs of the North. Groupers (Serranidae) are top predator fish with slow growth and low reproduction rates. In overfished reefs large groupers are one of the first animals to disappear (Samoilys *et al*., 2011).

Figure 7.2 – **Leopard blenny (*Exallias brevis*), in the Northern Quirimbas, Cabo Delgado Province (Photo: Marcos Pereira)**

7.2.3. Seahorses

There are at least 30 species of pipefish and 2 species of seahorse (*Hippocampus* spp.) recorded in Mozambique, however it is likely that this number is underestimated (Pereira, 2008b). Quantitative data on pipefish and seahorse conservation status in Mozambique is almost non-existent. Seahorses and pipefish are exploited for souvenirs and the aquarium market (Pereira, 2008b). Moreover, anecdotal information, personal observations and media news on illegal trade suggest that they have been heavily exploited for the Asian market where they are used in traditional medicine (Figure 7.3). For example a container with 67 kg of dried seahorses from Mozambique was seized in Hong Kong in August 2014 (http://hongkong.coconuts.co/2014/08/08/67-kg-dried-seahorses-seized-container-ship-arriving-mozambique). Interviews with tourism operators suggest a collapse in the seahorse population at the Pomene Estuary due to the destruction of seagrass and in Bilene Lagoon due to the illegal collection for Asian market (Y. Tibiriçá, pers. obs.).

Figure 7.3 – Seahorse (*Hippocampus reidi*) at Barra Lagoon, Inhambane Province (Photo: Yara Tibiriçá)

7.2.4. Macro-Invertebrates

Macro-invertebrates such as crustaceans and molluscs are key food resources (de Boer & Longamane, 1996; de Boer *et al*., 2002). On intertidal reefs they are a significant source of protein for the poorest families who cannot meet subsistence needs through fishing and agriculture (Whittingham *et al*., 2003). Moreover macro-invertebrates are important for bioprospecting of medicinal and nutraceutic compounds (Fenical, 1996) and for the resilience of reefs as they are extremely diverse and play a complex role in the equilibrium of the ecosystem (Gibson *et al*., 2011). However, the easy access to the coastal intertidal habitats associated with the increased demand for food has resulted in uncontrolled exploitation and collapse of coastal reefs.

Unfortunately intertidal reefs are often neglected in conservation actions and many species of macro-invertebrates might disappear before we even “discover” them (Figure 7.4).

According to the World Register of Marine Species (WORMS, 2014) there are 400 species of molluscs recorded in Mozambique. This number is highly underestimated and reflects the lack of baseline knowledge on macro-invertebrates, particularly for the non-commercial species. For example, a current study on diversity of sea slugs (Nudipleura) in Mozambique revealed 170 species in an area of 20 km of coastline. There were 80% of new records for the country and 36 potentially undescribed species (Tibiriçá, 2013). Some species of mollusc may play an important role in the equilibrium of ecosystems. For instance, the giant triton (*Charonia tritonis*) is one of the few predators of sub-adult and adult crown-of-thorns starfish (*Acanthaster planci*). The removal of the giant triton may result in an outbreak of crown-of-thorns starfish. This can cause the collapse of the reefs as crown-of-thorns voraciously feed on live coral tissue (Endean & Stablum, 1975). Giant triton shells as well as other species are heavily harvested as souvenirs in Mozambique (Y. Tibiriçá, pers. obs.), but no data exist in either the ecology or the economic impacts.

Figure 7.4 – Nudibranch (*Nembrotha purpureolineata*) at Závora, Inhambane Province (Photo: Yara Tibiriçá)

7.2.5. Dugong (*Dugong dugon*)

Although once widespread, the distribution of dugongs (Vulnerable, IUCN Red List) is highly fragmented within the Western Indian Ocean. The Bazaruto Archipelago represents the last stronghold within the region and is thought to be the only viable population estimated to contain between 247 and 359 animals (Findlay *et al*., 2011). Outside of the Bazaruto Archipelago, past surveys reported two individuals near Inhaca Island in the South (Guissamulo & Cockcroft 1997) and one lone animal in the Quirimbas Archipelago in the North (Motta, 2001). Additionally, aerial surveys documented small groups (<10 animals) in Inhambane Estuary in 2013 (J. Williams, pers. obs.; Figure 7.5). Major threats to dugongs include accidental capture in gill nets, seine nets, palisade fish traps and trawlers, habitat degradation, and increased boat traffic (Guissamulo, 2004).

Figure 7.5 – Dugong mother and calf, north of Linga Linga, Inhambane Province (Photo: Jess Williams)

7.2.6. Crustaceans

The Phylum Crustacea contains over 50,000 species, which are nearly all aquatic and predominantly marine, although many occur in freshwater environments (Richmond & Le Vay, 1997). The group includes some of the most familiar members of the coastal fauna such as crabs, shrimps and lobsters. Crustaceans can be found in almost every marine habitat from the littoral fringe to deep-sea waters. This high diversity makes them a unique group producing rich assemblages of species. Smaller crustaceans constitute the dominant component of marine zooplankton, while the larger groups are important human sources of protein.

A wealth of literature exists on decapod crustaceans (see review by Kinsley, 1981). African crustacean fauna has, however, received little attention and there are very few records. The Phylum Crustacea contains six classes (Figure 7.6): Branchiopoda, Thecostraca, Malacostraca, Ostracoda, Cephalocarida and Remipedia. The last two classes include very few and poorly known species that will not be considered in this review.

Class Branchiopoda: This class is composed of freshwater organisms mainly, with more than 900 species described so far and divided into four orders. The only true marine representatives are planktonic and belong to the order Cladocera. The order Anacostraca includes brine shrimps of the genus *Artemia*, which are highly used in aquaculture. The only record for this group in Mozambique is the brine shrimp (*Artemia* sp.), which inhabits hypersaline waters, coastal saltpans, inland and salt lakes (Le Vay, 2011).

Figure 7.6 – Durban dancing shrimp (*Rhynchocinetes durbanensis*) at Závora, Inhambane Province (Photo: Yara Tibiriçá)

The class Ostracoda comprises about 5000 species worldwide. These include very distinctive and small crustaceans (1-25 mm) in which the body is enclosed within a bivalve carapace, which may be simple or sculptured (Le Vay, 2011). Most are benthic, living on or burrowing in the substrate, although some are planktonic. Over 100 species have been described from the intertidal areas of Inhaca Island, Mozambique (Olafsson & Ndaro, 1997).

The Thecostraca (often called Maxillopoda) belong to a very diversified group of organisms best represented by Coppepoda and Cirripedia. The Mystocarida and Branchiura (with more than 150 species) also integrate this group. The most commonly reported Maxillopodes in Mozambique are *Parelepas palinuri* (Barnard, 1924), *Conchoderma auritum* (Linnaeus, 1767), T*emnaspis* *amygdalum* (Aurivillius, 1894), *Chtamalus dentatus* (Krauss, 1848), *Tetraclita squamosa* (Brugueire, 1789), *Balanus amphitrite* (Darwin, 1854) (Jones, 1997; Litulo, 2007).

The most dominant and well-studied group of crustaceans are the Malacostraca with over 25000 species worldwide. Here a very high diversity of organisms can be found in the orders Amphipoda and Isopoda with 7000 and 5000 species. Species like the coconut crab *Birgus latro* (Linnaeus, 1767), the skunk cleaner shrimp (*Lysmata amboinensis* (De Mann, 1888), *Periclimenes nonodophila* (Berggren, 1994), *Tuleacaris sarec* (Berggren, 1994) and *Naushonia lactoalbida* (Berggren, 1992) occur in marine protected areas and reserves in Mozambique (Berggren, 1992, 1994). Their benthic habitats range from the eulittoral to shallow sublittoral areas (Kensley, 1981).

7.2.7. Whales and Dolphins

The widely distributed humpback whale (*Megaptera novaeangliae*) can be separated into four genetically distinct subpopulations in the Western Indian Ocean (WIO). Animals sighted along Mozambican continental waters (Figure 7.7) belong to the East African Coast genetic sub-unit (C1; waters from South Africa to Kenya). This is the second largest subpopulation in the region and may consist of more than 6,000 animals (Best *et al*., 1998).

Figure 7.7 – Humpback whale (*Megaptera novaeangliae*) at Závora, Inhambane Province (Photo: Yara Tibiriçá)

Additionally, there are seven other baleen whales known to occur in the Mozambican Channel, however only the Southern right (*Eubalaena australis*) and Minke whale (*Balaenoptera* *acutorostrata*) are considered as migratory (Table 7.2). The status and distribution of the other species is not well documented, especially for blue whales (Branch *et al*., 2007). Of the toothed whales, nine species occur in the Mozambican Channel (Kiszka *et al*., 2007; Table 7.2).

Four species of dolphins are resident in coastal waters, Indo-Pacific humpback (*Sousa chinensis*), Indo-Pacific bottlenose (*Tursiops aduncus*), spinner (*Stenella longirostris*) and spotted dolphin (*Stenella attenuata*). These species are vulnerable to human activities due to their use of coastal habitats, where they are at risk of by-catch in coastal artisanal fisheries and gill net entanglement (Kiszka *et al*., 2008). Six other species of dolphin occur in the Mozambican Channel; however their distribution and status is not well known (Karczmarski *et al*., 2000; Kiszka *et al*., 2007; Table 7.2).

Knowledge of occurrence, abundance and distribution of cetaceans (26 spp.) within continental waters and the Mozambican Channel is very limited (Kizska *et al*., 2008; Peddemors, 1999). All species are likely to be at risk of temporary or permanent auditory trauma when exposed to seismic survey activities occurring in northern waters (Anadarko, 2007).

Table 7.2 – Cetacean species occurring in Mozambican waters.

Dolphins	Baleen whales	Toothed whales
Common dolphin (*Delphinus delphis*)	Southern right (*Eubalaena australis)*	Pygmy sperm whale (*Kogia breviceps*)
Risso's dolphin (*Grampus griseus*)	Blue whale (*Balaenoptera musculus*)	Dwarf sperm whale (*Kogia simus*)
Rough-toothed dolphin (*Steno bredanesis)*	Fin Whale (*Balaenoptera physalus*)	True sperm whale (*Physeter macrocephalus*)
Fraser's dolphin (*Lagenodelphis hosei*)	Sei Whale (*Balaenoptera borealis*)	Great killer whale (*Orcinus Orca*)
Striped dolphin (*Stenella coeruleoalba*)	Gray Whale (*Eschrichtius robustus*)	Melon headed (*Peponocephalus electra*)
Indo-Pacific humpback (*Sousa chinensis*),	Bryde's Whale (*Balaenoptera edeni*)	False killer (*Pseudorca crassidens)*
Indo-Pacific bottlenose dolphin (*Tursiops aduncus)*	Minke whale (*Balaenoptera acutorostrata*)	Short-finned pilot (*Globicephala macrorhynchus*)
Common Bottlenose dolphin *(Tursiops truncatus)*		Pygmy killer whale (*Feresa attenuata*)
Spinner Dolphin (*Stenella longirostris*)		Dense beaked whale (*Mesoplodon denirostris*)
Spotted dolphin (*Stenella attenuata*)		

7.2.8. Marine Turtles

Five species of marine turtles occur in Mozambique, the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochleys coriacea*), hawksbill (*Eretmochelys imbricata*), and olive ridley (*Lepidochelys olivacea*). The Olive ridley turtle is the only species confined to the northern region and the other four have been observed along the entire coast (Fernandes *et al*., 2014; Hughes, 1974; Louro & Fernandes, 2013; Louro *et al*., 2012; Pereira *et al*., 2009; 2010b; Videira *et al*., 2008, 2011). Loggerhead (Figure 7.8) and leatherback turtles are known to nest from Ponta do Ouro to Bazaruto. The green and hawksbill turtles nest from Bazaruto to northern Mozambique and the olive ridley turtle nests exclusively in the north (Fernandes *et al*., 2014; Louro & Fernandes, 2013; Louro *et al*., 2012; Pereira *et al*., 2009; 2010b; Videira *et al*., 2008; 2011).

Figure 7.8 – Loggerhead turtle (*Caretta caretta*) at Ponta do Ouro, Maputo Province (Photo: Raquel Fernandes)

Recent monitoring programs cover only 8 to 9 % of 1,200 km of potential marine turtle nesting habitat (Fernandes *et al*. 2014; Pereira *et al*. 2010; Table 7.3). The majority of nesting activity is reported from the Ponta do Ouro Marine Partial Reserve (POPMR) and Vamizi and Rongui Islands. In the 20013/14 season a total of 1,073 nests were recorded, of which 91% were from the POMPR, 6% from Vamizi and Rongui Islands and the remaining from Inhambane and Bilene. The dominant species were the loggerhead (910 nests), leatherback (84 nests) and green turtle (64 nests).

Table 7.3 – Period covered by marine turtle monitoring programs and overall percentage of area covered

Program	**1988-94**	**1994-96**	**1996-98**	**1998-01**	**2001-04**	**2004-05**	**2005-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**
Vamizi and Rongui islands									■	■	■	■	■	■
Quirimbas National Park									■		■		■	
Primeiras and Segundas Islands National Park							■	■		■	■			
Bazaruto Archipelago National Park				■	■	■	■	■	■	■	■	■	■	■
Cabo de São Sebastião							■	■			■	■	■	
Tofo (Barra - Praia Rocha)										■	■			
Závora										■	■			
Zavala										■	■	■	■	
Bilene								■	■	■	■			
Xai-Xai								■	■	■	■	■	■	■
Manhiça								■	■	■	■	■	■	
Macaneta								■	■	■	■			
Inhaca Island and Portuguese Island	■	■	■	■	■	■	■	■	■	■	■			
P. Chemucane to Santa Maria								■		■	■	■	■	■
P. Dobela to P. Chemucane			■			■		■	■	■	■	■	■	■
P. Malongane to P. Dobela		■	■	■	■	■	■	■	■	■	■	■	■	■
P.Ouro (Boarder) to P. Malongane		■						■	■	■	■	■	■	■
% of covered area	**1**	**4**	**6**	**10**	**8**	**10**	**9**	**17**	**16**	**20**	**25**	**18**	**18**	**8**

Although protected by national law, several cases of marine turtle mortality (targeted poaching, bycatch, and entanglement) have been reported. These reports are likely to only reflect a small portion of the mortality events. Government authorities neglect enforcement of laws designed to protect turtles, which places a strong threat to Mozambique's marine turtle populations and hampers conservation efforts (Brito, 2012; Fernandes *et al.*, 2014; Louro *et al.*, 2006).

7.3. FLORA

Here, plants include all photosynthetic prokaryotic and eukaryotic organisms. As primary producers, plants are the major components of many communities and ecosystems. The survival of plants is essential to maintaining the health of those ecosystems. To humans, plants are also important in numerous direct ways. They are for example a source of food, construction material, and chemicals.

7.3.1. Flora of the Western Indian Ocean

The marine macro taxa of flora occurring in the intertidal and shallonw seas of the WIO comprise an estimated 10,992 species. While mangroves and seagrasses form entire habitats, of high importance both ecologically and economically, these groups are represented only by few species. Beentje & Bandeira (2007) reported the occurrence of 8 species of mangrove trees. Richmond (2011) lists about 1,011 species of algae. Ngusaru (2011) reported that there are least 10 seagrass species with common occurrence in the WIO region, where the most common genera include: *Thalassia*, *Halodule*, *Syringodium*, *Halophyla*, *Cymodocea* and *Thalassodendron*. Seagrasses grow mainly in sandy substrates and occur generally from the eulittoral to depths of about 20 m.

7.3.2. Coastal Vegetation

Conventionally, the Mozambique coastal zone traverses two phytogeographical regions (White, 1983): the Zanzibar - Inhambane regional mosaic extending from the mouth of the Limpopo River (Latitude 25° S) to the Rovuma River (and northwards); and the Tongaland - Pondoland Regional Mosaic (TPRM) extending southwards from the Limpopo River. Although they differ floristically, both comprise a matrix of forest, wooded grassland, secondary grassland, edaphic grassland and mangrove communities (Massinga & Hatton, 1997). The TPRM was not recognised as a true centre of endemism but rather as a transitional zone with many linking elements. van Wyk (1994) proposed an Indian Ocean coastal centre of plant diversity, the Maputaland-Pondoland Region (MPR), with two clear foci of high endemism in the region: the Maputaland Centre and the Pondoland Centre. The Maputaland Centre is defined as the part of southern Mozambique and north-eastern Kwazulu-Natal bounded in the north by the Limpopo River, in the west by the western foothills of the Libombos, in the south by the Sta Lucia estuary and in the east by the Indian Ocean (Hatton, 1995). The Ponta do Ouro - Xai-Xai coastline is almost entirely situated in this centre of endemism, emphasising the high biodiversity value of this stretch of coast (Massinga & Hatton, 1997).

Figure 7.9 – Coastal dune forest at Dune de Dovela, Inharrime, Inhambane Province (Photo: Jess Williams)

Due to the long history of anthropogenic land use along the coast, much of the landscape is changed and comprise a mosaic of agricultural fields, interspersed by exotic tree species, such as coconut (*Cocos nucifera*), cashew (*Anacardium occidentale*) and mango (*Mangifera indica*). A more or less continuous cover of dune forest occurs between Ponta do Ouro in the south and Bazaruto in the north (Figure 7.9). Behind the dune forests the vegetation is characterised by grasslands, wooded grassland, swamp forests (in the south), and woodland. Between Maputo and Inhambane much of the indigenous coastal vegetation behind the dunes has been cleared for agriculture (Massinga & Hatton, 1997).

7.3.3. Macroalgae

Algae belong to the plant kingdom and comprise a very diverse group of organisms. They are classified in seven divisions including both prokaryotes and eukaryotes. Algae are very important in marine ecosystems (Oliveira *et al*., 2005; South & Whittick, 1987). The prokaryotes division includes Cyanophyta and Prochlorophycota. Eukaryotes include Rhodophycota, Chromophycota, Euglenophycota and Chlorophycota. In this review only three groups will be described in detail: Rhodophyta, Phaeophyta and Chlorophyta usually called macroalgae or seaweeds (Anderson & Bolton, 2005).

According to de Clerck & Coppejans (2011), seaweeds are macroscopic plants abundant in the littoral region, as well as the sublittoral. Together with seagrasses, seaweeds are the major primary producers in coastal areas. Dense beds of seaweeds can be more productive than an equivalent area of the richest agricultural lands. Bolton *et al*. (unpublished) reported that they form the basis of many food webs consequently vital for the life in the sea, forming the diet of many and different organisms. Seaweeds are useful organisms for studying diversity patterns and planning the conservation and sustainable use of inshore marine resources, and are also useful as indicators of climate change.

Several seaweeds, such as *Caulerpa* (sea grapes), have been collected in the wild for many centuries and used for human or cattle food, or as fertilizer. Other species are collected or cultivated and used in the food industry.

7.3.4. Seaweed Farming

Humans have collected seaweeds for thousands of years for many purposes. More recently, a variety of seaweed species have been used to provide alginates (additives used to thicken food). At present, several red algae species including genera *Gelidium*, *Eucheuma* and *Gracilaria* are collected in the tropics, while numerous brown species are harvested in the cooler regions of the world. Seaweeds are also used for local cooking in Madagascar. In Zanzibar, wild *Eucheuma* was exported to Europe until stocks became depleted. Then in 1989 farming of *Eucheuma cotonni* and *E*. *denticulatum* began (Sinclair & Richmond, 2011). Farming of *Eucheuma* is also done in Mozambique in Cabo-Delgado and Nampula provinces.

8. MARINE PROTECTED AREAS

8.1. TYPES OF MPAs

As described in Section 4.3.2., MPAs in Mozambique have traditionally been designated under essentially three different legislations: the Land Law, The Forest and Wildlife Law and the Regulation for General Maritime Fisheries. There are four "types" of MPAs in Mozambique:

(i) Partial Reserves (e.g. Ponta do Ouro Partial Marine Reserve);
(ii) National Parks (e.g. Bazaruto Archipelago National Park and the Quirimbas National Park);
(iii) Environmental Protection Areas (Primeiras and Segundas Environmental Protection Area);
(iv) Total Protection Zones (Cabo de São Sebastião Total Protection Zone).

The restrictions and functional conditions of each "type" are somewhat arbitrary, which prompted a thorough revision of the system. As explained before in section 4.1.2, according to the new Biodiversity Conservation Law, conservation areas in Mozambique should be classified as Total Conservation Areas, where the extraction of natural resources is not allowed [the relevant categories to the marine environment are: Integral Nature Reserve; National Park (Figure 8.1); and Cultural and Natural Monument] and Sustainable Use Conservation Areas where a certain level of natural resources extraction is allowed but subject to a Management Plan (the categories relevant to the marine environment are: Special Reserve; Environmental Protection Area; Community Conservation Area; Sanctuary; and Municipal Ecological Park).

The terminology and classification of current MPAs will be updated according to the new system put in place by the recently approved Biodiversity Conservation Law (Law 16/2014 of 20 June).

Community managed marine areas, locally known as community sanctuaries have only recently been formally recognized by the Biodiversity Law. These have been established as partnerships between local communities through CCPs, and private sector, NGOs or conservation authorities. The ones in Vamizi and Sencar, Ibo and Matemo islands (at the Quirimbas National Park) have proven successful either in the form of completely closed areas, thus seeding surrounding areas, or as temporarily closed areas to allow the replenishment of local stocks. Some of the challenges associated with these initiatives include continuous training, supervision and mentoring/encouragement. There is great potential to replicate this model along the coast, but local conditions must be accounted for beforehand.

Figure 8.1 – Mangroves and estuary, Quirimbas National Park, Cabo Delgado Province (Photo: Marcos Pereira)

8.2. EXISTING AND PROPOSED MPAs

Currently, MPAs cover a total area of about 20,462 km^2 of which 8,633 km^2 encompass marine ecosystems (Table 8.1).

The first MPA of Mozambique and perhaps the WIO region was designated in 1965 to protect the coral reefs at Inhaca and Portuguese islands. It covered a 1 km^2 area (Rocliffe *et al.*, 2014). In 2009, this MPA was incorporated into the Ponta do Ouro Partial Marine Reserve (POPMR) which is currently the only fully marine MPA, as it extends from the high-tide mark to three nautical miles offshore.

In 1971, Bazaruto National Park was the first National Park of Mozambique. It comprised the three southernmost islands Banguè, Magaruque and Benguérua. Santa Carolina was established as a zone of special concern. The protected area was then extended in 2002, to include the remaining islands of the archipelago (ie. Bazaruto and Santa Carolina), and was renamed as the Bazaruto Archipelago National Park, with a total area of 1,430 km^2.

Throughout the years, there have been several proposals for the designation of MPAs in Mozambique (Balidy *et al.*, 2008; Paula, 2008; Pereira, 2002; Sitoe *et al.*, 1994; Tinley, 1971). These include protected areas at Benguelene Island. (Incomáti estuary), Bilene, Inhambane (Tofo and Paindane), Nacala (Nacala bay and Relanzapo), Mossuril, Mozambique Island and Lumbo

(Cobras Island and Goa Island), and Palma. Bilene and Tofo are the only areas where documentation and formal proposals were submitted (or are currently underway) to the Council of Ministers.

Table 8.1 – Existing MPAs in Mozambique.

MPA	Year	Total area (km^2)	Marine ecosystems (km^2)
Quirimbas National Park	2002	7,506	1,430
Primeiras and Segundas Environmental Protection Area	2012	10,409	5,000
Cabo de São Sebastião Total Protection Zone	2003	300	80
Bazaruto Archipelago National Park[1]	1971	1,430	1,295
Ponta do Ouro Partial Marine Reserve[2]	2009	678	678
Total		20,462	8,633

[1]Extended in 2002; [2] includes the marine reserves at Inhaca and Portuguese Islands, designated in 1965.

8.3. MANAGEMENT AND EFFECTIVENESS OF MPAs

In Mozambique, conservation areas in general and MPAs in particular, are under-staffed and poorly equipped (Soto, 2009). Also lacking for the majority of the MPAs are management procedures and tools (including management, monitoring and research plans) as well as adequate science to support them (Pereira & Fernandes, 2014b).

Pereira *et al*. (2010b) analysed the effectiveness and representativeness of the MPA network in Mozambique, focusing on two indicators: a “static” resource with high socio-economic importance (i.e. coral reefs) and a highly migratory and endangered species group (marine turtles). In general they concluded that the network did not effectively represent or protect coral reefs in Mozambique, nor marine turtles. The nesting grounds of loggerhead and leatherback turtles for instance were not afforded any significant protection. More protection of marine resources resulted from the designation of the Ponta do Ouro Partial Marine Reserve and the Primeiras and Segundas Environmental Protection Area in 2009 and 2012, respectively. However, other ecosystems and species such as seagrass beds, mangroves, the dugong, mantas rays and the whale shark are still poorly represented in the current MPA network in Mozambique.

9. FISHERIES

9.1. PRODUCTION BY FISHERIES (ARTISANAL, SEMI-INDUSTRIAL AND INDUSTRIAL) AND AQUACULTURE

Mozambique has three main types of fisheries: industrial, semi-industrial and artisanal. Analysing the total production of these sectors over the past eight years (Figure 9.1) shows an overall growth from 87,000 t in 2005 to 213,436 t in 2012. However, the annual industrial fishing production declined from 10,643 t in 2005 to 6,520 t in 2012, and contributed to only 3% to the total production. Meanwhile, artisanal fisheries have more than tripled during the same period. In 2012, artisanal landings reached 186,214 t, representing 87% of the total production and a revenue of 459 million USD (MIPE, 2013).

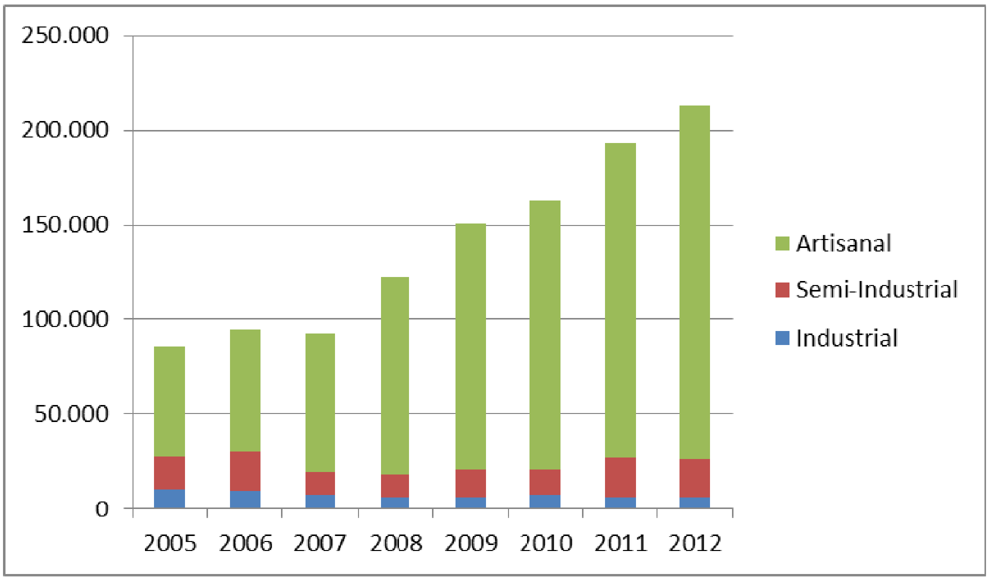

Figure 9.1 – Evolution of the production of the different fisheries sectors in tons from 2005 to 2012

The significant increase in artisanal production is the result of several improvements the government made in this sector and the increase of demand for fish caused by a growing population. In 2012 the population of Mozambique was estimated at 22 million. It is projected to reach 31.34 million by 2030 (INE, 2012; USAID, 2010).

Semi-industrial fisheries contributed to 9% of landings in 2012, and production ranged between a minimum of 11,513 t in 2008, and a maximum of 21,101 t in 2006. Industrial and semi-industrial production combined generated a revenue of 66 million USD in 2012 (MIPE, 2013).

Aquaculture in general is emerging and growing significantly. Freshwater fish production has grown from 3 t in 2005 to 409 t in 2012. Unfortunately the prawn aquaculture has decreased from 1067 t in 2005 to 39 t in 2012. An outbreak of White Spot Disease caused by the White Spot Syndrome Virus affected the production in the entire coast in 2012 (MIPE, 2013; RAF, 2013).

9.2. CATCH INFORMATION (SPECIES, VOLUMES)

9.2.1. Artisanal Fishery

Artisanal fisheries consist of individuals or small groups of fishermen, with or without boats, operating subsistence or a small-scale commercial fishing in coastal areas using traditional techniques. The fishing boats are less than 10 m long. Most of them use oars or sails. Some have motors not exceeding 100-horse power. The most common boats are dugout canoes, “chata”, and dhows. The gears, operated manually, are beach seine nets, gillnets, hand lines, fence traps, and baited traps (Figure 9.2). This sector includes also harvesters of intertidal invertebrates and other marine resources and divers who use harpoons. Preservation of catches is limited to the use of ice. Landings and commercialization are done in informal ways at fishing centres along the coast of Mozambique (FAO, 2007; General Regulation of Marine Fisheries, 1996; IDPPE, 2013).

Figure 9.2 – Example of a fish trap at Quirimbas, Cabo Delgado Province (Photo: Jacques Rousselot)

The last census of artisanal fisheries done by IDPPE in 2012 registered 792 marine fishing centres, 135,529 fishermen with boats and 144,511 without boats. A high number of women are involved in the harvesting, processing, and selling of the marine products. The provinces with more concentration of fishing centres were Zambezia, Nampula and Cabo Delgado. The total number of fishing boats and canoes was approximately 15,000, of which only 3% were equipped with engines. There were more than 43,000 gears used in marine fisheries (Table 9.1) (IDPPE, 2013). The total number of gears licensed by the authorities in 2012 was 11,182. Nampula, Maputo and Sofala are the provinces with most licenses (MIPE, 2013). The most used gears were gillnet (34%), hand lines (29%) and seine nets (21%) and they are more abundant in Nampula, Zambezia and Sofala Provinces (IDPPE, 2013). In a probability-based survey done in 19% of the total fishing centres, Afonso (2006) estimated that the beach seine generates 73% of the captures, gillnet 15%, and hand line 13%.

Artisanal fisheries take place along the entire coastline in a wide diversity of habitats. Around 1500 species of fish are present in the Mozambican Sea, of which 400 are of direct commercial importance (Fischer *et al*., 1990; Lopes & Pinto, 2001). However, artisanal fisheries are confined to near coastal areas. In tropical coastal waters catches are usually composed by a large number of species but in small quantities.

Table 9.1 – Types of fishing gear per province (numbers of gear per Province)

Province	Beach seine	Gillnet	Longline	Seine	Chilimila	Traps	Hand line	Cast net	Spear	Total
Niassa								0	0	
Cabo Delgado	684	1,358	24	108	0	440	3,017	10	776	6,417
Nampula	3,699	2,115	21	139	4	208	4,259	24	497	10,966
Zambezia	2,372	3,268	496	56	1	760	2,033	531	86	9,603
Sofala	1,320	3,457	114	57	1	597	1,353	124	455	7,478
Inhambane	516	1,214	8	20	0	276	1,012	203	164	3,413
Gaza	183	1,468	3	0	0	242	581	124	366	2,967
Maputo	183	1,450	4	0	7	47	167	17	21	1,896
Maputo (city)	85	487	8	0	0	6	261	0	2	849
Total	9,042	14,817	678	380	13	2,576	12,683	1,033	2,367	4,3589
%	20.7	34.0	1.6	0.9	0.0	5.9	29.1	2.4	5.4	100

In estuarine areas the species diversity is even greater since there are species that use the habitat permanently and those that use it occasionally for feeding, spawning or as a nursery ground (King, 1995). Estuaries and adjacent areas are dominated by small pelagic and demersal fish and crustaceans. At coastal islands fishing activities focus on demersal species on rocky substrates and some large pelagics, but also small coastal pelagics and lobsters. On rocky coastal seafloor the targets are particularly demersal fish, cephalopods, molluscs, small pelagics, tunas and rock lobster (MIPE, 2010; NORAD, 2013).

In 1997, the IIP implemented a Statistical Program to collect data on artisanal fisheries of the entire coast. Sampling was done using a stratified random method to acquire information on catches, species composition, effort and catch per unit effort of the different gears from artisanal fisheries. Overall, the main products of the artisanal fisheries were fish (87%), prawn (3%) and squid (2%; Figure 9.3). The catch composition was different among fishing gears and varied depending on the techniques, location, seasons, and time of the day that they were normally used. In general the marine fish captured were demersal and pelagic species including grouper, snapper, emperor and sea bream and also some tuna species, swordfish and sharks. The crustaceans were penaeid prawns, crayfish, lobsters and mangrove crab. Cephalopods and molluscs included squid and octopus (FAO, 2007).

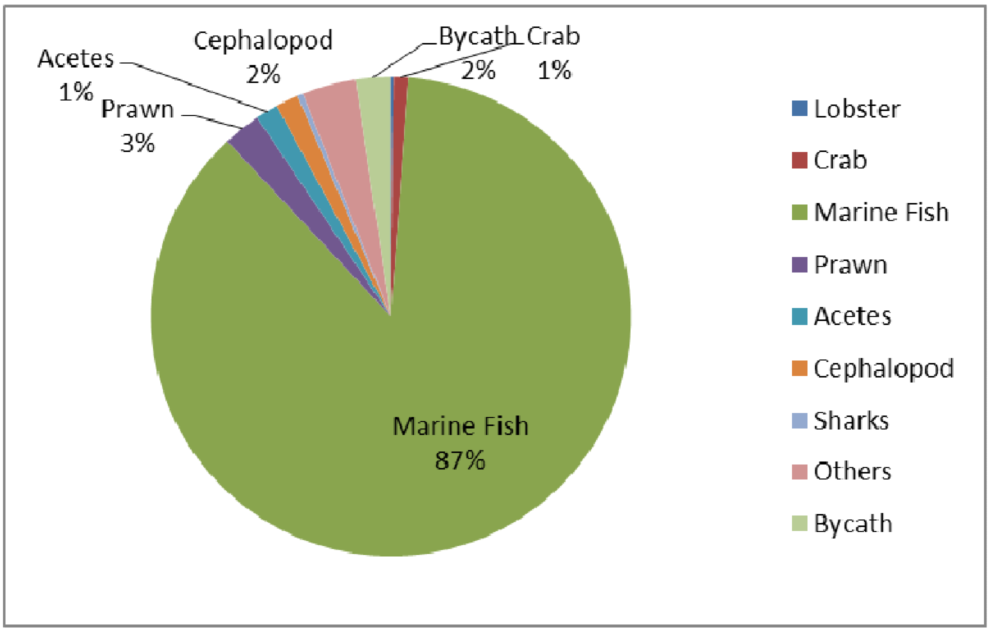

Figure 9.3 – Artisanal production per resource in 2012

A recent study by Pereira *et al*. (2013) on the socio-economic benefits of the artisanal tuna fishery, concluded that despite the lack of data on tuna stocks, and given the current number of fishers involved and the existing fishing technology, the inshore stocks are sufficient to sustain an artisanal tuna industry. However, it was noted that tuna is not part of the general "dietary culture" of Mozambicans and there is a strong need to develop a marketing and education strategy in order to develop the domestic market. Pereira *et al*. (2013), also highlighted the need to develop the overall fishing and processing technology in the artisanal sub-sector of the tuna fishery, not only regarding the fishing gear used, but immediate processing on board (bleeding and/or gutting) and preservation. Implications of such development include education programmes and subsidies to enable local artisanal fisheries to develop their capacity. Furthermore, inland processing, storage and distribution facilities and infrastructures are largely lacking.

9.2.2. Industrial Fishery

Industrial fisheries use vessels that are over 20 meters in length equipped with freezing systems and cold facilities on board to preserve the catch. They can operate continuously and remain up to 30 days at sea and most of the catch is processed and packaged on board. The main gears are longline, gillnet, and trawl that can operate at depths between 5 and 70 meters (FAO, 2007).

Quelimane and Beira are the major ports for the industrial fleet that operates essentially on the Sofala Bank. This comprises an extensive area, representing 65% of the continental shelf of Mozambique. These fishing grounds are usually very rich in nutrients and very productive areas. They support important fisheries of crustaceans and fish. At Sofala Bank there is the largest proportion of marine resources of the country, mainly penaeid prawns. Other important banks are the São Lázaro Bank to the north and the Boa Paz Bank to the south where pelagic and demersal fish, cephalopods and deep-water crustaceans are found (NORAD, 2013).

Industrial fishing is dominated by joint venture companies between the government and foreign companies mainly from Japan and Spain. The total industrial fleet comprises 207 vessels, 129 of which are used in the tuna fisheries. In 2012, the licensed and operating fleet was composed of 57 vessels targeting penaeid prawns, 16 pursuing deep-water shrimp, and 63 fishing tuna (MIPE, 2013). Except in the case of deep-water shrimp, the requests for licenses are decreasing due to the high operating costs and the overexploitation of resources.

The fishing industry employs approximately 1,550 fishermen, of which approximately 80% are Mozambicans (FAO, 2007). The principal industrial fisheries are penaeid prawns, deep water shrimp (gamba), tuna and line fish like swordfish and sharks, demersal fish captured with gillnets, and lobster and crab captured with fishing pots (Table 9.2).

Table 9.2 – Industrial production per resource from 2005 to 2012 (Tons)

	Production (tons)								
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2012(%)**
Lobster with fish pots	2	0	0	0	0	37	63	38	1
Crab with fish pots	1	0	0	14	41	168	20	2	0
Gamba	1,774	1,803	1,366	1,432	1,116	1,261	1,288	1,899	28
Demersal Fish with gillnet	0	0	0	38	193	454	117	469	7
Bycatch Deep Water	670	525	569	243	309	358	555	614	9
Total Deep Water	2,447	2,328	1,935	1,727	1,659	2,278	2,043	3,022	45
Demersal Fish with line	131	124	94	117	83	95	54	31	0
Prawn	6,787	6,070	5,813	4,626	4,801	4,806	4,017	2,005	30
Bycatch Shallow Water	1,278	1,138	320	307	147	437	660	1,243	18
Tuna	0	0	0	0	0	0	0	219	3
Others	0	0	0	0	0	0	0	54	1
Swordfish	0	0	0	0	0	0	0	111	2
Shark	0	0	0	0	0	0	0	54	1
Shallow water	8,196	7,332	6,227	5,050	5,031	5,338	4,731	3,717	55
Total	**10,643**	**9,660**	**8,162**	**6,777**	**6,690**	**7,616**	**6,774**	**6,739**	**100**

9.2.3. Penaeids and Deep-water Shrimp (Gamba)

At Sofala Bank, industrial fishing targets penaeid prawn species, especially the Indian white prawn (*Fenneropenaeus indicus*) and brown prawn (*Metapenaeus monoceros*). This has been the most studied fishery since the 1980's. Unfortunately this resource shows signs of overexploitation. The production decreased significantly from 2005 to 2012 with captures falling from 6,787 tons to 2,005 tons (Figure 9.4). In 2012 the prawn industry only represented 30% of the total catches of the industrial fisheries whereas in 2005 their contribution was 64% (MIPE, 2013).

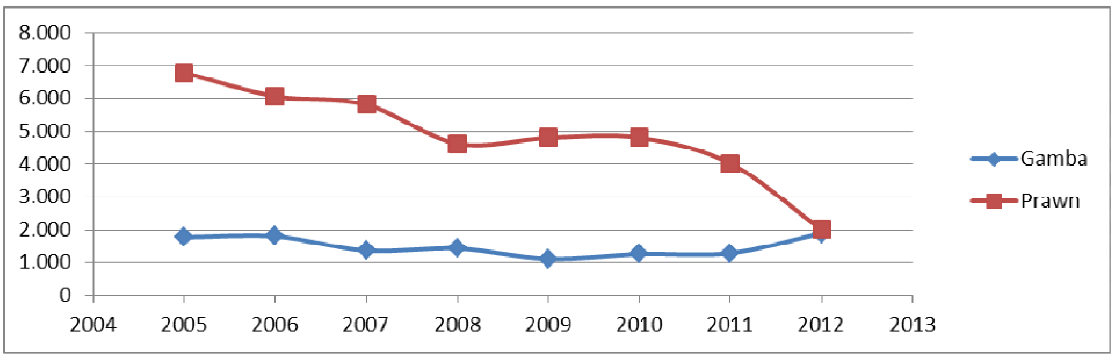

Figure 9.4 – Evolution of catches of penaeid prawns and gamba in tons from 2005 to 2012

Gammelsrod (1992) identified the Cahora Bassa dam on the Zambezi River as the cause for the reduction in the abundance of prawns on Sofala Bank. Other factors leading this fishery to a recession include the increasing cost of fuel, the economic crisis in export markets, as well as the reduction in income due to a high fishing effort needed. Actually, the industrial prawn trawl fishery at the Sofala Bank is closed to new vessels and is subject to a seasonal closing lasting about 3 to 6 months (MIPE, 2010; Palha de Sousa, 2012).

The other important resource exploited offshore is the deep-water shrimp or "gamba" using bottom trawl nets in water depths of 200 to 700 m. The main species captured are the pink prawn (*Haliporoides triarthrus*) and the red prawn (*Aristaeomorpha foliacea*). Several studies suggest a large stock of deep-water shrimp that may tolerate increased catches. IIP recommends a catch of 3,000 t per year, but only 1,899 t were caught in 2012 (Table 9.2).

The high production costs and the lack of specialized vessels, challenge the economic viability of this fishery. Some measures such as adding value to the gamba and revised license taxes are intended to promote the development of this fishery (MIPE, 2013).

Shallow penaeid prawns and deep shrimp trawlers have a significant by-catch. Up to 70% to 80% is composed of lobster, crabs, crayfish, cephalopods, and demersal fish including sparids, groupers and snappers (Table 9.3).

Table 9.3 –Specific composition of bycatch in tons.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Lobster	1	8	8	4	13	61	141	154
Crab	158	107	125	59	54	40	62	48
Crayfish	149	94	153	100	115	94	145	130
Fish	197	202	145	38	64	74	104	167
Cephalopod	165	114	138	42	63	89	103	115
Total	**670**	**525**	**569**	**243**	**309**	**358**	**555**	**614**

Most of the production is exported to other countries mainly to Japan and the European Union. Combined, the penaeid prawns and deep-water shrimp fisheries in Mozambique represent the most important fisheries in terms of the value of catches and earnings from export trade. In 2012 the production of penaeid prawns generated more than 20 million USD and deep-water shrimp generated more than 9 million USD (MIPE, 2013).

9.2.4. Tuna

The tuna fleet is mainly foreign (China, European Union, Japan and Seychelles) on the basis of fishing agreements. Fishing gear includes longline and purse seine in the EEZ of Mozambique to follow migrating tuna. The fishing potential in Mozambique is estimated at 37,000 t per year. The production in 2012 dropped to 1,407 t. The average production over the past years was almost 5,000 t (Table 9.4). The most important species were yellowfin (*Thunnus albacares*; 63%), skipjack (*Katsuwonus pelamis*; 18%), big eye (*T. obesus*; 11%), and albacore (*T. alalunga*; 8% - Figure 9.5; MIPE, 2013).

Table 9.4 – Tuna production by foreign fleet in tons from 2005 to 2012

	2005	2006	2007	2008	2009	2010	2011	2012
Yellowfin	2,929	4,667	3,402	3,192	902	1,613	2,678	890
Bigeye	209	397	372	493	184	274	512	154
Albacore	267	667	581	920	106	248	747	114
Skipjack	1,305	167	791	3,405	2,508	2,346	1,796	249
Bluefin	1	3	0	0	0	0	0	0
Total	**4,711**	**5,901**	**5,146**	**8,010**	**3,700**	**4,481**	**5,733**	**1,407**

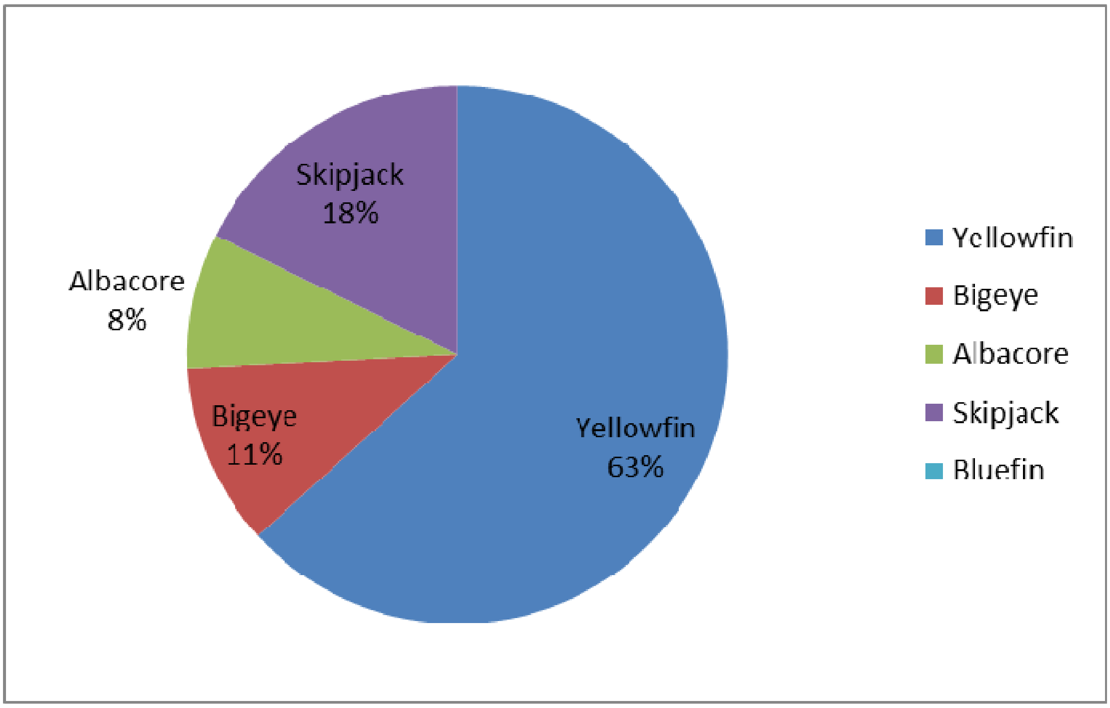

Figure 9.5 – Species composition of the tuna fishery in 2012

Catches are stored on-board and discharged in foreign ports especially in Seychelles, Kenya, Madagascar, Mauritius, and South Africa. This fishery is managed by the Indian Ocean Tuna

Commission (IOTC) to which Mozambique belongs since 2012 (ADNAP, 2013).With the relatively recent acquisition of 24 fishing vessels there are great expectations that Mozambique may develop its own tuna fishing industry. In 2013 the Ematum (Empresa Moçambicana de Atum, SA, the Mozambique Tuna Company) was founded. It is owned by both public and private capital. The Ematum will operate the longliners. Ematum expects to have an average catch of 3 t per day per boat and 150 fishing days on average per year to generate an annual production of 9,000 t (Portal do Governo, 2013).

9.2.5. Semi-industrial Fishery

The semi-industrial fishery uses motorized vessels 10 to 20 m in length that operate in coastal waters where they can stay up to a week. Some vessels have freezing systems. Others use ice on-board to preserve the catch (FAO, 2007).

The main ports of the semi-industrial fishery are Angoche, Beira and Maputo. This fishery is focused on the prawn of Sofala Bank. In 2012 there were 43 licensed trawlers. For the demersal long line fishery, in the southern coast there were 43 licensed vessels (MIPE, 2013). Mozambican nationals usually own these vessels. The products are processed onshore and sold on regional, domestic, South African, and European markets.

9.2.6. Aquaculture

The great diversity of ecosystems and the availability of suitable native species for farming are some of the excellent conditions that support the development of aquaculture in Mozambique. There are potentially 33,000 ha of land suitable for coastal aquaculture.

Marine aquaculture focuses mainly on penaeid prawn farming given its economic importance for export markets. The main marine species farmed in Mozambique include black tiger prawn (*Penaeus monodon*), Indian white prawn (*Feneropenaeus indicus*) and kuruma prawn (*P. japonicus*). Normally they are produced in ponds located close to mangroves on banks of estuaries.

Other important aquaculture species are crustaceans, including mud crab (*Scylla serrata*), bivalves like oysters (*Sacrostrea cucullata)*, clams (*Meretrix meretrix*), and mussels (*Perna perna* and *Modiolus philippinarum*). In the coastal areas of Cabo Delgado and Nampula Provinces, local communities are involved in seaweed farming (*Eucheuma* and *Kappaphycus* spp) in a system of poles installed in shallow areas close to the shore (FAO, 2007).

9.3. LOCAL SEAFOOD MARKET

The World Health Organization (WHO) recommends a *per capita* fish consumption of 18 kg. The consumption per habitant per year in Mozambique has risen from 4.2 kg in 2005 to 10.4 kg in 2012 (MIPE, 2013). Demand for fish products in the country is much higher than the domestic industry can supply. It is expected that demand for seafood will grow substantially over the next 25 years, and consequently there is a need to increase supply (FAO, 2007; USAID, 2010).

Typically, the artisanal fishery products are consumed locally mainly in the coastal area. Products of the semi-industrial fishery are also consumed locally, some of it is exported. Products of industrial fishing are intended for export.

Artisanal fishing products are sold fresh (13.1%), frozen (3.5%) or preserved by sun-drying (21.2%), salting (38.8%) or smoking (15.4%; IDPPE, 2013). The semi-industrial fleet uses land-based fish processing plants and the industrial fishery processes and packages the catch on-board. There are 20 fish processing plants (16 approved for the EU market and three of which are linked to shrimp aquaculture enterprises).

In the artisanal fisheries the commercialization of the catch is done as soon as the boat arrives to the fishing centre. Normally the intermediaries are women called "vendedeiras" that buy the product from the fishermen and re-sell in local markets (Figure 9.6). The buyers and sellers can always bargain on the price. Fish are separated in commercial value categories. In the so-called first category there are, for example, the narrow-barred spanish mackerel (*Scomberomorus commerson*), groupers (*Epinephelus tauvina and E. rivulatus*) or jacks and trevallies (*Caranx* spp.); in second category fishes like grunts (*Pomadasys kaakan*), sillagos (*Sillago sihama*) and croakers (*Otolithes ruber*); and in the third category pike congers (*Muraenesox bagio*), kelee shad (*Hilsa kelee*) or spiny flatheads (*Platycephalus indicus*).

Normally the first quality and more valuable fish is sold fresh or frozen and transported to the main cities or even exported to South Africa. Prawns and lobster are also sold fresh to the major urban centres and for export. Fish of second category is sold mainly in local markets. Lack of cold storage facilities usually forces people to employ traditional processing methods of smoking and sun-drying mainly for second and third category fishes. Prices vary considerably by site, and they may increase two to three times in urban markets (FAO, 2007; Santana Afonso, 2006).

Figure 9.6 – "Vendedeiras" at Morrumbene, Inhambane Province (Photo: Rodrigo Santos)

New fish markets have been built over the last years. In 2012, 209 markets were operating. Zambezia is the province with the highest concentration of markets (41.1%; IDPPE, 2013). The cities of Maputo and Inhambane will soon have new fish markets.

9.4. SEAFOOD TRADE FLOWS

In general, the seafood foreign trade of Mozambique is characterized by exports of high-value products and imports of low-value fish (FAO, 2007).

Over the last years imports have grown significantly from 7,000 t in 2006 to more than 44,000 t in 2012. Exports of marine products on the other hand decreased from almost 13,000 t in 2005 to above 9,000 t in 2012 (Figure 9.7).

Almost all the imports consist of horse mackerel captured in Namibia. This product represents an important source of fish affordable to the population. It is imported with 0% importation duties. As for the exports, prawns are still the most important product even though they are declining. The total marine product exportation earnings were estimated at 52,275,000 USD. Prawn represented more than half of the value (MIPE, 2013). For the global national exports, the fisheries sector represents 4% (INE, 2013).

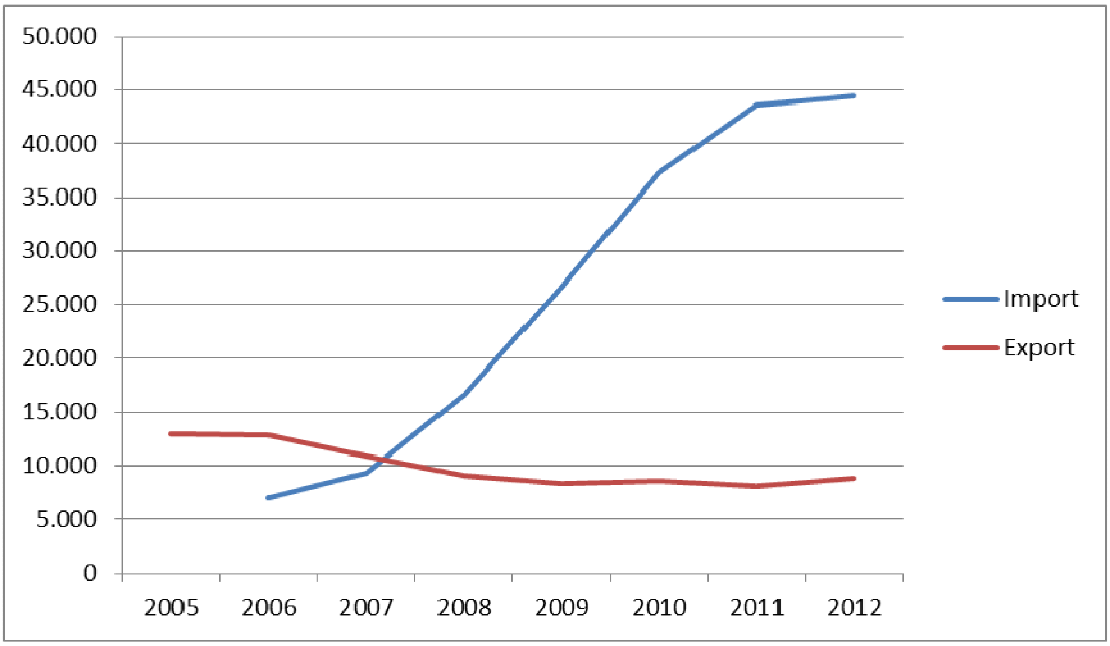

Figure 9.7 – Official statistics on import and export of seafood in tons from 2005 to 2012

During the 1980s and 1990s, the export of marine products represented one of the largest sources of foreign income and prawn accounted for up to 45% of overall exports (Blythe *et al.*, 2013). However, this percentage diminished as exports from other resource sectors have recently grown particularly the booming mining sector.

The most important destinations for the marine products are South Africa, Spain, Zimbabwe, Portugal and China. The economic crisis that occurred in international markets forced a reduction of the consumption of seafood products and caused reductions of Mozambican exports.

Marine and fresh water products for exportation are subject to quality control. Microbiological, sensory and chemical analysis of the products, water analysis and control of residues and heavy metals are done by National Institute of Fish Inspection (INIP) at five laboratories located in Maputo, Beira, Quelimane, Nacala, and Angoche. The Maputo laboratory was internationally accredited in 2012.

9.5. MANAGEMENT CAPACITY OF FISHERIES

The Ministry of Fisheries is responsible for establishing management measures on the basis of the legislation, statistical data, biological evidence and economic justification.

The industrial and semi-industrial fisheries are the most managed sectors. Fishing effort is adjusted each year depending on the information on the status of the stocks. The number of licenses authorized and attributed quotas based on the Total Allowable Catch (TAC) and Total Allowable Effort (TAE) for each fishery is assessed on an annual basis. Seasonal spawning and reproduction of fish are protected by fishing closures. The duration of closures can vary from year to year. To improve the selectivity of fishing gear a minimum mesh size is regulated and the use of TEDs is mandatory (FAO, 2007; Santana Afonso, 2006).

Figure 9.8 – Manta rays (Manta sp.) caught in fishing nets at Závora, Inhambane Province (Photo: Yara Tibiriçá)

Annual licenses are required for artisanal fisheries. The cost varies according to the target species, gear used, vessel type, and province. The only gear limitation is the control of the minimum mesh size, set at 2.5 cm, for seine nets. The other gears are not regulated. Mosquito nets and seine nets with bags made of mosquito netting were banned by the government because of their detrimental effects on larval and juvenile fish populations.

Artisanal fishing management measures are difficult to implement and monitor given the wide distribution of fishing areas and characteristics of the artisanal fisheries (Figure 9.8). Most of the gears are used for family subsistence and catches consist of a wide diversity of species with different biological characteristics. For these reasons the participation of the local fishery communities in the management of the fishery resources has been implemented, in order to ensure their sustainable exploitation and alleviate conflicts among fishers and between fishers and other stakeholders. This co-management between local communities and authorities actually defines measures such as closed seasons for beach seining in several regions and implements the monitoring of their compliance.

9.6. STATE OF LOCAL AND EXTERNAL ILLEGAL, UNREPORTED AND UNREGULATED FISHING

The extensive coastline and lack of infrastructures make Mozambique an easy target for Illegal, Unreported and Unregulated (IUU) fishing, particularly offshore. IUU fishing includes a wide range of illicit activities such as fishing without permission or out of season, harvesting prohibited species, using outlawed fishing gear, and non-reporting or under-reporting of catches (Lopes & Pinto, 2001). These actions contribute to unsustainable impacts on both target species and ecosystems, reducing productivity, biodiversity and ecosystem resilience (MRAG, 2005).

Most of the illegal activities reported in the artisanal fisheries sector are fishing during the closed season, using “mosquito” nets with a mesh smaller than the minimum permitted, and the capture of protected species.

In the industrial fisheries sector, foreign trawlers do most of the illegal activities. In 2008, a study published by the NGO “Stop Illegal Fishing” (SIF) described that there were possibly over 100 unlicensed industrial boats operating off Mozambique (SIF, 2008). The Ministry of Fisheries estimated that all these illegal activities combined are costing Mozambique loses of around 74 million USD per year. Only considering the tuna resource, it is assumed that 20,000 t of tuna are being caught illegally each year in the Mozambican EEZ, resulting in loses of 40 million USD (MIPE, 2012). Other targets are sharks and shark-like rays for the high value of their fins on Asian markets. Authorities have arrested several vessels, mainly Chinese flagged long-liners, with tons of shark fins. One of them, arrested in 2008, the Namibian flagged vessel “Antillas Reefer” was converted into a patrol ship in 2012 by the Government of Mozambique.

Non-reporting and under-reporting catch data is a constant problem with the European Union vessels operating under the Fisheries Agreement with Mozambique. Some vessels have been entering and leaving the Mozambique waters without any reporting to the authorities and some declared zero catches. It was estimated that the tuna purse seiners failed to report over 500 t of tuna in 2010. Another major concern is the unauthorized transhipments of catches from one vessel to another.

The Government of Mozambique implemented several strategies to combat IUU fishing through the National Plan of Action to Prevent, Deter and Eliminate IUU fishing approved in 2009 (Diploma Ministerial nº 58/2009). The MIPE with NORAD assistance introduced the satellite Vessel Monitoring System (VMS) to monitor the licensed vessels. With this technology it is possible to follow in real time the position, direction and velocity of each vessel registered in the Mozambican EEZ and check violations of the area reserved to the artisanal fisheries, which extends 3 nautical miles from the shore. Patrolling missions are being done with two vessels, the “Kuswag I” and the converted “Antillas Reefer”. During 2012 these vessels did 14 patrol missions during 118 day at sea, where 149 fishing vessels were inspected. No aerial patrols were made due to financial limitations (MIPE, 2012).

At the regional level, Mozambique is involved in several efforts to combat IUU fishing. In 2010, the Southern African Development Community (SADC) established the Regional Fisheries Monitoring, Control and Surveillance (MCS) Coordination Centre in Mozambique. The objective was to set up a regional platform to conduct a regional Patrol Plan and to support the capacity building to implement the SADC Protocol on Fisheries.

The Southwest Indian Ocean Fisheries Project (SWIOFP), funded by the Global Environment Facility (GEF) provided support for the creation of a regional observer corps. In December 2012, Mozambique also joined a regional initiative entitled “FISH-I”, that aims to bring greater co-ordination and information sharing between five West Indian Ocean countries, the others being the Seychelles, Comoros, Kenya, and the United Republic of Tanzania. Also, the Indian Ocean Tuna Commission (IOTC) provides regular patrols and satellite monitoring of the region.

Most recently Mozambique joined the Indian Ocean Tuna Commission (IOTC) that coordinates the regional patrolling effort and ensures that tuna vessels follow the resolutions of this organization. In 2014 Mozambique signed the FAO Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing. Through this agreement Mozambique vouched to use its capacities as a port state to properly inspect foreign vessels that seek port entry or that are in port. This concerted action between port States and flag States can ensure the detection of vessels suspected of illegal activities and block the flow of IUU-caught fish into national or international markets (FAO, 2014).

10. MAIN EXISTING AND POTENTIAL THREATS TO MARINE ECOSYSTEMS

10.1. FISHING PRESSURE

Human population quadrupled in Mozambique during the past 50 years. This resulted in a substantial increase in fishing pressure. This is more evident in large urban areas with high population density such as Maputo Bay and the Nampula coast. In these areas there is a significant increase of the artisanal fishing in response to a growing population (INE, 2012; USAID, 2010). It is expected that demand for seafood will continue to grow over the next 25 years, which will exert further pressure on fisheries (FAO, 2007; USAID, 2010). Fishers are currently witnessing changes in fish abundance and distribution. They are also experiencing changes in their physical, social, and cultural environments. All of this is driving an ever increasing fishing effort (Blythe *et al.*, 2013).

It is estimated that only 25% of fish stocks in the region are underexploited. Most species are either highly exploited or overexploited. In particular, the FAO commented that recent catch data show the intense exploitation of demersal and pelagic fish, penaeid prawns and deep-water lobsters.

The fish stocks that require special attention include crayfish, large and small pelagic fish, deep-water fish, cephalopods, and algae (MIPE, 2010; SIF, 2008). The fish stock assessment IIP conducted (IIP, 2011) reviewed 34 species of small pelagics, demersal fish and crustaceans, which contributed approximately to 66% of the total artisanal production. This study showed that 60% of these species are either heavily exploited or overexploited (IIP, 2011).

The IDPPE counted more than 43,000 nets used in marine fisheries during the last census even though the authorities have licensed only 11,182 nets in 2012 (MIPE, 2013). A large proportion of these nets often include illegal or non-selective mesh sizes that catch a large number of juvenile fish or undersized fish. The fishing gears known as “chicocota” and “mosquito nets” are forbidden throughout the country but are still in use. Some beach seine nets use mosquito netting as cod-end. This is a matter of concern as beach seines represent 32% in volume of the total artisanal catch in the country (IIP, 2012).

Sharks and shark-like rays are being overexploited for their fins and their high value in Asian markets. Shark finning (Figure 10.1) consists in the removal of shark fins and discarding overboard the remains of the shark. Mozambique has experienced growth in an informal shark fin trade promoted by Chinese nationals who purchase dried shark-fins caught by local fishers. Other species sought by the Asian markets are being overexploited as well, such as marine turtles, seahorses, terrapins, and sea cucumbers (Transparent Sea, 2014).

Figure 10.1 – Shark finning, Tofo Beach, Inhambane Province (Photo: Jess Williams)

The penaeid prawns fishery in Sofala Bank shows signs of overexploitation resulting from the high pressure exerted by industrial, semi-industrial and artisanal fishing sectors. The management of this fishery is based on scientific information; however there is little information on key aspects of the interaction between species, fishing gears and environmental factors (Brito, 2010). This fishery generates significant by-catch, up to 70% to 80%. The IIP estimated that the total by-catch of this fishery ranged between 8,512 to 13,072 t. The IIP also described the species composition of the by-catch (IIP, 2012). This mostly included Sciaenidae (76%), followed by Ariidae (12%), and Trichiuridae (8%). This by-catch is discharged at sea or transferred to artisanal fishermen (IIP, 2012).

An environmental assessment of the penaeid prawn fishery using the ecosystem approach concluded that the impact of this fishery on the target species is high and medium on by-catch species. The assessment found that there was a medium risk of the incidental capture of marine turtles. The introduction of Turtle Excluder Devices (TEDs) could reduce the incidental take of marine turtles and elasmobranchs (IIP, 2012).

In 2002 a network of fisheries institutes from several countries of the Western Indian Ocean region identified the main problems of the different types of fisheries in this region. They concluded that less than half of the fisheries are sufficiently documented to support management. They found that 53% of fisheries have sustainability problems, in 20% of fisheries by-catch impacts threatened species; only 16% of fisheries have an adequate management plan; and in 83% of fisheries there was no evidence of co-management (Samoilys & Church, 2004).

10.2. INDUSTRIAL AND COASTAL DEVELOPMENT

Mega industrial projects proposed or recently implemented have increased the pressure on coastal and marine ecosystems and species of Mozambique. These include large extractive projects such as titanium mining in coastal dunes of Moma (by Kenmare Resources plc), offshore exploration for oil and gas by several companies (Anadarko, Statoil, Eni, Sasol), as well large-scale projects to upgrade (Nacala and Pemba harbours) or construct ports (e.g. Techobanine in southern Mozambique within the Maputo Special Reserve and the Ponta do Ouro Partial Marine Reserve) (Figure 10.2).

Figure 10.2 – Examples of industrial and coastal development (from left to the right and clockwise: i) urban pressure at Tofo, Inhambane Province, ii) Oil&Gas vessels at Pemba Bay, Cabo Delgado Province, iii) lodges on the dunes in Barra, Inhambane Province, iv) Ponta Techobanine, Maputo Province) (Photos: Hugo Costa)

The major challenges associated with such mega-projects include a lack of proper regional environmental planning, a poor legal and institutional framework, institutional weakness (with regards to human resources, equipment, and funding), as well as lacking baseline data to objectively assess the impacts of such projects and to assess the need for mitigation, monitoring, and compensatory measures. There generally is a poor capacity to assess and monitor the implementation of EIAs and EMPs. Additionally, lack of transparency, and violations of land rights of local communities (Salomão, 2013; Selemane, 2009) deserve particular attention.

10.3. NATURAL RESOURCES EXPLOITATION

The major existing and potential threats to marine natural resources of Mozambique include human-induced changes to river runoff in coastal areas, production of timber from mangrove trees, extraction of coral reef organisms, coastal mining, oil and gas development, and tourism. As Mozambique has a high population density on the coast and is experiencing a considerable population growth, increasing pressures on marine natural resources and associated ecosystems are expected to occur and, ultimately, lead to a decline in marine biodiversity.

10.3.1. Controlling River Runoff

Structures installed to alter the natural flow of rivers have been increasingly observed in Mozambique and neighbouring countries. Water is being retained for irrigation, domestic and industrial use and, most importantly, electricity generation (ASCLME, 2012). Changes to the course and flow of rivers made for freshwater storage, and the reduction or increase of river runoff due to the operation of dams negatively impact coastal ecosystem dynamics and their functioning (Poff *et al*., 2007; Syvitski *et al*., 2005).

The construction of dams is particularly damaging to the natural functioning of coastal ecosystems. Controlling river discharge to produce a steady flow throughout the year leads to an unusually high flow during dry season and a low flow during the rainy season, which contrasts with naturally-occurring flows. The Cahora Bassa dam on the Zambezi River exemplifies the negative impacts on marine ecosystems and in particular the shrimp fishery on the Sofala Bank caused by controlling river output (Gammelsrod, 1992). Damming of the Zambezi River affects the shrimp catch as river runoff would otherwise provide the necessary nutrients to coastal waters (Leal *et al*., 2012) and stimulate shrimp recruitment (Vance *et al*., 1985). Shrimp larvae enter mangrove swamps during the dry season to settle and juveniles migrate seaward. However, the controlled runoff, which is characterized by a uniform flow throughout the year, is expected to affect the environmental cues that stimulate shrimp migration both in and out of the mangrove areas.

The reduction of river runoff further modifies water quality of coastal areas, which leads to habitat degradation and loss of biodiversity (Rosernberg *et al*., 1997; Snoussi *et al*., 2007). Furthermore, damming contributes to a decreased sediment input to coastal areas (Syvitski *et al*., 2005). This will ultimately cause erosion and, consequently, the destruction of coastal marine habitats such as seagrass habitats (Short & Wyllie-Echeverria, 1996). While this issue has not been reported in Mozambique, it is anticipated that coastal erosion caused by the damming of rivers will lead to the destruction of important marine habitats and associated nearshore ecosystems (Gillanders & Kingsford, 2002) that serve as nurseries and breeding grounds (Gell & Whittington, 2002; Paula *et al*., 2001b;).

10.3.2. Mangrove Exploitation

Mangroves cover a total area of 396,080 ha in Mozambique, but are being depleted at a rate of 4.9% per year in the Sofala province to 15.2% per year in the Maputo province (ASCLME, 2012). Mangroves are loosing cover due to:

- Increased population pressure in coastal regions.
- Uncontrolled exploitation for firewood, charcoal and timber production.
- Clearance for agriculture and salt production.
- Increased coastal pollution particularly discharges of untreated sewage and industrial effluents.
- Reduction of freshwater flow due to river damming.

Clearing mangrove forests to create shrimp ponds and tanks is also observed in Mozambique. This is an important developing industry, particularly around Quelimane and Beira (Hoguane & Pereira, 2003).

Mangrove wood is the cheapest and most readily available source of energy, both for cooking and heating, for the majority of the coastal population that cannot afford electricity (Hoguane & Pereira, 2003). Mangrove timber is also used for building houses and artisanal boats.

As mangrove habitats provide valuable ecological and economic resources and services, such as nursery grounds, breeding habitats, sediment trapping and protection against coastal erosion, the human-induced loss of mangrove forests will lead to the loss of marine biodiversity and ecosystems (Alongi, 2002).

10.3.3. Extraction of Coral Reef Organisms

Coral reefs provide important ecological goods and services (Moberg & Folke, 1999). Besides their importance as fishery grounds for coastal populations, coral reefs also support the production of physical natural resources used for lime production, curios, and construction (Hoguane & Pereira, 2003). Coral reefs also provide biological natural resources such as fish and invertebrate species that are harvested to supply the marine aquarium trade (Bruckner, 2001; Rhyne *et al*., 2009, 2012). Ornamental shrimp and corals are among the most popular invertebrate species in the marine ornamental trade and are exported from Mozambique to several countries including Portugal, Italy, Spain, United States of America and Germany (CITES, 2014; Wood *et al*., 2012). It is important to note that the collection of reef organisms for the marine ornamental trade often uses destructive fishing methods such as trawling, dynamite and cyanide fishing, which severely impact coral reef ecosystems (Thornhill, 2012).

Increasing bioprospecting efforts observed worldwide suggest that coral reef organisms of Mozambique may become appealing to pharmaceutical companies in the search of marine bioactive compounds for the development of drugs. For the time being Mozambique has not been a main biodiscovery hotspot of natural products based on marine algae or invertebrates (Leal *et al*., 2012, 2013b).

10.3.4. Coastal Mining

Coastal mining is one of the fastest growing sectors of Mozambique and is particularly focused on the production of aluminum, coal, titanium, zirconium, and rutile (titanium dioxide) from coastal areas, particularly sand dunes (ASCLME, 2012). The aforementioned minerals are usually exported, thus making this sector an important source of foreign exchange. However, the lack of coastal management and appropriate measures to minimize and compensate for negative environmental impacts contributes to habitat degradation. Coastal mining is particularly harmful to the marine environment as it increases sediment loads that affect coral reefs and induce coral erosion and water pollution.

10.3.5. Tourism

While tourism based on the marine environment does not extract natural resources from the marine environment, it uses natural resources to attract tourists (Figure 10.3). The rapid development of tourism without proper measures to minimize negative impacts on marine ecosystems may become harmful to the marine environment and biodiversity in the long term (Harriott, 2002; Lamb *et al*., 2011).

Figure 10.3 – Whale shark (*Rhincodon typus*), Tofinho, Inhambane Province (Photo: Jess Williams)

Tourism activities in Mozambique associated with marine ecosystems are mainly snorkelling, SCUBA diving, and coral picking around coral reefs. These activities are becoming increasingly popular, and may significantly contribute to the economy of several coastal areas of Mozambique (Hoguane & Pereira, 2003). However, these activities will also lead to biodiversity loss and habitat degradation if no preventive and protective measures are implemented (Harriott, 2002). Despite the fact that their impact is not as significant as that of other activities previously reported, such as the extraction of coral reef organisms, it is important to limit these activities in order to minimize the gradual destruction of coral reefs.

10.4. SOURCES OF POLLUTION

Casedei (1989) conducted the most comprehensive review of pollution in Mozambique, especially with regards to health issues. Massinga & Hatton (1997) and Weerts *et al*. (2009) reviewed the land-based sources of pollution impacting coastal and marine environments of Mozambique and concluded that, at the time, it did not represent a major threat to the marine environment as a whole. However, in the vicinity of major urban settlements, especially Maputo (recently reviewed by Scarlet & Bandeira, 2014), several forms of pollution were identified as posing a threat to human health and altering the quality of the marine environment:

i) Industry: (textile, tannery, paints, brewery, cement, detergents, paper). Significant amounts of both organic and inorganic pollutants enter Maputo Bay by the Infulene River runoff although no quantification of the amount of such pollutants has been systematically conducted (Massinga & Hatton, 1997; Scarlet & Bandeira, 2014). However, recent studies (Böhlmark, 2003; de Abreu *et al*., 2014; Ogata *et al*., 2009; see also Scarlet & Bandeira, 2014) identified heavy metals (Zn, Cr, Pb, Cu, Mn, Fe) and persistent organic pollutants (POPs – DDT, HCH, PCB) in clams, shrimp, sediments, and resin pellets. The sources of such pollutants have been identified (Scarlet & Bandeira, 2014).
ii) Domestic sewage: There is no indication of the amounts involved, but sewage is one of the major sources of organic and bacteriologic pollution in port areas (Massinga & Hatton, 1997). In Maputo, less that 50% of the domestic sewage is treated at the Infulene plant, thus the remaining is discharged directly to the sea (Fernandes, 1995; Louro & Pereira, 2004). As a result, total coliform counts have been as high as >500,000 MPN per 100 g of clam tissue, which far exceeds the "prohibited" limit for human consumption (>60,000 MPN coliforms per 100 g tissue) (Collin *et al*., 2008). Other pathogens have also been identified in the bay including *Vibrio parahaemolyticus*, Hepatitis A virus, five strains of *Salmonella, Klebsiella* spp., *Enterobacter cloacae* and *Shigella* spp. In addition *Acinetobacter baumannii*, *Flavimonas oryzihabitans*, *Erwinia* spp. and *Serratia marescens* were found. Some samples, especially those from the fish markets, were heavily contaminated with *Pseudomona spp.* (Collin *et al*., 2008; 2013; Kronkvist, 2006; Nenonen *et al*., 2006).
iii) Shipping and Port Activities: Some of the issues highlighted by Massinga & Hatton (1997) and Scarlet & Bandeira (2014), include exhaust fumes discharged to the atmosphere; oily bilge water and oil sludge from engine rooms discharged to the sea; toilet sewage discharged to the sea; garbage and galley waste discharged to the sea; dredging; ballast; antifouling; and accidental oil spills from damaged tankers such as the *Katina P* accident, which spilled about 72,000 t of heavy fuel oil in April 1992;
iv) Agriculture: Massinga & Hatton (1997) found that agriculture might also represent a significant source of marine pollution in coastal waters. Rivers flowing into the Maputo Bay include the Incomáti and Maputo Rivers, which originate in South Africa and the

Umbeluzi River, which starts in Swaziland. Intensive agriculture is practised upstream the Incomáti, Umbeluzi and Maputo River valleys, including several thousand hectares of sugar cane plantations. No accurate data regarding agro-chemicals entering Maputo Bay are available.

v) Marine litter: Although easily assessed, surprisingly very few studies have been done on marine litter in Mozambique. Assessments were only conducted in southern Mozambique, at various locations (Ponta do Ouro and Malongane; Catembe, Maputo, Inhassoro) and revealed that plastics, cans and glass (originating from recreational use) dominated the litter (Fernandes *et al*., 2012), especially in urban centres, while litter on remote beaches originate from shipping activities (Pereira, 2006; Pereira *et al*., 2001). Despite several awareness and education campaigns, the situation is very serious in Maputo and Catembe, which affects the aesthetic value of these areas and raises public health concerns.

Despite the widespread use of pesticides, including DDT and other persistent agricultural chemicals, and other forms of pollution, no on-going monitoring of marine pollution exists in Mozambique (Massinga & Hatton, 1997; Mora, 2006). This is deemed fundamental, not only as a matter of public health, but also for the production of management and conservation measures in critical areas.

10.5. WEATHER EXTREMES

A variety of natural factors threaten the marine biodiversity of Mozambique due to the extreme variation of environmental conditions. Storms destroy mangroves through the siltation of mangrove creeks (ASCLME, 2012). Strong winds associated with storms also cause the erosion of deforested dunes and the consequent siltation destroys corals (Hoguane & Pereira, 2003). The same sedimentary phenomenon occurs during cyclones, which often cause the siltation of seagrasses and corals (ASCLME, 2012). Corals are particularly sensitive to sedimentation as it may cause disease outbreaks and decease photosynthetic capacity of the algal symbiont (Bruno *et al*., 2007; Fabricius, 2005; Haapkyla *et al*., 2011). Corals are also sensitive to anomalous warm water events (Hoegh-Guldberg, 1999). High water temperatures cause coral bleaching, which is a phenomenon that has been attributed to prolonged elevated seawater temperature and high solar irradiance, and sometimes disease, and involves the whitening of corals due to loss of symbiotic algae and/or their pigments (Brown, 1997; Hoegh-Guldberg, 1999; Douglas, 2003).

Coral bleaching in Mozambique is also associated with the effects of El Niño. For instance, the 1997-1998 El Niño event caused extensive coral bleaching due to a dramatic increase in temperature beyond the tolerable level of most coral species (Motta *et al*., 2002; Schleyer *et al*., 1999). As the regeneration of corals after this event did not always occur, high mortality rates were observed and, consequently, caused the collapse of certain coral reef ecosystems along the coast of Mozambique. For instance, exposed reefs in the north of Mozambique recorded up to 99% coral mortality (Muthiga *et al*., 2008; Schleyer *et al*., 1999). Bleaching events (up to 90% coral bleaching) were observed in the south of Mozambique, particularly at Inhaca Island (Schleyer *et al*., 1999).

Extreme floods and draughts are common in Mozambique and stress estuarine and coastal ecosystems (ASCLME, 2012). Such stress is mostly associated with abrupt variations of salinity levels, dramatic increases in sediment discharge and water turbidity, as well as waterborne transport of agricultural and industrial pollutants and nutrients (Shumway, 1999). The dramatic input of freshwater to coastal areas is also harmful to coral reefs, as observed at Inhaca Island (Perry, 2003) and Xai-Xai (Pereira & Gonçalves, 2004) during the 1999 and 2000 floods that caused freshwater-induced coral bleaching.

11. CONSERVATION RECOMMENDATIONS

11.1. PROTECTION AND RESTORATION OF MARINE ECOSYSTEMS

11.1.1. Mangroves

Mangroves in Mozambique are protected within the MPA network, which includes the Quirimbas and Bazaruto Archipelago National Parks, Primeiras and Segundas Environmental Protection Area, the Cabo de São Sebastião Total Protection Zone and the Marromeu, Pomene and Ponta do Ouro Reserves. The majority of mangrove forests is, however, located outside formal protected areas such as the Zambezi Delta (Chevallier, 2013).

Although Barbosa *et al*. (2001) mentioned that within the provisions of the Land Law (Law 19/97 of 1 October), "… all mangroves are subject to partial protection together with other living resources occurring within areas from the coastline to 100 m inland…", this protection has not been implemented in practice. In fact, the Forest and Wildlife Regulation (Decree 12/2002 of 6 June), lists mangrove trees (*Avicennia* spp., *Barringtonia racemosa*, *Bruguiera gymnorhiza*, *Ceriops tagal*, *Heritiera littoralis* and *Rhizophora mucronata*) as producers of 3rd class timber, subjected to commercial exploitation. On the other hand, the "Beach Regulation" clearly states in Article 62 (Coastal Native Flora) that "Logging is prohibited within the areas that constitute the object of the present regulation". Such areas are, according to Article 3 of the same Regulation, "areas which constitute public domain, maritime, lacustrine and fluvial, including all fragile ecosystems located near the coast…". However, Article 62 Nr. 3) further states that "Local communities have the right to exploit the native flora occurring in the areas that constitute the object of the present regulation". The same legislation states that special licenses should be acquired before any infrastructures can be built in areas with mangroves, and these should be restricted to infrastructures that provided basic social services i.e. water, electricity, sewage, etc. EIAs and environmental standards should also be followed.

Mangroves are widely used in Mozambique by local communities for firewood and charcoal production, construction materials, fishing paraphernalia, animal fodder, and domestic uses (Barbosa *et al*., 2001), with no regard to any protection (Figure 11.1). Despite initial steps taken for the preparation of a National Mangrove Management Plan, such instrument was never formalized. Similarly to other protection and conservation legislation in the country, as highlighted by Chevallier (2013), the actual enforcement of these legal provisions to protect mangroves is still weak due to financial and technical constraints, although there is an increasing institutional and political recognition of the importance of EIAs both within and beyond MICOA.

Figure 11.1 – Aerial view of Pemba Bay with a significant area of mangroves (several areas being burned can be seen in the background), Cabo Delgado Province (Photo: Hugo Costa)

Several mangrove restoration initiatives have been undertaken throughout the country, although rarely documented (e.g. Brower *et al*., 2002). Given the ease with which seeds are obtained and the relative low-cost of replanting mangroves, community-based initiatives have been promoted by NGOs, local municipalities and Governmental institutions such as MICOA, in Maputo (Costa do Sol), Limpopo river mouth, Nhangau, Savane and Beira, the Zambezi Delta, Nacala-Mossuril, Angoche and Moma, Mozambique Island and the Quirimbas National Park (Ibo and Quirimba islands). One such project is being undertaken in Nhangau – Sofala, by ADEL (a local NGO – www.adelsofala.org.mz). So far, 17 ha of mangroves (*Ceriops tagal* and *Rhizophora mucronata*) have been planted by 20 community members. At this stage, the success rate is largely unknown, as the results of the majority of these initiatives are not published. A project on mangrove ecosystem services is currently being undertaken by the Department of Biological Sciences of EMU and should provide information, which will be invaluable for further valuation and conservation of mangroves in Mozambique (C. Macamo, pers. com.).

Conservation of mangroves should follow a systematic approach and the logical way to address this is through a national strategy via a management plan, with clear institutional responsibilities, goals and objectives and achievable results. Accurate coverage of mangrove area through remote sensing techniques for either entire country or 'index' sites to be produced to act as comprehensive baseline. An evaluation of current rehabilitation efforts to date needs to be conducted. Relevant stakeholders include the Department of Biological Sciences of EMU and the National Directorate of Land and Forests of the Ministry of Agriculture.

11.1.2. Primary Dunes and Sandy Beaches

Primary dunes and sandy beaches are prominent habitats, especially from Bazaruto southwards, where these play an important role as nesting habitat for marine turtles. The protection of primary dunes and sandy beaches is also conferred by the "Beach Regulation", given their role "as fundamental habitats for the normal development of marine turtles". Infrastructure development needs special licenses, driving on the beach is prohibited (Figure 11.2). There are provisions for heavy fines for violations. No effort has been put forward to restore primary dunes apart from isolated cases where some measures to control erosion to protect tourism infrastructure in Macaneta and Ponta Mamoli. These were largely unsuccessful. Law enforcement and compliance is virtually non-existent throughout the country.

Figure 11.2 – Example of driving on beach, Praia do Bilene, Gaza Province (Photo: Hugo Costa)

Suggested practical actions include: i) creation of beach signage in problematic areas; ii) capacity strengthening and training of enforcement officers; iii) physical barricades installed on beach accesses to prevent driving beyond boat launching areas; and iv) create community-based patrolling and local "hot lines" with training and participation of local stakeholders (e.g. local authorities, NGOs and tourism operators).

11.1.3. Seagrass Beds

Despite their recognized ecological and socio-economic importance in Mozambique (Bandeira, 1995) and the WIO region (Gullström *et al.*, 2002), no formal and direct protection is given to seagrass species or seagrass beds in Mozambique. *Zostera capensis*, a species endemic to the southeastern part of the Atlantic and south of the WIO region (Bandeira, 2011; 2014) is listed in the IUCN Red List as Vulnerable and currently not protected in Mozambique. Apart from seagrass beds occurring within MPAs (Quirimbas and Bazaruto National Park, Primeiras and Segundas and Ponta do Ouro Reserve) no further protection is afforded.

Despite sustaining physical damage from trampling and boat traffic, collection of invertebrates, anchoring, coastal erosion and other impacts (Bandeira, 1995; Gullström *et al.*, 2002), no attempts to restore seagrass beds in Mozambique have been reported. This should especially be the case in areas such as Maputo and Bazaruto bays (Bandeira, 1995; Mafambissa, 2002; Scarlet, 2005; Videira, 2011), where seagrass beds are threatened and play fundamental ecological and socio-economic roles. Additionally, comprehensive mapping and current coverage estimates using remote sensing techniques must be conducted as well as the establishment of index sites inside and outside of MPAs. The Department of Biological Sciences of the EMU, NGOs as well as MPA authorities are seen as key players.

11.1.4. Bays and Estuaries

Protection of marine ecosystems in bays and estuaries is done indirectly by the General Regulation for Maritime Fisheries (Decree 43/2003 of 10 December), which prohibits industrial and semi-industrial vessels with freezing capacity from fishing in these areas. Additionally, purse nets are not allowed in these areas. There is generally no compliance to these provisions and enforcement is very poor.

Suggested immediate actions include the identification of priority sites for intervention (e.g. Pemba, Nacala, Inhambane and Maputo) and implementation of measures such pollution control, wastewater management and treatment of industrial effluents. Management plans for estuaries of special concern need to be prepared. These measures should primarily be implemented or coordinated by the municipalities in close collaboration with NGOs and the private sector, as well as the research institutions.

11.1.5. Coral Reefs

In addition to the protection of coral reefs located within MPAs, coral reefs are protected under the "Beach Regulation" (Figure 11.3). All practices that may cause physical damage to corals, including collection of invertebrates, corals or reef fish for the curio trade, as well as fishing within 100 m of the reef, anchoring and several recreational activities are prohibited. Notwithstanding these prohibitions and heavy fines, the regulation is not being implemented and is largely ignored (Pereira *et al.*, 2010b). Coral restoration in Mozambique has not been attempted due to prohibitive costs and low capacity.

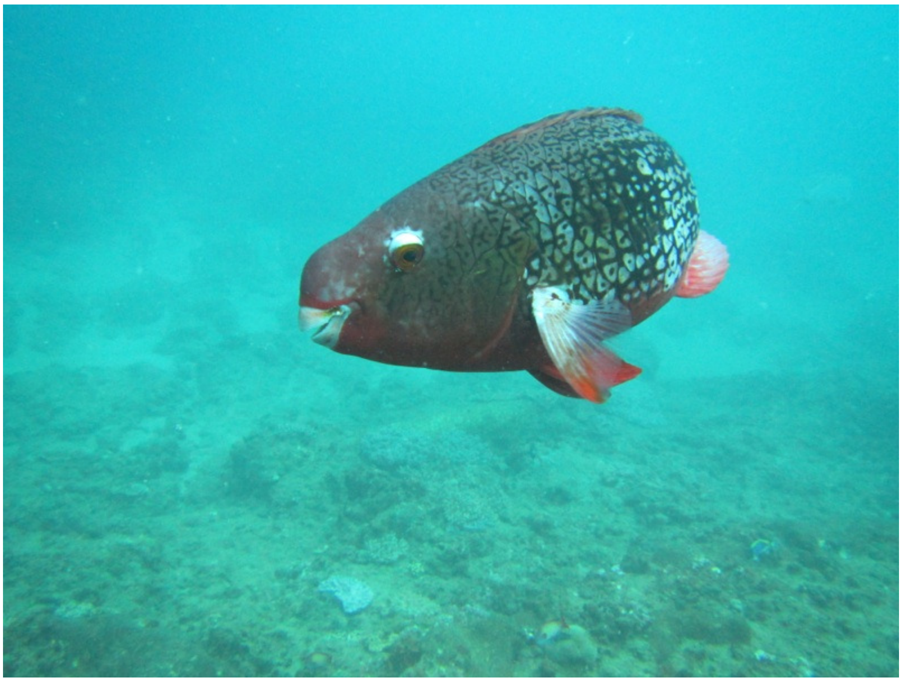

Figure 11.3 – Parrotfish (*Scarus rubroviolaceus*) at Ponta do Ouro, Maputo Province (Photo: Raquel Fernandes)

Apart from law enforcement and compliance, there is a pressing need for a national management plan for coral reefs. Again, institutional responsibilities need to be clear. Other priority actions include the establishment of "hot lines" and community patrolling programmes through locally managed marine areas. This will necessarily entail training and capacity building to local authorities and key players (NGOs, tourism operators, community leaders). Artificial reefs, using for example reefball modules (www.reefball.org), should be tested in order to alleviate the pressure from tourism on natural reefs. NGOs and the private sector (i.e. tourism operators) are logical stakeholders in promoting and implementing these actions and should work closely with Governmental entities (e.g. MICOA, Fisheries).

11.2. PROTECTION AND RESTORATION OF FISHERIES

According to the General Maritime Fisheries Regulation (Decree 43/2003 of 10 December 2003), the list of protected species and the conditions of their protections shall be determined by the Minister of Fisheries, upon advice from the Commission of Fisheries Administration.

Currently, the list of marine protected species (Table 11.1) is only applicable to recreational and sport fishermen (as it is sanctioned by the Recreational and Sport Fishing Regulation, Decree 51/99 of 1 August). Some of these species including marine turtles (Gove *et al*., 2001) and sharks (Pierce *et al*. 2008) are directly targeted or captured as by-catch, by both subsistence and commercial fisheries and are thus, not legally protected. Several other iconic species such as the whale shark, manta ray, Napoleon wrasse and the humphead parrotfish, considered endangered or vulnerable by the IUCN Red list, are currently not protected (Warnell *et al*., 2013). There is, therefore, a pressing need to update the list of protected species in Mozambique and expand it to cover all fishing sub-sectors.

It is clear that past and current fisheries management measures have not been successful in Mozambique. A more sustained effort into promoting co-management and locally-managed areas should be implemented. The establishment of a representative network of medium to small, cost-effective and ecologically sound MPAs should also be considered a priority.

The current state of fisheries in Mozambique clearly requires a different approach in terms of its management, enforcement and restoration**. Improved protection of threatened species is a must and the need to design, proclaim and effectively enforce fisheries restoration measures (be it through co-management at the local level, MPA designation, added value of fisheries products or use of innovative gear) is paramount for the future of fisheries in Mozambique.**

Table 11.1 – Current list of marine protected species in Mozambique (Recreational and Sport Fishing Regulation)

Species	Common name	Protection
Marine fish		
Chrysoblephus puniceus	Slinger	4 per angler/day
Cheimerius nufar	Soldier	
Polysteganus coeruleopunctatus	Blueskin	
All species	Rockcods	
All species	Parrotfish	1 per angler/day
All species	Sharks, except the great white shark	2 per angler/day
Epinephelus lanceolatus	Brindle bass	Fully protected
Polysteganus undulosus	Seventy-four	Fully protected
Epinephelus tukula	Potato bass	Fully protected
Petrus rupestris	Red steenbras	Fully protected
Carcharodon carcharias	Great white shark	Fully protected
Marine crustaceans		
All species	Deep-water lobster	2 per angler/day
All species	Shallow -water lobster	2 per angler/day
All species	Crayfish	2 per angler/day
All species	Shallow-water shrimp	0 per angler/day
All species	Deep-water shrimp	0 per angler/day
Freshwater crustaceans		
All species	Lobsters	2 per angler/day
All species	Shrimp	0 per angler/day
Reptiles		
All species	Marine turtles	Fully protected
Mammals		
All species	Whales	Fully protected
All species	Dolphins	Fully protected
Dugong dugon	Dugong	Fully protected
Bivalves		
Tridacna squamosa	Fluted giant clam	Fully protected
Tridacna gigas	Giant clam	Fully protected
Gastropods		
Cassis cornuta	Horned helmet	Fully protected
Charonia tritonis	Trumpet triton	Fully protected

Suggested practical actions include i) the designation of locally managed sanctuary areas with strong community participation to allow for spillover effects; ii) education about sustainable fishing practices at local (CCP), provincial and national levels (including minimum sizes, deleterious impacts of gill netting, shark fining and turtle poaching); iii) stronger collaboration with IDPPE for consistent, representative monitoring (catches, biomass, threatened species) at index landing sites; and iv) promotion of sustainable fishing techniques (e.g. circle hooks, turtle excluding devices). The use of artificial reefs should also be explored as a tool for enhancing locally depleted stocks.

11.3. REAL-WORLD SOLUTIONS: INFLUENCE ON LIVELIHOODS OF COASTAL COMMUNITIES

Conservation initiatives can have positive and negative impacts on the livelihoods of people. They might be well accepted or badly rejected by local communities. Several research projects have showed that the “top-down” approach, led by a central government, often results in non-acceptance of protected areas by local communities (Figure 11.4). Further, many community-based natural resource management (CBNRM) efforts fail due the lack of community command and enforcement (Oracion *et al*., 2005). Ideally, co-management should blend views from the communities and by the government, scientific, NGO and private sectors. One of the biggest challenges to participatory conservation approach is mutual understanding between managers, local communities and other stakeholders.

Figure 11.4 – Artisanal fishermen in a dhow, Inhambane Bay, Inhambane Province (Photo: Rodrigo Santos)

In Mozambique the level of formal education is low, thus biological and ecological principles fundamental for conservation are not fully understood by the local community. Equally, decision makers and managers are rarely part of the coastal communities they are dealing with and might not understand local cultural values and traditional management. Therefore, the exchange of formal and traditional knowledge is vital for proper co-management and implementation of conservation actions (McClanahan *et al*., 2012). A classical example is the creation of no-take areas. If it is only done to protect a species for tourism and imposed by the Government, it may result in several conflicts between government, private sector and local communities. However, if a participatory approach is adopted and the community understands the positive outcomes not only for tourism but also for small scale fisheries they are more likely to support the idea, especially if they can participate in the decisions on the size, area and rules.

The Mozambique Government is working through decentralization and implementation of local committees (Nelson & Agrawal, 2008). In coastal areas the most representative community organizations are the CPPs (Community Consul of Fisheries). CCPs might work only with problems related to fisheries or may play a bigger role in the community dealing also with health and security. The size of the CCPs and its capacity to co-manage natural resources vary widely around the coast. McClanahan *et al*. (2012) show that CCPs that work with environmental NGOs and conservation groups are more likely to understand and support conservation. Additionally, they highlight that CCPs working in a small region are more successful than CCPs responsible for large areas.

There are several conservation practices that might be applied in order to conserve marine resources, <u>such as creation of no-take areas (or sanctuaries), restriction in fish size and breeding season protection</u>. The best option is site specific and depends on local socio-economic and environmental issues (McClanahan *et al.*, 2012). It is important to evaluate each case and ensure that all stakeholders are aware of positive and negative outcomes. Obviously, it is not possible to apply this approach to the entire coast of Mozambique so it is important to <u>define priority areas</u>, which hopefully will provide examples for other places.

Future conservation actions should include <u>a participatory approach and empowerment of the CCPs in conjunction with a strong educational component</u>, knowledge exchange is essential prior to decision making. Management decisions should be based and analysed from the scientific and social perspective prior implementation. Key stakeholders include local NGOs, community leaders, tourism operators, CPPs, Ministry of Fisheries and local authorities.

11.4. INDICATORS AND RECOMMENDATIONS

11.4.1. Priority Indicators

Long-term monitoring of ecosystems, species, their exploitation through fisheries and the well-being of the coastal communities is a key fact of positive conservation actions. In order to assess these, careful consideration of suitable indicators is required. More than 200 indicator species have been proposed to describe marine ecosystem health (Rice, 2003). In order for indicators to be effective in allowing the early detection of changes in species, ecosystems and pressures upon these, they should retain the following properties (UNESCO, 2003):

1. Indicator must be sufficiently sensitive to provide early warning of change
2. They must be distributed over a broad geographical area or otherwise widely applicable
3. Capable of providing a continuous assessment over a wide rage of stress
4. To be relatively independent of sample size
5. Easy and cost effective to measure, collect and calculate
6. Able to differentiate natural cycles or trends from those induced by anthropogenic stress
7. Indicators must be relevant to ecologically significant phenomena.

With these principles in mind, selected indicators are proposed in Table 11.2.

The National Fisheries Research Institute (IIP) currently runs monitoring systems, for fisheries-related data, which has traditionally been strongly focused on industrial fisheries, but has been expanded to small-scale fisheries as well (Santana Afonso, 2006; Balói *et al*., 2007). Thus, indicators for fisheries have not been included in this review. However, certain subsectors (e.g. recreational and sport fishing), species groups (e.g. sharks), as well as by-catch, are poorly represented and need to be improved. This is especially the case of the small-scale and artisanal fisheries and harvesting activities, which are deficiently covered by the monitoring system. A notable improvement to the national data gathering framework would be the implementation of regular census of diggers, harvesters, and small boats working on rocky shores, seagrass meadows, tidal platforms and shallow seaward side of biogenic (coral) and rocky reefs. Coupled with on-site interviews and inspection, these census could provide a powerful tool for small-scale fishery management that could help overcome the difficulties in monitoring these easily report-escaping fishing activities.

Indicators should be collected prior, during and after implementation of management or conservation plans. While some may require expert capacity and specialized equipment, the majority can be monitored using basic equipment and personnel available at the MPA level or provincial directorates. Several indicators, particularly socio-economic indicators, can be collected through interviews with local communities and focused group workshops. Validation of such indicators should be done with key stakeholders. Stakeholders such as fisherman and dive operators can be involved on basic data collection for a more participative and funding effective approach.

Table 11.2 – Proposed priority indicators for monitoring marine ecosystems and species and condition of coastal communities.

Marine ecosystems and species	Coastal communities
1. Mangroves - Distribution, extent and percentage of area protected - Natural and human disturbances and controlled procedures applied - Number of endangered or rare mangrove dependent species - Most common species composition and biomass - Pneumatophore and seedling density - Stump density - Invertebrates diversity per group and abundance	**1. Basic needs (indicators directly related to the well being of a population):** - Population with access to water and type of access (%) - Number of health centres, hospitals, maternities - Access to electricity (%) - Type of sanitation system
2. Coastal dunes - Distribution and extent - Vegetation structure and composition of dominant species - Use of the dunes (i.e. percentage of the area covered by vegetation, exposed dune, houses, tourism infrastructure, businesses) - Inclination and height (scale from 0 to 10)	**2. Sources and level of income (these indicators help to establish which resources the communities depend on, income trends and capacity to adapt):** a) Population employed by sectors (%) b) Population living from fisheries or partially dependent (%) i. Fishing technique - Ownership of boat - Ownership of fishing gear - Catches per month (kg) c) Population living from macro-invertebrates (molluscs and crustaceans; %) d) Population partially depend on macro-invertebrates e) Number of livestock per species (e.g. goats, poultry, etc.)
3. Barrier lakes - Water quality (biological, and physico-chemical) - Depth - Most common faunal diversity and abundance (benthos, fish, birds) - Lake perimeter usage (percentage for farming, tourism and industry infrastructure).	**3. Population structure** - Age and gender structure - Population density (inhabitants/km²) - Population growth - Literacy level
4. Rocky shores - Dominant species of invertebrates and abundance (% quadrat cover) - Dominant species of algae and abundance (% quadrat cover) - Human access and dependence (scale from 0 to 10)	**4. Education** - Population with access to schools (%) - Number of primary and secondary schools - Number and percentage of children by gender reaching the different levels of education

Marine ecosystems and species	Coastal communities
5. Seagrass beds - Distribution and extent - Dominant species and biomass - Diversity and abundance of invertebrates per group - Rare and dominant fish species - Percentage damage and disturbance to meadows (e.g. dredging, anchor and mooring scars)	**5. Household assets** - Fridge - Solar panels - Television - Vehicle per type (car, motorbike, bicycle)
6. Coral reefs - Coral and other benthos cover - Reef rugosity - Abundance of common invertebrates - Dominant and key fish composition and abundance (e.g. groupers per size, cleaner fish, sharks, herbivorous fish) - Disturbance indicator species e.g. crown-of-thorns and *Diadema* urchin, macroalgal abundance. - Prevalence of coral disease (white and black spot) and bleaching	**6. Community empowerment and social network:** - Population participating in community organized groups (e.g. CCPs; %) - Number of organized community groups (e.g. associations, science clubs, etc.)
7. Species - Marine turtles (distribution and number of nests and their hatch and emergence success) - Abundance of groupers per size class - Elasmobranchs (populations estimates) - Marine mammals (population estimates) - Sea birds (distribution and population estimates) - Pressure indicator (percentage of bycatch and poaching of these species).	
8. Estuaries and bays - Quantity of marine traffic - Scale of activities within the area and activity types - Water quality (biological, and physico-chemical)	

11.4.2. Priority recommendations

Research and Monitoring

1) Establishment of long-term monitoring programmes for ecosystems and species, especially those that are threatened, keystone, endemic or high-valued;
2) In-depth baseline biodiversity assessments in hotspot areas;
3) Assessments on the distribution, abundance, exploitation and conservation status of high-valued and threatened species;
4) Research on poorly known taxonomic groups needs to be conducted, especially regarding the potential for natural products (e.g. soft corals, sponges and ascidians);

Management and Conservation

5) Smaller and more cost-effective MPAs need to be designated in an integrated manner, in order to move towards an ecologically coherent network;
6) Limits, size and zoning schemes of current MPAs need to be evaluated and re-assessed, based on the ecological condition and function;
7) Research and monitoring plans need to be drafted for all MPAs, as well as country-wide, management or conservation plans for specific species or ecosystems;
8) Improved enforcement and compliance of current legislation, especially regarding protected species.
9) Legislation (laws and regulations) must be communicated in a clear way to coastal user groups (particularly tourism operators, beach users and fishers);

Networking, Dissemination and Capacity Building

10) Specialist technical and scientific meetings need to be held on a regular basis;
11) A local scientific journal should be established;
12) An association of professionals working in the marine and coastal environment needs to be created;
13) Integration of local community members in monitoring and educational programmes needs to be promoted;
14) A national on-line database (repository) with all published and reports on coastal and marine issues needs to be created to facilitate information sharing;

15) Capacity building with local universities and other institutions to ensure/maintain/increase skilled graduates for marine sciences, conservation and management needs to be implemented on a regular basis;

Legal and Institutional Framework

16) The list of protected species in the country needs to be updated;
17) Protected species legislation to be amended (or new legislation created) to include garner protection to currently species (e.g. whale shark, manta rays and other shark species);
18) The institutional mandate for the protection of marine species and ecosystems needs to be clarified;

Funding

19) Available funding for MPAs (staff, operations, management) needs to be increased;
20) Funding for research, monitoring and conservation of threatened, high-valued species through international donors should be raised;
21) Lobbying with local funding mechanisms (i.e. National Research Fund, Environmental Fund, BIOFUND[7] and MOZBIO[8]) should be promoted so that a specific funding line for marine and coastal conservation could be established;
22) Funding priorities must be made clear in a strategic plan for the marine environment, which would also provide a national monitoring and research agenda with clear priorities.

[7] BIOFUND is the acronym of "Foundation for the Conservation of Biodiversity", which aims to support the conservation and sustainable management of Mozambican natural resources and aquatic and terrestrial biodiversity , including the consolidation of the national system of Conservation Areas. CI-GCF, AFD, KfW, UNDP-GEF and WWF are the institutions that finance the Foundation.

[8] MOZBIO is the acronym of "Conservation Areas for Biodiversity and Development Project". This project is being designed to enhance the economic benefits from tourism and other development activities to the communities in and around targeted conservation areas, and to be the main instrument to implement the 2009 Conservation Policy and recently approved Conservation Areas Law. Community incentives for conservation are to be addressed by the Mozbio Project through direct promotion in parallel of existing livelihoods systems and conservation compliance at a scale sufficient to impact families at household level. It is financed by the World Bank and by UNDP-GEF.

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