Understanding and valuing the marine ecosystem services of the Northern Mozambique Channel

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Abstract

The Northern Mozambique Channel (NMC) region is host to one of world's outstanding terrestrial and marine biodiversity areas. The coastal communities and economies of the region are intimately dependent on its marine and coastal resources, through fishing, tourism and other economic activities, making its management and protection of key importance to the countries. The NMC region is currently at a crossroad regarding its future socio-economic development and environmental status due to the concomitant presence of: (1) rich natural assets, as yet only moderately impacted by human activities; (2) rapidly evolving socio-economic drivers and pressures (e.g., demographic change, growth of tourism and oil and gas sectors); and (3) a strong need to achieve sustainable livelihoods and poverty reduction. This study deals with understanding and valuing the coastal and marine ecosystem services in the NMC region with the goals to (1) providing monetary estimates of the benefits provided by key coastal and marine ecosystem services, (2) identifying and prioritizing current knowledge gaps, and (3) providing guidance and recommendations to the local policy and decision-makers on how ecosystem service values can help to sustainably manage the existing natural capital. Six key coastal and marine ecosystem services are identified: coastal tourism, coastal recreation, fishery, mariculture, carbon sequestration and coastal protection. A range of economic valuation techniques is implemented to provide spatially explicit monetary estimates of the current flow of ecosystem services values for each of the six ecosystem services as well as aggregated values at the province or Exclusive Economic Zone (EEZ) level. We implement the Driver-Pressure-State-Impact-Response (DPSIR) conceptual framework in the investigation of a range of social, economic, environmental and governance indicators, specifically at the province level for each of the NMC countries. We consider six categories of indicators: (1) biodiversity; (2) ecosystem service value flows; (3) multidimensional poverty; (4) institutional responses; (5) pressures; (6) drivers. Each of the categories includes one or more sub-categories and between three and eleven distinct indicators, for a total of 32 distinct indicators. The indicator values are standardized and aggregated in composite indices for each of the components of the DPSIR framework. The values of the composite indices for each of the countries or provinces in the Western Indian Ocean are analysed with the help of spider diagrams. In the face of competing actions and interests by different users and stakeholders, economic valuation of the benefits provided by coastal and marine ecosystems in the region can help increase the magnitude and level of integration of regional environmental policies, thus potentially helping to guide the NMC towards a sustainable growth path.

Keywords: Marine ecosystem services; biodiversity hotspots; economic valuation; ecosystem service mapping; Africa; DPSIR.

JEL Codes: Q01; Q57; Q51

1 INTRODUCTION

Ecosystems provide many valuable services to human beings. Unfortunately, the critically valuable ecosystem services tend not to be economically valued, as they are often not reflected in the prices of goods and services in markets. This occurs not only because some of these goods are public goods, that is, non-excludable (owners cannot prevent others from enjoying it) and non-rival (providing the good to more people can be done at zero cost), but also because of the existence of market failures even when the goods are not public.

This study deals with understanding and valuing the coastal and marine ecosystem services in the Northern Mozambique Channel (NMC). This area is of particular interest as it is rich in subsoil assets, including oil and gas and, as such, is potentially exposed to the (in)famous 'natural resources curse' (Armas et al. 2014). The relationship between natural resources and economic growth depends on how the rents from the natural resources are invested and is thus influenced by the strength of the country's institutions as well as by the strength of natural capital and ecosystem valuation and accounting. It is believed that the current lack of economic assessment of coastal and marine ecosystem services in the NMC region is a real weakness and that economic valuation can help increase the magnitude and level of integration of regional environmental policies, thus potentially helping to guide the region towards a sustainable growth path. Although some studies have been undertaken to assess the benefits derived from the marine natural resources and / or the costs associated with environmental degradation and depletion, they have not been compiled into a comprehensive assessment and are, by and large, outdated.

In addressing the issues of (1) estimating the benefits provided by coastal and marine ecosystem services in the region, (2) identifying and prioritizing current knowledge gaps, and (3) providing guidance and recommendations to the local policy and decision-makers on how ecosystem service values can help to sustainably manage the existing natural capital, some methodological issues need to be addressed beforehand. First, marine ecosystems services in the NMC region are associated to different types of interconnected ecosystems, which include coastal systems and open water systems in the Exclusive Economic Zone (EEZ) of the neighbouring countries. Services related to these ecosystems include coastal tourism and recreation, coastal protection, commercial and subsistence fishing, support for biodiversity, and many others. While the Total Economic Value (TEV) framework provides a useful point of departure for the study, valuation of all components of the TEV requires a large-scale research effort, which is beyond the scope of the present study. A useful approach, which is followed in the present work, consists in first identifying the different values and then proceed to focus on the ones that are most important and that are capable of being valued with reasonable accuracy (TEEB, 2013). The second methodological point is investigating potential links between economic growth in this area and the state of the marine systems, as well as identifying the threats and anthropogenic pressures that are exerted on coastal and EEZ systems. If marine ecosystems deteriorate, the services they provide will decline and a given growth in the economy will take some of the capital for other investment to replace the services. This will reduce future growth. The third methodological point relates to the importance of distributional effects. Who has lost out as a result of the degradation of marine services and who may lose out in the future following the current trends? How are the losers and gainers distributed from a geographical standpoint? Conversely the same groups (and some others) will benefit from

potential improvements. They need to be identified and to the extent possible their benefits quantified within the valuation study.

The present paper addresses the above-described questions with specific reference to the characteristics of the coastal and marine ecosystems in the NMC region. The layout of the paper is as follows. Section 2 provides some background information on the study region, including the identification and general description of the most important marine ecosystem services that are submitted to economic valuation and a qualitative description of the current management trends and how they may affect the region in the future. In Section 3 a range of economic valuation methodologies are implemented to explore the current significance of some crucial coastal and marine ecosystem services in the NMC regional economics and investigates how the provision of these services may be affected in the future as a result of the current threats and the trade-offs that exist between different services. Section 4 builds upon the economic valuation results to discuss the main implications of the study in terms of how they can be used to support policy decisions in the NMC. Section 5 summarizes the main conclusions of the study.

2 THE NORTHERN MOZAMBIQUE CHANNEL: BACKGROUND

2.1 General description of the study area

The Northern Mozambique Channel (NMC) is bounded by northern Madagascar, northern Mozambique and southern Tanzania, with the Comoro archipelago at its heart. It extends from about 9° Latitude South near Aldabra Island in the north, to 17° Latitude South at the narrowest part of the Mozambique Channel in the south. The area is entirely covered by the Exclusive Economic Zones of the countries in the region – Mozambique, Madagascar, Tanzania, Comoros, Seychelles and France. Figure 1 shows the geographic scope and boundaries of the NMC region.

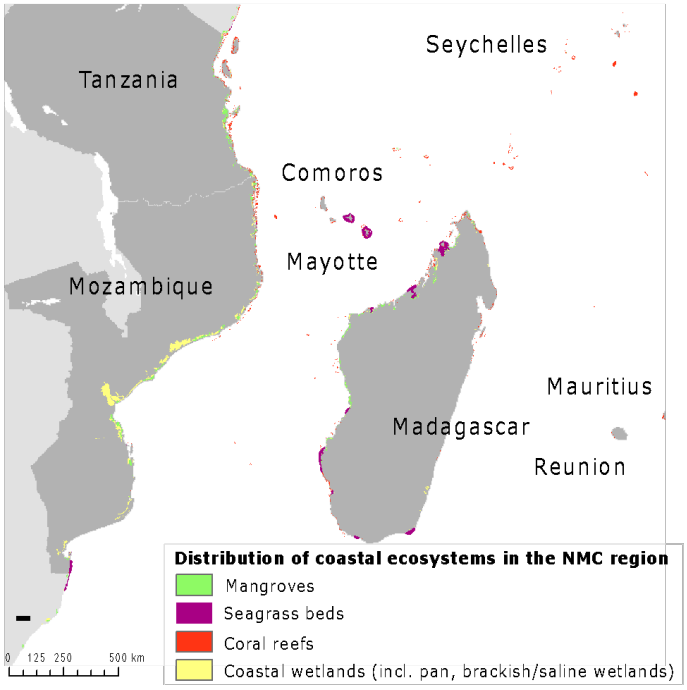

Figure 1. Geographic scope of the Northern Mozambique Channel region in the Western Indian Ocean and distribution of coastal ecosystems and habitats

The coastal communities and economies of the region are intimately dependent on its marine and coastal resources, through fishing, tourism and other economic activities, making its management and protection of key importance to the countries. Table 1 shows the countries and administrative subdivisions, which are located within or in proximity to the NMC region. Although the focus of the study is on the NMC region, we extended our analysis, where possible, to contiguous areas so as to allow for the evaluation of our findings in the larger regional context.

Table 1 Countries and administrative subdivisions pertaining to the NMC region

Country	Province	Population[a]	Extension (in km^2)
Madagascar (MDG)	**Antsiranana**	1,592,631	44,784
	Fianarantsoa	3,625,860	85,939
	Mahajanga	2,491,836	150,023
	Toamasina	3,158,039	75,812
	Toliary	3,140,683	157,405
Mozambique (MOZ)	**Cabo Delgado**	1,606,568	78,778
	Gaza	1,228,514	75,334
	Inhambane	1,271,818	68,775
	Maputo	2,300,337	23,040
	Nampula	3,985,613	79,010
	Sofala	1,642,920	67,753
	Zambezia	3,849,455	103,478
Mayotte (MYT)		212,645	374
Seychelles (SYC)		90,945	455
Tanzania (TZA)	Dar-Es-Salaam	4,364,541	1,393
	Kaskazini-Pemba	211,732	574
	Kaskazini-Unguja	187,455	470
	Kusini-Pemba	195,116	332
	Lindi	864,652	66,040
	Mtwara	1,270,854	16,710
	Pwani	1,098,668	32,547
	Tanga	2,045,205	26,677
	Zanzibar South and Central	115,588	854
	Zanzibar West	593,678	230
Comoros (COM)		798,000	2,236

Note: countries and provinces within the NMC region boundaries are highlighted in **Bold**. [a] Sources: Institut National de la Statistique, 2011 (Madagascar); INE Census 2007 (Mozambique); Central Statistical Office, Census 2011 (Mauritius); INSEE, Government of France, Census 2012 (Mayotte); INSEE, France, population in 2013 (Réunion); National Bureau of Statistics (NBS), Census 2010 (Seychelles); National Bureau of Statistics, Census 2012 (Tanzania); estimated population in 2010 (Comoros).

The NMC is host to one of world's outstanding terrestrial and marine biodiversity areas and a biological reservoir for the entire coastal area of East Africa. It encompasses a range of diverse coastal and marine ecosystems (including coral reefs, seagrass beds, mangroves, estuaries, sandy beaches and lagoons) and terrestrial coastal forests that showcase an enormous potential to provide products and deliver services to people, including resources, both renewable (e.g. fish, wood, crops, water), and non-renewable (fossil fuels), sinks that absorb or recycle wastes (e.g. mangrove forests, oceans), and processes, such as climate and carbon cycle regulation.

The Mozambique Channel contains a large proportion (35%) of the entire Indian Ocean's coral reefs (ca. 11,000 km^2 in the Channel, corresponding to about 4% of the global

coral reef area), ca. 5% of world's mangrove forests (ca. 7,300 km^2 in the Channel) and seagrass beds. Figure 1 shows the distribution of coral reefs, mangroves and other coastal wetland ecosystems in the NMC region. The data underlying Figure 1 are derived from a series of sources. For coral reefs, we rely on the maps generated by the Reefs at Risk Revisited Project (WRI, 2011). The information on the distribution of mangroves and seagrass beds is derived respectively from the global atlases produced by Spalding et al. (1997) and UNEP-WCMC (2005). For the distribution of coastal wetlands, we rely on the database by Lehner and Döll (2004).

Owing to its high productivity, the Mozambique Channel is one of the most important breeding and foraging areas for key indicator and flagship marine species and functions as a corridor for migratory species, such as sea turtles, sharks, marine mammals and tuna. Surveys of the eastern and central parts of the channel have shown several regions of prime importance for foraging megafauna, while recent work on the Mozambique coastline has revealed high concentrations of whalesharks and manta rays in the south, and humpback whales in the northern part of the channel. The Mozambique Channel and East African coast are also the prime habitat of the coelacanth; perhaps because the old and steep coastlines (going back 180 million years) and fixed shape of the Channel have provided the long term oceanographic stability needed for a 'living fossil' of this type to survive here.

The biological importance of the Northern Mozambique Channel was first identified by experts during a regional workshop organized through the Indian Ocean Commission (IOC) in November 2009, in Antananarivo, Madagascar. In 2012, an assessment by the UNESCO World Heritage Centre Marine Programme identified the Mozambique Channel as the highest priority region for the designation of a new World Heritage Site, comprising multiple sites of potential Outstanding Universal Value. The same year, the NMC was integrated into the list of areas meeting the criteria for Ecologically or Biologically Significant Areas (EBSAs) under the Convention on Biological Diversity.

The NMC region is currently at a crossroad regarding its future socio-economic development and environmental status due to the concomitant presence of factors, which include: (1) rich natural assets, as yet only moderately impacted by human activities; (2) rapidly evolving socio-economic drivers and pressures, such as demographic change, present and future growth of economic sectors such as tourism, oil and gas, shipping and fisheries; (3) a strong need to achieve sustainable livelihoods and poverty reduction; and (4) a yet inadequate framework of standards of environmental governance. Unsustainable management of the natural resources in the face of competing actions and interests by different users and stakeholders can severely impact on the future welfare and prosperity of the region's residents. In the present paper we explore the use of economic thinking and the economic valuation toolbox to shed light on the values of coastal and marine ecosystem services in the NMC region and how these can feed into the explicit management and decision-making regarding trade-offs towards the sustainable development of the region.

2.2 Valuing marine ecosystem services in the NMC

Ecosystem services are the benefits people obtain from ecosystems. They can be broken down into three categories that include: (1) provisioning services, i.e., the benefits that ecosystems provide in the form of 'products' or 'goods' that are consumed by humans or used in the production of other goods, such as fish, materials, timber, water and genetic resources; (2) regulation and maintenance services, i.e., the benefits obtained from an ecosystem's control of natural processes such as climate, disease, erosion, water quality and

flows, and pollination, as well as protection from natural hazards such as storm and wave damage; and (3) cultural services, i.e., the non-material benefits people obtain from ecosystems such as recreation, spiritual values, and aesthetic enjoyment (Haines-Young and Potschin, 2013).

The use of monetary methodologies for the valuation of ecosystem services in the NMC region is still in its infancy. As part of the present study, we conducted a comprehensive review of valuation studies of ecosystem services in the region that are available through databases of previous review studies (Ghermandi et al., 2010; de Groot et al., 2012; Ghermandi and Nunes, 2013), personal communications, and online repositories such as the Environmental Valuation Reference Inventory (EVRI; https://www.evri.ca) and the Marine Ecosystem Service Partnership (MESP, http://www.marineecosystemservices.org/). Overall, the review resulted in the identification of 24 studies with a total of 86 value observations, which are presented in Ghermandi and Nunes (2014). The review reveals substantial gaps of information for the NMC region and especially concerning coastal and marine ecosystems, which are valued in only 7 out of the 24 studies.

3 ECOSYSTEM SERVICES CONTRIBUTION TO NMC ECONOMIC SECTORS

We explore the potential of economic thinking and the use of a series of valuation techniques (including market-based information, avoided damage cost, and meta-analytical value transfer) to shed light on the benefits of coastal and marine ecosystems in the NMC region and the role ecosystem services values can play in guiding the regional development towards sustainable targets. We identify six coastal and marine ecosystem services that are critical to the regional economies and welfare of the local population, and submit them to economic valuation. These are: cultural services such as (1) coastal tourism and (2) coastal recreation; provisioning services such as (3) fisheries and (4) mariculture; and regulating services such as (5) carbon sequestration and (6) coastal shoreline protection. The economic valuation exercises are presented, reviewed and discussed in the following section.

3.1 TOURISM SECTOR

3.1.1 Characterization of current state

A major difficulty in understanding the coastal tourism sector's dynamics in NMC is that the data is rather limited. In this context, as the first step of the economic analysis we looked at international tourism flows during the period 2001-2011, taking into account the most recent statistics available at the United Nations World Tourism Organization (UNWTO) – see Table 3. As we can see, tourism is an important economic sector for the NMC countries; in fact, with the exception of Mozambique, during this decade of analysis (2001-2011) of the financial revenue generated by this sector range from a minimum of 20.08% (registered in Tanzania in 2009) to 38.94% (registered in the Seychelles in the year 2008) of total export. Second, for the Small Islands Developing States of Comoros and Seychelles, the tourism sector plays a key role in their economies as the revenues from this economic activity contribute approximately to one third of the total exports. Third, in all the NMC countries, this economic sector registers an impressive growth both in terms of international arrivals as well as in terms of revenues. The fastest growth in the number of international arrivals in the decade 2001/10 has been registered in Mozambique with an increase of 542%, which in the year 2010 amounted to 1.718 million arrivals. The fastest growth in the revenues has

been registered in Madagascar with an increase of 425%. Finally, if we combine these two statistics we are able to compute the average tourist expenditure[1], per year. This amounts to 3,091 USD for Comoros, 3,230 USD for Madagascar, 1,948 USD for the Seychelles, and 1,870 USD for Tanzania.

Table 3: Overview of international tourism flows for NMC countries

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Comoros											
International tourism arrivals ('000)	19	19	21	23	26	29	15	15	11	-	-
Revenues (in '000,000 US$)	9	11	16	21	24	27	30	39	34	-	-
Revenues (in % of total exports)	-	-	-	-	-	-	-	-	-	-	-
Madagascar											
International tourism arrivals ('000)	170	62	139	229	277	312	344	375	163	196	225
Revenues (in '000,000 US$)	149	109	119	239	290	386	506	620	518	633	-
Revenues (in % of total exports)	-	-	-	-	31.8	-	-	-	-		
Tanzania											
International tourism arrivals ('000)	501	550	552	566	590	622	692	750	695	754	795
Revenues (in '000,000 US$)	626	639	654	762	835	986	1215	1293	1192	1279	1487
Revenues (in % of total exports)	-	-	-	-	28.1	28.62	23.18	23.13	20.08	-	-
Mozambique											
International tourism arrivals ('000)	323	541	441	470	578	664	771	1193	1461	1718	-
Revenues (in '000,000 US$)	64	65	106	96	138	145	182	213	217	224	270
Revenues (in % of total exports)	-	-	-	-	6.61	5.24	6.34	6.84	7.84	7.64	7.04
Seychelles											
International tourism arrivals ('000)	130	132	122	121	129	141	161	159	158	175	194
Revenues (in '000,000 US$)	221	247	258	256	29	323	396	408	349	352	378
Revenues (in % of total exports)	-	-	-	-	37.38	37.98	38.6	38.94	33.82	35.48	34.61

Mozambique shows the smallest average tourist expenditure, per year figure, 130 USD. But when combined with the average length of stay (reported by the UN-WTO), then we can compute the average tourist expenditure per night, per year. This statistics amounts to 442 USD for Comoros, 70 USD for Mozambique, and 191 USD for Seychelles.

[1] International tourism expenditures are expenditures of international outbound visitors in other countries, including payments to foreign carriers for international transport.

3.1.2 Economic significance of the coastal tourism in the NMC

In a second step we investigate the economic significance of coastal tourism in the NMC region. In order to address this, we disaggregated the international tourism arrivals into sub-national regions, focusing on coastal regions. This approach sheds light on tourism flows targeted at the coastal regions, which are interpreted as coastal tourism flows. We followed the state of the art Nomenclature of Units for Territorial Statistics (NUTS) at the II level, which generally corresponds with 'province' level administrative units (and where level I equals the country level). From an economic and policy viewpoint this classification is of particular interest since provinces are often the basic units for the application of regional policies. In addition, we complement the analysis in the NMC by adding the domestic tourism flows (Table 4). Combining these figures with the average annual tourist expenditure we are able to compute the coastal tourism values. As we can see, these figures confirm the consolidated positions in terms of coastal tourism values for Madagascar, especially the East coast, Seychelles and Comoros. Coastal tourism is also important for Tanzania, but with lower values when compared to Madagascar and Seychelles. Mozambique shows the lowest coastal tourism values for the NMC. This outcome is in accordance to a recent a study by the Foreign Investment Advisory Service (FIAS), which showed that on average, Mozambique attracts six times fewer inter-continental travellers than the rest of Africa.

Table 4: Decomposition of international and domestic tourism flows among coastal administrative regions in the NMC countries

Country	Province	International (number)	Domestic (number)	Total (number)
Comoros		11,000	6,668	17,668
Madagascar	**Antsiranana**	14,335	16,857	31,192
	Fianarantsoa	33,218	39,061	72,278
	Mahajanga	50,744	59,670	110,414
	Toamasina	23,815	28,004	51,819
	Antananarivo	19,324	22,722	42,046
	Toliary	54,564	64,161	118,724
Mozambique	**Cabo-Delgado**	170,938	88,156	259,094
	Gaza	165,225	85,209	250,434
	Inhambane	148,632	76,652	225,284
	Maputo	51,413	26,515	77,928
	Sofala	147,109	75,867	222,976
	Nampula	170,796	88,082	258,878
	Niassa	281,529	145,189	426,719
	Tete	220,799	113,869	334,668
	Zambezia	224,413	115,734	340,147
	Manica	137,144	70,728	207,872
Seychelles		194,000	20,583	214,583
Tanzania	Arusha	71,354	47,954	119,308
	Pwani	27,338	18,373	45,711
	Dodoma	35,307	23,728	59,035
	Iringa	47,796	32,122	79,918
	Kigoma	40,247	27,049	67,296
	Kilimanjaro	11,297	7,592	18,889
	Lindi	55,749	37,467	93,215
	Mara	24,968	16,780	41,747
	Mbeya	52,476	35,267	87,743
	Morogoro	59,784	40,179	99,962
	Mtwara	14,588	9,804	24,392

Note: countries and provinces within the NMC region boundaries are highlighted in **Bold**. Comoros (2009), Mozambique (2010), Madagascar, Mauritius, Seychelles and Tanzania (2011).

3.1.3 Discussion

Compared to neighboring countries where the leisure segment accounts for upwards of 70% of tourists, Mozambique's leisure market seems particularly depressed (FIAS, 2006). There are a number of reasons as to explain the facts. According to Sarmento (2007) the Mozambican national private sector is still in its infancy. Local producers and suppliers face constraints as they cannot react adequately to the volumes and standards required by the hospitality and tourism industry. The large majority of the Mozambican micro and small scale businesses have difficulty in directly accessing the tourist market because they are not registered officially, the tourism industry depends heavily on imports instead of local capacity, and lastly direct benefits have been very limited because of poor policy decisions. Nevertheless, in Mozambique's coastal provinces, like Inhambane, tourism provides employment and income to a significant number of households. The industry has an impact at the household level through the wages and salaries paid to employees of the tourism industry. Coastal resort areas like the Bazaruto Archipelago and Vilanculos employ a significant proportion of the local population for tourism related activities. The southern resorts of Ponta do Ouro, Inhambane and Bilene are popular beach based leisure spots, Bazaruto and Vilanculos are the more up-market resorts and lodges and recently there has been increased investment in the northern coastal areas of Pemba, the Quirimbas archipelago and Nacala. The central coastline of Mozambique is less favorable to tourism but plays an important role in fish and prawn farming (Turpie and Wilson 2011).

In this perspective, the Government of Mozambique has taken a series of actions to promote the tourism sector, including creating a separate Ministry of Tourism (MITUR) in 2001 and adopting a Tourism Policy and Implementation Strategy (2003) (Republic of Mozambique, 2003). The Tourism Policy and Implementation Strategy of 2003 defines the high-level tourism objectives, identifies the focal points for government intervention and provides tactical guidelines on how to optimize and operationalize its competitive edge (Republic of Mozambique, 2003). The Strategic Plan for the Development of Tourism in Mozambique (SPDTM) argues that tourism in many developing countries has been proven to be a significant catalyst for economic growth and job creation. The SPDTM incorporates a vision for 2020, that Mozambique will be Africa's most vibrant, dynamic and exotic tourism destination, famous for its outstanding beaches and coastal attractions, exciting eco-tourism products and intriguing culture, welcoming over 4 million tourists a year[2]. (SPDTM, 2004, Spenceley and Batey 2011).

[2] According to the tourism plans eighteen areas have been identified as Priority areas for Tourism Investment (PATIs): three areas as type "A" or existing destinations; five as type "A/B" destinations with limited existing tourism development; and 10 (ten) as type 'B' destinations, areas with high potential to develop into a tourism destination but with very few products and services developed yet. Despite the investments to date, the tourism sector remains under developed due to the absence of large, international investment capable of driving high-value markets and building local supply chains, high input costs, low productivity of current tourism businesses, and sub-optimal use of resources and other attractions. Facilitating large international investments has been the primary objective of the Ministry of Tourism for the past decade and many advances have been made, including the creation of TIZs (Tourism Interest Zones) and Anchor Investment sites and region specific master planning. However the timing of the launch of these areas, designed to remove many of the legal and practical barriers to rapid investment and development of tourism facilities in pre- zoned areas coincided with the global economic crisis resulting in minimal uptake from international investors or national private sector. Equally a lack of capacity to market the opportunities, administrate the investments processes and mobilize the required infrastructural development in these areas means that many key challenges still need to be addressed if the country's tourism potential is to be realized (Spenceley and Batey, 2011).

3.1.4 Institutional framework and stakeholders

The sustainable long-term development of marine tourism and recreation ranks high on the list of priorities of the governments in the NMC region. In Mozambique, for instance, the potential of tourism to promote national development and poverty alleviation has been widely recognized already in the 2004 Strategic Plan for the Development of Tourism in Mozambique 2004-2013 (Ministry of Tourism, 2004). The Ministry of Tourism, through its local representatives in the Provincial Directorates of Tourism, remains the primary institution that is responsible for the promotion and licensing of tourism activities. As noted by McLean et al. (2014) the overlap of responsibilities, lack of coordination among institutions, and political instability may prevent or hinder the successful implementation of sustainable management practices. For instance, in the province of Inhambane, one of the Priority Areas for Tourism Investment within the Ministry's Strategic Plan, the development of tourism management strategies may conflict with the responsibilities of the Ministry for the Coordination of Environmental Affairs, which is responsible for the overall environmental management in Mozambique, the Institute for Development of Small Scale Fisheries and the National Fisheries Research Institute, which handle issues related to fishing in MPAs, and the Maritime Administration in the Ministry of Transport and Communication, which assists with artisanal fisheries licensing, licensing diving centers, and enforcing some tourism regulations such as preventing vehicles from driving on the beaches (McLean et al., 2014). Other key stakeholders in the province include the Inhambane Municipal Council, Council of Employers of the Province of Inhambane, National Divers Association of Mozambique, Hotel and Tourism Association of the Province of Inhambane, and the National Institute for Economic Activities (McLean et al., 2014).

3.2 COASTAL RECREATION

3.2.1 Characterization of current state

Coastal recreational activities have grown remarkably in the countries making up the NMC region over the past two decades. The coastal recreation industry represents today an important sector and a key factor for growth in the region. This is particularly true where suitable infrastructure has been established such as in several areas in Tanzania (e.g., Zanzibar, Pemba, and Mafia) and southern Mozambique, particularly in proximity of the coral reefs (e.g., in Pemba, Mozambique Island, Bazaruto Archipelago, Inhambane, Inhaca Island, and Ponta de Ouro) (Costa et al., 2005). A 2001-02 survey of divers in southern Mozambique, between Ponta do Ouro and Cabo Santa Maria, reports for instance 115,000 annual tourists visits in southern Mozambique and between 10,000 and 13,000 visits in Ponta do Ouro and Ponta Malongane region (Pereira and Schleyer, 2005). About 60-72% of the latter are estimated to be certified SCUBA divers, while the remaining visitors are primarily involved with fishing and camping activities (Pereira and Schleyer, 2005). More recently, McLean et al. (2014) estimate in 150,000 the annual visitors to the Inhambane province, out of which 50,000 visited the Tofo, Barra and Tofinho area.

The typologies of recreational sites include both sites that are almost exclusively depending on the influx of international visitors (from South Africa, Zimbabwe, Europe and USA), and sites that are important to both international and local visitors. A survey of divers in southern Mozambique, for instance, reveals that the majority of respondents are from South Africa and Europe, with only 3% of locals (Pereira and Schleyer, 2005). Most of the survey respondents were recurrent visitors, having been at least one time in the region between 2 and 5 years prior to the survey (48.5%) or more than 5 years earlier (16.5%). Recreational activities that are dependent on coral reefs, sea-grass beds and mangrove forests in the region include glass-bottom-boat viewing, snorkeling, recreational and sport fishing and SCUBA diving (McLean et al., 2014).

The high local biodiversity and relative good conditions of the coral reefs in the NMC region are among the main attractions for recreational visitors and tourists. The possibility to experience marine megafauna (dolphins, whales and whale sharks) ranks, for instance, as the highest attraction for divers in southern Mozambique, preceding tropical fish (e.g., manta ray) and corals (O'Malley et al. 2013; Tibiriçá et al. 2011; Pereira and Schleyer, 2005). Unpolluted terrestrial surroundings are also identified as an important part of the recreational experience (Pereira and Schleyer, 2005). Sandy beaches, dunes, lagoons, mangrove forests and sea-grass beds add to the attractiveness of the region for marine recreationists (McLean et al., 2014). The region includes sites with enormous cultural heritage value. A recent study by Obura et al. (2012) found six coastal sites within the NMC region with a potential for designation as marine World Heritage Site. These include two sites in Mozambique (Quirimbas-Mnazy Bay, Bazaruto-Tofo), two in Madagascar (Ambodivahibe-Sahamalaza, southern Madagascar), the Comoros Archipelago, and the Iles Éparses (Glorieuses island, Geyser Bank, Juan de Nova, Bassa da India, and Europa).

3.2.2 Economic significance of the recreation sector in the NMC

From a welfare perspective, the cultural services provided by marine and coastal systems through their support of recreational activities generate positive welfare impacts, which may be felt at the local, regional or global level but, because of their public good nature, are not reflected in the current markets and respective price signals. In other words, the current market prices, in their wide range of market goods and services, fail to embed a substantial fraction of the beneficial contribution that marine and coastal system have for society. Since market prices do not reflect the broad range of ecosystem services, decision-making will be inefficient and fail to preserve or defend these values.

The review of primary non-market valuation studies of ecosystem services in the NMC region, which is presented Ghermandi and Nunes (2014), reveals substantial gaps of information regarding the economic value of several of the ecosystem services provided by coastal and marine ecosystems in the NMC region, including cultural services. In this context, we rely in this section on the application of a state-of-the-art meta-analytical value transfer methodology, integrated with Geographic Information System (GIS) tools, to provide a spatially explicit assessment of the values of the coastal recreation services provided along the coastline of the NMC (see Ghermandi and Nunes, 2013). Although primary valuation research is always a first-best strategy in which information is gathered specific to the time, location, and action being evaluated, value transfer is generally considered a useful second-best strategy, when primary valuation is not possible or plausible (Liu et al., 2012). In the present application to the NMC region, the value transfer exercise is aimed at: (1) providing a first, spatially explicit estimate of the regional and local

economic importance of the ecosystem services for which primary data is lacking; (2) allowing for the identification of priority areas where it may be worthwhile to focus future primary valuation studies; and (3) providing policy-relevant information and a robust, econometrically estimated model on which to evaluate alternative future policy and management scenarios.

The yearly flow of welfare benefits from recreational activities is estimated to range between 7.2 and 1,909.7 US$/ha/year, PPP[3] (Figure 2). The economic values in the map are determined by the combination of the local values of multiple explanatory variables: GDP per capita, population density, human development, anthropogenic pressure, site accessibility, marine biodiversity and climate. Although pristine (i.e., less developed) areas tend to be more highly valued by recreationists, the highest values are found close to large urban centers, where accessibility and proximity to the market of recreationists are highest.

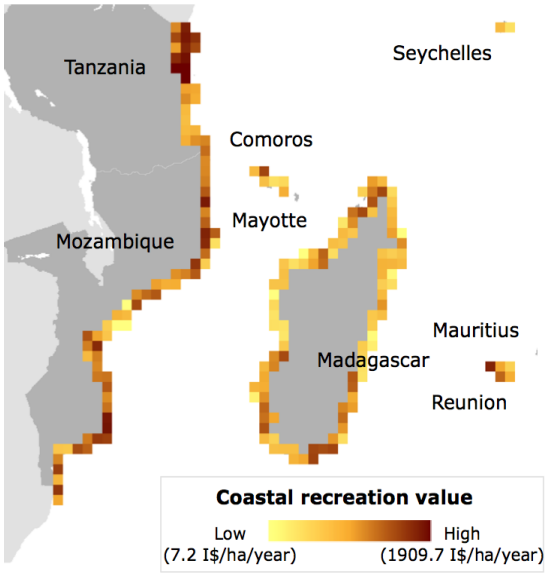

Figure 2. Map of estimated coastal recreational values in the Western Indian Ocean

The welfare contribution of the yearly flux of coastal recreation benefits in the countries making up the NMC region is estimated in 763.3 million US$/year (PPP), while the average hectare of coastal land in the region is valued at 390.5 US$/ha/year (PPP) as far as support of recreational activities is concerned. Table 6 shows the value estimates aggregated by country and administrative province.

The highest per-hectare recreation values are found in three regions of Tanzania, namely Dar-es-Salaam, Pwani and Zanzibar South and Central. In addition to being a source of welfare benefits and revenues for the local economies, recreation and tourism also play an important economic role in supporting a large number of jobs, either directly or indirectly. McLean et al., (2014) estimate that in 2011, 45% of the 130,000 jobs in the formal employment in Inhambane - one of the poorest provinces in the region, where approximately 80% of the population lives in conditions of extreme poverty - could be traced back to marine tourism and recreation. Such jobs include employment as beach traders, boat and dive operators, and other activities involved in sport fishing, snorkelling, diving, surfing, kayaking and boating (McLean et al., 2014).

[3] Purchasing Power Parity

Table 6. Estimated yearly monetary value of coastal recreation in the NMC region

Country	Province	Average unit value (US$/ha/year, PPP)	Total value (million US$/year, PPP)
Comoros		26.2	1.8
Madagascar	**Antsiranana**	433.1	140.0
	Fianarantsoa	111.1	10.4
	Mahajanga	67.0	26.6
	Toamasina	46.2	7.9
	Toliary	107.1	32.2
Mayotte		96.2	2.5
Mozambique	**Cabo-Delgado**	208.5	30.9
	Gaza	416.1	14.1
	Inhambane	175.7	27.7
	Maputo	515.4	32.4
	Nampula	213.4	45.4
	Sofala	381.1	51.7
	Zambezia	269.9	43.4
Seychelles		26.1	1.2
Tanzania	Dar-es-Salaam	1,293.4	34.0
	Kaskazini-Pemba	771.2	21.0
	Kaskazini-Unguja	517.5	9.7
	Kusini-Pemba	664.5	20.7
	Lindi	64.0	5.2
	Mtwara	197.2	7.0
	Pwani	1,293.4	110.0
	Tanga	442.7	32.0
	Zanzibar South and Central	1,011.3	28.7
	Zanzibar West	832.1	9.0

Note: Administrative regions and countries within the NMC region are highlighted in **Bold**.

3.2.3 Discussion

The large growth of the recreation sectors has come along with concerns regarding the sustainability of the current recreation intensity and calls for improved regulation and management of coastal ecosystems, including coral reefs and mangroves (Pereira and Schleyer, 2005; Vasseur et al., 1988). Such concerns are particularly relevant within the context of developing countries, where governance systems, development structures, environmental regulation and its enforcement are often only emerging. In the lack of sustainable management, local residents risk to experience primarily the negative impacts from the development of the tourism and recreation industry, in the form of environmental degradation, rather than its benefits.

The Collaborative Actions for Sustainable Tourism (COAST; http://coast.iwlearn.org/en) project has recently acknowledged the existence of these challenges in East Africa and the NMC region by selecting the Tofo, Barra and Tofinho area in Inhambane province and Bagamoyo, north of Dar-es-Salaam, as demonstration sites for testing Best Available Practices and/or Best Available Technologies and promote sustainable reef and marine recreation (McLean et al., 2014; Garcia et al., 2013). This study identifies five key challenges for the sustainable management of marine tourism and recreation in the region: (1) the lack of awareness of the importance of healthy marine and coastal environments by decision makers, user groups and visitors; (2) the lack of management of coastal tourism (e.g., inadequate enforcement of tourism laws due to lack of technical and financial resources); (3) inadequate protection of important sensitive reef and marine ecosystems and species (e.g., through the establishment of MPAs); (4) unsustainable marine tourism practices (e.g., driving on the beach, poor diving and snorkeling practices); and (5) lack of collaboration, coordination and communication among all user groups. A crucial aspect to be taken into

account when devising improved management practices is the expected response of the recreationists. A survey of recreational divers in southern Mozambique, for instance, reveals that “hard” solutions such as the deployment of mooring buoys and artificial reefs are less acceptable (and thus more detrimental to the overall recreation experience) than awareness campaigns and pre-dive briefings (Pereira and Schleyer, 2005), findings corroborated in Kenya (den Haring, 2014).

Coastal recreation activities in the NMC region are particularly threatened by the declining conditions of sensitive supporting ecosystems such as coral reefs. Souter and Linden (2005) identify bleaching, overexploitation of fish, destructive fishing practices, and pollution from land-based sources as the main causes of reef degradation in the Western Indian Ocean. Among the drivers of degradation, one can identify a high dependence on coral reef products due to a lack of alternative sources of food and income, open and unregulated access, low awareness of the value of healthy ecosystems to support human activities, inadequate regulations that are poorly enforced also due to a lack of coordination among agencies, and, finally, a lack of political will to improve the current governance for instance through the establishment of MPAs and other conservation measures (Souter and Linden, 2005). In addition, climate change is considered an exacerbating threat that has an influence on the resilience of ecosystems and can affect their ability to sustain services: for instance coral reefs in the region were severely damaged by a widespread coral bleaching event in 1998 that affected coral reefs around the world (Goreau et al. 2000; Hoegh-Guldberg et al. 2007; Hughes et al. 2003).

Destructive fishing practices, such as involving the illegal use of explosives along wide stretches of the coast of Tanzania (African Conservation Foundation, 2013; Tanzania Natural Resource Forum, 2009), are an important threat, particularly to the more accessible and shallow coral reef ecosystems. Souter and Linden (2005) estimate a live cover of 80% for hard coral of deep reefs in Mozambique and only 20% live cover for shallower reefs in Tanzania. In some locations such as Tutia Reef in Mafia Island in Tanzania, reef ecosystem recovery is hindered by competition from macro-algae, which presence has been linked to overfishing and nutrient inflow from land-based pollution sources (Souter and Linden, 2005; Suleiman et al., 2005). Reefs protected by MPAs, such as in the Quirimbas Archipelago in Mozambique, tend to fare better than unprotected reefs in terms of recovery of live coral cover once the damaging pressure is removed (Souter and Linden, 2005). The recovery may, however, be at least partly due to the expansion of opportunistic genera that are, for instance, less susceptible to bleaching, at the expense of more vulnerable, previously dominant genera such as *Acropora* (Obura, 2005a). Such development is a threat to coral reefs in Mozambique and southern Tanzania, which are among the richest in terms of biodiversity in East Africa (Obura, 2005b).

In addition to destructive fishing practices and pollution, the mining of shallow corals as sources of calcium carbonate, although widely banned from the region, remains a threat in several regions in southern Tanzania, Mozambique and Madagascar, particularly for denser coral forms such as Porites (McClanahan et al., 2000; Obura, 2005a). McClanahan et al. (2000) estimate that, on average, 950 metric tons of live corals have been mined around Mafia Island in Tanzania every year between 1985 and 2000.

Unmanaged tourism and recreational activities, such as uncontrolled scuba diving, represent another threat to coral reefs integrity in the region (Obura, 2005a). Although previous studies suggest that the impact from the current activities in the NMC region may still be relatively small (Pereira, 2003; 2005), other adjacent regions such as the Seychelles

islands appear to have suffered several impacts from poorly managed tourism and recreational activities, both directly through anchoring and trampling during snorkeling and diving, and indirectly during hotel and infrastructure construction and operation (e.g., discharge of untreated sewage) (Payet et al., 2005). It appears crucial that good management practices based on the evaluation of the tourist carrying capacity of these ecosystems should guide future developments in this sector. An approach to the management of coastal recreational activities that is along these lines is used for instance by Zacarias (2010) to estimate 5,301-10,601 visits/day as the physico-ecological carrying capacity of Tofo Beach in Mozambique.

An additional threat to recreational activities such as bathing in coastal waters comes from pollution from land-based sources, such as discharge of municipal wastewater. The rapidly expanding coastal population and coastal tourism are a primary driver of microbiological pollution, while agricultural activities contribute substantially to nutrient pollution of coastal waters (Lyimo, 2009; Garcia et al., 2013). Several studies observed moderate to high faecal contamination in coastal waters that are used for recreational purposes in near-shore waters of Tanzania (Mwakalobo et al., 2013), including Zanzibar (Mohammed, 2002) and Dar-es-Salaam (Lyimo 2009). Although coastal habitats such as mangroves and salt marshes contribute to regulate the quality of coastal water by removing several types of pollutants, this may not be sufficient to cope with rising pollution levels from land-based sources. Abbu and Lyimo (2007), for instance, observed a concentration of faecal bacteria in excess of the World Health Organization and US Environmental Protection Agency standards for bathing in proximity of mangrove forests in Dar-es-Salaam.

3.2.4 Institutional framework and stakeholders

The reader may refer to section 3.1.3 for a discussion of the institutional framework and stakeholders for the tourism and coastal recreation sectors.

3.3 FISHERY SECTOR[4]

3.3.1 Characterization of current state

The area of sea defined by the United Nations' Food and Agriculture Organisation (FAO) as the Western Indian Ocean – that comprises Comoros, Kenya, Madagascar, Mauritius, Mozambique, Réunion (France), Seychelles, Somalia, South Africa, and Tanzania (including Zanzibar) – covers approximately 8% of the world's oceans and is responsible for the generation of 4.8% (4.5 million tonnes) of the total global fish catch (FAO 2009). Fisheries statistics published by FAO indicate that there has been a slow increase in the marine catch between 1997 to 2005 in the Western Indian Ocean fishing area (FAO, 2009) – see Figure 3.

[4] This section is based on the UNEP/GEF report (2009).

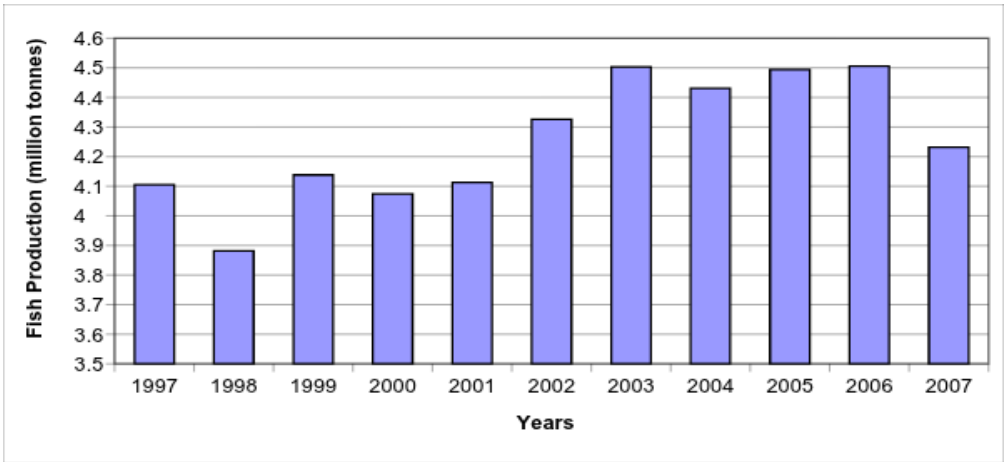

Figure 3: Total marine catch in the Western Indian Ocean (Source: FAO Fisheries Statistics, 2009)

Most of the commercial fisheries of the region are subjected to harvesting by the coastal states but the higher value oceanic resources are harvested mainly through purse seining and long-lining by foreign fishing vessels from Europe and Eastern Asia, with trans-shipment and canning in the region, primarily for export (FAO, 1997). The reliability of these fisheries data can be questioned. While some of the statistics appear to be sound, catch records submitted to the FAO are often under-reported and there may be distortions of actual fish landings, both from artisanal and the commercial/industrial sub-sectors. This is the situation for much of central and northern Mozambique, most of Tanzania and Kenya and, most likely, large parts of Madagascar (van der Elst et al. 2005; Jacquet et al. 2007; 2008). Consequently, use and interpretation of these data should be treated with caution.

3.3.2 Economic significance of the fishery sector in the NMC

In this study, we focus our attention on the NMC fishery sector. The NMC fishery sector can be divided into two main segments: industrial/commercial and artisanal/community based fisheries. Commercial fishing is performed with large/medium sized ships and operated with fishing companies from other countries like Japan and Spain. Most fish that these boats catch is exported. The team coordinated by Professor Rashid Sumaila worked at improving the quality of fisheries data for the region and computed the economic landed value of commercial fisheries, disaggregated at the province level (Table 7 and Figure 4). Figure 4 shows that there is a rich spatial distribution of economic landed value of commercial fisheries among the NMC region. As we can see, the coast of Mozambique is characterized by the lowest economic values in the region, immediately followed by the provinces of the south of Tanzania. Figure 4 also informs us that these ecosystem services are of particular value for the SIDS in the region, particularly to the Seychelles. Finally, Madagascar is characterized by the highest economic values in the region, which is particularly true for the west coast, bordering the NMC region.

On the other hand, artisanal/small-scale fishing[5] is performed with small boats, close to shore and mainly for local consumption. Table 8 provides an overview of artisanal fisheries

[5] Definition of artisanal fisheries (FAO Glossary): T*raditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, definition varies*

activities in the NMC region. Small-scale fisheries make key contributions to food security, sustainable livelihoods and poverty reduction, yet to date the economic value of small-scale fisheries has been poorly quantified (Barnes-Mauthe et al., 2013; Allison and Ellis, 2001; Satia and Staples, 2003; FAO, 2005; Béné et al.,2007; Garcia and Rosenberg, 2010). Artisanal fisheries are conducted in all coastal habitats, including sandy beaches, estuaries, coral reefs, lagoons, wetlands, bays, and mangrove forests and seagrass beds. While artisanal fishers may not venture directly into oceanic waters, they do harvest considerable numbers of oceanic and pelagic fishes, when such species move closer inshore. These small-scale fishers supply a wider range of domestic markets and some sell their catch to middle-men for export. Although typically individual daily catches per fisher are no more than a few kilograms, the collective total of the large number of fishers is considerable (UNEP 2009). In the case of Tanzania, Kenya, Comoros and Madagascar, this account for more than 80% of their countries' total marine catch.

Table 7. Overview of landed fish value statistics per country

Country	Province	Landed value (million US$/year, 2010)
Comoros		4.81
Madagascar	**Antsiranana**	24.45
	Fianarantsoa	12.27
	Mahajanga	26.09
	Toamasina	19.95
	Toliary	16.15
Mayotte		2.79
Mozambique	**Cabo-Delgado**	2.84
	Gaza	1.77
	Inhambane	8.36
	Maputo	4.55
	Nampula	3.03
	Sofala	5.26
	Zambezia	6.22
Seychelles		25.72
Tanzania	Dar-es-Salaam	1.8
	Kaskazini-Pemba	1.23
	Kaskazini-Unguja	1.17
	Kusini-Pemba	0.81
	Lindi	6.94
	Mtwara	1.25
	Pwani	7.05
	Tanga	2.91
	Zanzibar South and Central	1.25
	Zanzibar West	1.69

Note: Administrative regions and countries within the NMC region are highlighted in **Bold**. *Source: Sumaila et al. 2013*

The following paragraphs describe the salient features of the fishery sector for NMC countries, taking into account these two segments, i.e. industrial/commercial and artisanal fisheries.

between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20-m. trawlers, seiners, or long-liners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. They are sometimes referred to as small-scale fisheries.

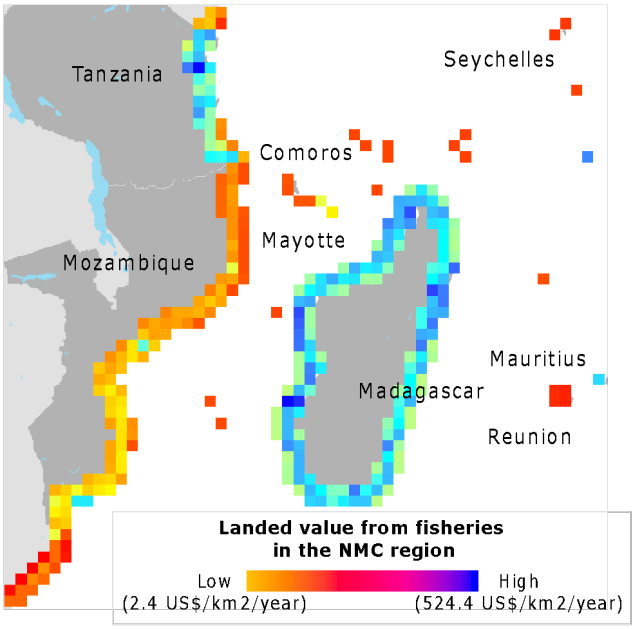

Figure 4. Map of estimated landed value from fisheries in the Western Indian Ocean

Table 8. Overview of selected artisanal fishing statistics per NMC country

Country	No. artisanal fishers	Artisanal catch (t/yr)	Principal fish families
Comoros	8,000	5,500 - 7,507 – 13,500 ('97)	Scombridae, Gempylidae, Decapterus
Madagascar	10,651	12,382 – 70,000	Mugilidae, Serranidae, Carangidae, Gerridae, Hemiramphidae, Elopidae
Mozambique	70,000	100,000 – 120,000	Siganidae, Monacanthidae, Labridae
Seychelles	1,700 – 1,800	4,000 – 5,000	Carangidae, Sphyraenidae, Scombridae, Siganidae, Serranidae, Scaridae
Tanzania (including Zanzibar)	58,000	70,000	Lethrinidae, Serranidae, Siganidae, Mullidae, Lutjanidae, Carangidae, Scombridae, Cluepidae

Source: UNEP (2009), adapted.

Comoros

Most of the fish production in Comoros is for local consumption and represents an important source of food security, but some fisheries production has generated export earnings since the latter part of the 1980s. It has been estimated that up to 30,000 tons of fish could be landed per year from the Comorian EEZ, using vessels equipped for deep-water fishing for both demersal species (e.g. snappers) and oceanic species like tuna. The fisheries agreement between the European Union and Comoros (2005 to 2010) is based on a catch of 6,000 tonnes per year, taken by European vessels (Spain, Portugal, Italy and France) in the Comoros EEZ waters (www.ec.europa.eu/cfp/bilateral agreements/Comoros).

The fisheries on all three of the Comoros islands are mainly artisanal, using pirogues and vedettes, some powered by engines and equipped with hand-lines, gill-nets and traps. Being largely volcanic, with little continental shelf, many operators also fish in deep water with lines for tuna, tuna-like species and oilfish (*Ruvettus ruvettus*), accidentally also taking coelacanths (locally *Gombessa*) at times. Closer to shore, large shoals of scad sp. (*Decapterus sp.*) are an important target for fishers and a valuable source of food at local markets. Unfortunately, very few investigations have to date been undertaken and documentation of catch, effort and species diversity is scarce and outdated (Williams, 1988; Walmsley *et al*., 2006). Comoros often fails to submit annual reports on fisheries to regional management bodies such as IOTC (IOTC, 2007). The annual productivity per unit area of the Comoros fishing grounds was believed to be about 7 tonnes/km^2 which is higher than the 5 tonnes/km^2 often assumed for highly productive coral reef grounds (Williams, 1988). In 1985 the total catch was calculated to be 5,500 tonnes, increasing to 9134 tonnes in 1990 and 14 115 tonnes in 2003. The average catch comprises of 70% pelagic species, 10% shark and 5% reef species such as Lethrinidae.

Madagascar

This large island state has an enormous coastline with a great diversity of fisheries, many of which provide critical socio-economic support and food security to the nation. Deepwater, offshore resources are accessed by about 100 industrial vessels that land about 25,000 tonnes a year, mainly tuna for export. The industrial shrimp fisheries, shallow and deep water, are similarly an important foreign exchange earner in Madagascar with over 7,600 tonnes landed in 1995 (FAO, 1997), increasing to 11,500 tonnes (FAO, 2003a). Artisanal shrimp fishing also takes place, mostly of a high quality and supplied directly to large processing plants. Shrimp fishing is seasonal from March to October (FAO, 2003b). Small pelagics are also important and in the late 1980s it was estimated that the fishery for this resource had a potential yield of 135,000 tonnes for the west coast and 11,800 tonnes for the east coast (Ralison, 1987).

Small-scale fishing is composed of 'traditional' fishers harvesting on foot or from dugout canoes and artisanal fishers using motorised boats that have an engine capacity of less than 50 horsepower (Soumy, 2005). Madagascar has about 80,000 traditional fishers, some of whom are engaged full-time and others part-time (Soumy, 2005). These fishers contribute significantly to the enrichment of the population's diet and in 2002 were responsible for about 53% of the total marine fish catch (Soumy, 2005). Artisanal gear types typically include various gill-nets, traps and beach seines.

Mozambique

Currently the fisheries sector contributes approximately 1.6% to the Gross Domestic Product (GDP) and is one of the largest generators of foreign exchange in Mozambique (National Institute of Statistics 2010, USAID 2010), with export of shrimp from Sofala Bank contributing to about 40% to the foreign revenue generated in the late 1990's (FAO, 1997). The contribution made by fish, including shrimp, has however dropped substantially in recent years, in part attributable to greater export earnings in other sectors, amounting to only 5.4% of total export value in 2005 (Macia, 2004; FAO, 2007b). The total marine fishery production is estimated at between 100,000 to 120,000 tonnes per year with domestic consumption estimated at 7.5 kg per capita (Hoguane *et al*., 2002). In 2009 the total

commercial catch was composed by 5,395 tons of shallow water shrimp; 1,448 tons of deep water shrimp; 649 tons of fish; 100 tons of langoustine; 74 tons of crab; 42 tons of cephalopods and 4 tons of lobster (USAID, 2010 and Turpie and Wilson, 2011)

Deepwater fishing by about 150 industrial and semi-industrial vessels earns the country close to US$ 100 million each year (US$ 96 million in 2005; FAO, 2007b). These landings include a variety of resources, including valuable deep water lobsters, langoustine and pink prawn. Sport line-fishing, mainly by South Africans, has increased significantly since 1992, and with little or no control in the southern waters of Mozambique. Many cases of "sports" fishers exporting quantities of valuable linefish to South Africa have been reported (Massinga and Hatton, 1996), although a draft new linefish management plan is likely to provide better control. Apart from fish and shrimp, other important exploited resources near urban centres include invertebrates such as crabs, clams, and sea urchins (WIOFish 2008).

While industrial fishing, at various levels, contributes significantly to overall landings, artisanal fisheries provide livelihoods for more than 70,000 fishers and their families, whilst also providing food to a large section of the population on the coast and in the hinterland. The number of artisanal vessels has been estimated at 15,000 (IDPPE, 2004; Hoguane *et al*., 2002). Wooden, non-motorised canoes are commonly used to reach fishing grounds, while hand-lines, cast-nets, beach seines, gill-nets, trap, cages and trolling lines are popular gear types. Although extensive data collecting systems are in place (Baloi *et al*., 1998) the historic data of artisanal landings appears to have been considerably under-reported (Jacquet *et al*., 2008).

Seychelles

The fishery sector is one of two major foreign exchange earners, along with tourism, and comprises industrial, semi-industrial and artisanal fisheries. In 2005, Seychelles earned US$ 192 million from tuna exports, equal to 41% of total export value for that year, (FAO, 2007b), derived mainly from the industrial fishery. The artisanal fisheries are also of great importance in terms of food security, employment, and cultural identity in the Seychelles. The total catch from the artisanal sector has remained fairly stable since 1985 with landings typically ranging between 4,000 and 5,000 tonnes per year (Robinson *et al.*, 2004).

The artisanal fishery sector employs approximately 1,800 fishers (Murray and Henri, 2005) and utilises 400 vessels (Azemia and Assan, 2006). Spiny lobster, crab, octopus and sea cucumber are very important resources in this sector, constituting valuable export products. Smaller boats (pirogues) of 5-16 meter length are used for more inshore areas, with hand-line, trapping, various nets and SCUBA diving gears used widely.

The main fishing grounds in Seychelles for the semi-industrial fleet are the offshore banks and drop-offs of the Mahé Plateau. Fishers use fully decked inboard vessels ('schooners') and fish with handlines, especially for the popular "Bourgoise" being the emperor snapper *Lutjanus sebae* (WIOFish, 2008). Most of the catch is sold and consumed locally, meeting the demands of the tourism industry, but a small percentage (< 5%) is exported (Azemia and Robinson, 2004).

Tanzania

In Tanzania freshwater catches outweigh marine landings. Data for 1984 - 1995, show marine fish landings ranged from 45,000 - 59,000 tonnes for mainland Tanzania (including

from Mafia Island) and 15,000 - 20,000 tonnes for Zanzibar (TCMP, 2001). The combined annual total of about 70,000 tonnes is a realistic figure for a fishery that employs an increasing number of fishers, estimated at 58,000 in 2000, who land about 90% of all catches (TCMP, 2001).

The coral reefs of Tanzania support 70% of the marine artisanal catches (Ngoile and Horrill, 1993), landed from dhows, outrigger canoes and canoes, using gill-nets, beach seines, hand-lines, fixed traps, basket traps, poison, dynamite and spear guns. Most fish caught from inshore waters by artisanal fishers are demersal, but large pelagic species (e.g. tunas) and small pelagic species such as sardines are also important. Others are sharks, rays, crustacean, octopus and squid (Jiddawi and Stanley, 1999). In addition, shrimp exports are an important source of foreign exchange. The trawling companies operate as joint ventures between Tanzanian and foreign companies (TCMP, 2001), and combined with the artisanal contribution, the shrimp fishery (for export) is worth over US$ 6 million annually.

Along much of the coast, the collection and fishing of marine products is without restriction or size limitation, and there is little monitoring, control or surveillance of the artisanal fishery. Some species of sea shells and sea cucumbers are now considered to be over-exploited, driven by the export market (Marshall *et al., 2001)*. There have been few population studies of commercially exploited species, however traders claim that the sizes have reduced tremendously. Shark fin trade has also declined and some fish species are now rarely seen in Tanzania waters (Barnett, 1997; Jiddawi and Shehe, 1999).

Artisanal fishing, though an important activity for the coastal population, has contributed to the severe degradation of the marine environment and reduced overall catches. Destructive fishing techniques continue to be widely used with considerable damage, especially to coral reefs (e.g. from dynamite fishing, drag nets and spear-guns). In Tanga for example, the coral reefs were severely damaged during the 1980s by dynamite fishing as evidenced by the present fractured massive framework of coral colonies, craters and rubble patterns, exacerbated by anchoring techniques employed by artisanal fishers, and reducing the recruitment rate of many species (Francis *et al*., 2002).

At the artisanal level, over 160 different fishing activities have been identified in five WIO countries, ranging from passive trap net fishing conducted at village level to extensive beach seine operations (Van der Elst *et al*., 2005; WIOFish, 2008). These authors conclude that the majority of the region's artisanal fisheries are not adequately supported by scientific information and that management strategies need to be improved if the enormous development and food security challenges of East African countries are to be met.

3.3.3 Discussion

In general, the Western Indian Ocean is considered not as productive (0.15 ton/km^2) as some of the other FAO fishing areas such as the northwest Pacific (1.03 ton/km^2) and the northeast Atlantic (0.65 ton/km^2). This can mostly be attributed to the absence of any large nutrient upwelling systems in the region but is possibly compounded by the under-reporting of catches (van der Elst et al. 2005). But according to the FAO statistics, this economic activity has recorded an increase in the last decade and today the fisheries sector is among the largest generators of foreign exchange in the countries located in the NMC region. Furthermore, statistical results inform that the artisanal fishery sector plays a fundamental role in the economy, informing the policy maker that this sector is not only important in terms of provision of protein to the local coastal communities but also supply a wider range

of domestic markets and export. Although typically individual daily catches per fisher are no more than a few kilograms, the collective total of the large number of fishers is considerable (UNEP 2009). In the case of Tanzania, Kenya, Comoros and Madagascar, this account for more than 80% of their countries' total marine catch. The recognition of these two, and distinct, fishery segments is of crucial importance in the design of future potential policies: each segment is characterized by distinct beneficiaries, each activity addresses different fish species and each segment makes the use of distinctive types of boats, both in terms of dimension, technology, and capacity of extraction of fishery resources from the sea.

3.4 MARICULTURE

3.4.1 Characterization of current state

Aquaculture is estimated to be the fastest growing animal production sector worldwide and possibly a key sector to deliver on food security and poverty alleviation in Africa (Troell et al., 2009). Such fast growth is observed in particular for mariculture, i.e., the aquaculture sector that revolves around the growth of marine organisms in seawater environments.

In the countries making up the NMC region, there is limited historical tradition in mariculture and the sector can still be considered in its infancy but both the public and private sectors increasingly recognize its huge potential for future development. For the year 2005, i.e., the year of maximum production so far, the Sea Around Us project's Global Mariculture database (Sea Around Us Project 2011; http://www.seaaroundus.org, accessed December 2014) puts the total mariculture production in the NMC region at 10.3 million tons[6]. Crustaceans farming (shrimps, lobster and crabs) make up the vast majority of this production (9.6 million tons) with various species of demersal fish (0.6 million tons) and oysters (3,000 tons) accounting for the remaining production. Most of the shrimp production is concentrated in Madagascar (7.7 million tons) and Mozambique (1.2 million tons). Figure 5 shows the temporal evolution of the aggregated mariculture production between 1970 and 2010 in the Western Indian Ocean, subdivided by country and commercial group[7].

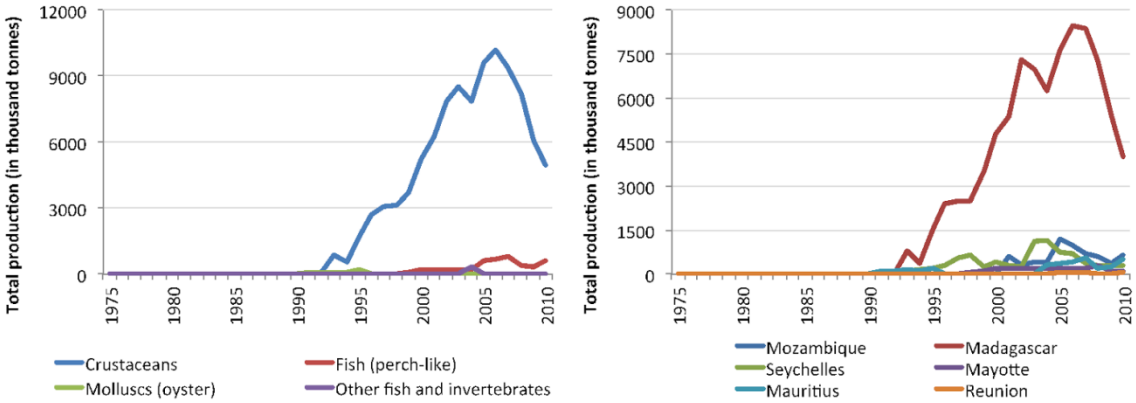

Figure 5: Mariculture production in the Western Indian Ocean in 1970-2010 by commercial species group (left) and country (right). Source: Sea Around Us Project 2011

[6] Tanzania and the French territories in the Mozambique Channel are not included in this statistic due to lack of data.

[7] Data for Flacq and Riviere du Rempart provinces of Mauritius are available until 2006. Data for Pamplemousses province of Mauritius are available until 2005.

Fish farming in the region started in the 70's, and commercial seaweed and shrimp farming activities were started in 1989, in coastal Tanzania and Seychelles, respectively before spreading to Madagascar and elsewhere (Mapfumo, 2009; Bryceson and Beymer-Farris, 2009). Cultivation of marine species emerged in the late 90's as an important regional economic sector and has primarily focused on local marine shrimp species such as Giant tiger prawn and Kurama prawn (*Penaeus* spp.) and seaweed (*Kappaphycus alvarezii* and *Eucheuma* spp., FAO, 2014). Shrimp farming typically involves commercial, semi-intensive farming (high input – high output), while seaweed farming generally occurs in extensive (low input – modest output) mariculture, often for subsistence purposes (FAO, 2014).

Although a small producer at global scale, Madagascar is the leading country in shrimp mariculture in Africa with an area of 2,228 hectares covered by shrimp ponds (Iltis and Ranaivoson, 2009). Madagascar experienced a severe crisis in 2008 due to increased international competition, declining shrimp prices, and rising cost of energy and fishmeal (Iltis and Ranaivoson, 2009), resulting in closure of two of the six commercial farms.

FAO (2014) reports three commercial shrimp mariculture enterprises operating in Mozambique, in Beira (Sofala Province, 500 ha), Quelimane (Zambézia province, 1,000 ha) and Pemba (Cabo Delgado province, 980 ha), and seaweed farms in Cabo Delgado province (from Pemba to Macomia and Quirimba archipelago) and Nampula province (between Angoche and Nacala). Such systems are commercial enterprises, managed by foreign investors from France and China (Mapfumo, 2009). Small-scale prawn farming in Mozambique is limited to three farms in Beira and Angoche, which produce prawns in 4-6 hectares ponds under extensive conditions (Omar and Hecht, 2009). In Tanzania, the first commercial shrimp farm was established on Mafia island in 2005 (Bryceson and Beymer-Farris, 2009). In the Seychelles islands, the first (and only) commercial shrimp farm was established in 1989 and remained in operation until 2008, producing in 2004 a peak of 1,200 tons and employing 350 people (Lesperance, 2009).

Fish mariculture in the Western Indian Ocean region is primarily located in Mauritius, Réunion and Mayotte (see Table 9). Réunion and Mayotte have several commercial red drum and goldline seabream farms, which started operation recently, in the 1999-2008 period. Both countries are heavily advancing their mariculture sectors, primarily due to the undersupply of local fishery (Lesperance, 2009).

Oyster cultures are primarily located in Seychelles (in Praslin since 1994) and Tanzania (in Zanzibar and Mafia since 2006) (Bryceson and Beymer-Farris, 2009; Lesperance, 2009). As far as other commercial groups are concerned, recent trends include the emergence of farming of sea cucumber (*Holothuria scabra*) and *Spirulina* in the south-west coast of Madagascar, although the mariculture sector in this country still firmly relies on shrimp farming. Table 9 shows the disaggregation of mariculture production by species and province in NMC countries in 2010 or the latest available year.

Seaweed is valuable for the extraction of gelling substances (carrageenan, agar or alginates), which are used in the food, textile, cosmetic and pharmaceutical industries (Bryceson and Beymer-Farris, 2009; Semesi, 2009). Its culture is practised particularly in Mozambique and Zanzibar (Tanzania), and the extract is exported, such as to Belgium, France and USA (Troell et al., 2009; Mmochi, 2009).

Table 9. Mariculture production (in tons) at species and province level in NMC countries for year 2010 or most recent available year. Source: Sea Around Us Project 2011

Country	Province	Species and commercial group			
		Crustaceans		Fish (perch-like)	Total
		Giant tiger prawn	Kuruma prawn	Red drum	
Mozambique	Maputo	34	33	-	67
	Sofala	67	67	-	134
	Zambezia	234	233	-	467
Madagascar	**Antsiranana**	1,200	-	-	1,200
	Mahajanga	1,440	-	-	1,440
	Toliary	1,360	-	-	1,360
Seychelles	Amirantes Alphonse Coetivy	300	-	-	300
Mayotte		-	-	100	100
Total		4,635	333	100	5,068

Note: Administrative regions and countries within the boundaries of the NMC region are highlighted in **Bold**.

Seaweed farming is practiced in the sand and rocky intertidal flats of northern Mozambique (Cabo Delgado and Nampula provinces) with about 70 small-scale farms and 2,000 families involved (Mapfumo, 2009; FAO, 2014), mainly as subsistence mariculture small ponds close to the shore. The 2003 production was estimated in 523 tons, with local farmers earning on average US$ 60 per month from the activity (FAO, 2014). Small-scale farming may be managed by local communities (e.g., seaweed farming in Pemba) or private firms (e.g., at Umbeluzi in Maputo province). Although technically successful, seaweed farming in Pemba has recently ended due to regulatory and export licensing problems (Semesi, 2009). Mmochi (2009) estimates the size of the seaweed mariculture production in Tanzania in the order of 5,000-9,000 tons per year, measured as dry weight. In Madagascar, seaweed farming is practiced primarily in the north and in coastal villages near Toliara, with a total production of 1,232 tons in 2007 (Iltis and Ranaivoson, 2009).

3.4.2 Economic significance of mariculture sector in the NMC

In order to estimate the economic value of mariculture in the NMC region, we rely on figures from the literature regarding the total yearly production and market prices per ton for the two main types of products, shrimps and seaweed. Following FAO (2014), we use in the calculations a market price of US$ 5,000 per ton of shrimps and US$ 200 per ton of seaweed, measured as dry weight. Semesi (2009) reports a range of US$ 60-320 per ton of seaweed for Tanzanian farmers. The same author reports an export price of US$ 300-650 per ton of seaweeds *K. alvarezii* and *E. denticulatum* for farmers in Madagascar. For shrimps, we use in the calculation the production in the latest available year from Table 9. For seaweed, we use the yearly production at country level for Mozambique, Madagascar and Tanzania as presented in the previous section. Table 10 presents the estimated yearly monetary value of shrimp and seaweed mariculture in NMC countries and their geographical distribution in the region.

In monetary terms, shrimp production provides a substantially larger contribution to the national economies than seaweed production. However, one should notice that the prices seaweed farmers currently receive are currently low partly due to the fact that they sell the raw, unprocessed product since they lack the industrial facilities for local processing. Moreover, a single buyer often controls the market and is thus able to maintain prices low. The market price for refined carrageenan is much higher and contributes to a global market

with a size of US$ 10 billion and yearly growth rate of 3-5% (Semesi, 2009). Overall, the size of the mariculture sector in NMC countries is relatively small in terms of its contribution to the Gross Domestic Product (GDP). For Madagascar and Mozambique the total value of mariculture from Table 2 amounts, respectively, to 0.22% and 0.04% of the GDP of year 2010 in current US$ as estimated by the World Bank (http://data.worldbank.org/indicator/NY.GDP.MKTP.CD).

Table 10. Estimated yearly monetary value of mariculture production in NMC countries

Country	Province	Value of shrimp production (thousand US$ / year)	Value of seaweed production (thousand US$ / year)
Tanzania		-	1,400
Mozambique		3,340	105
	Maputo	335	-
	Sofala	670	-
	Zambezia	2,335	-
Madagascar		20,000	246
	Antsiranana	6,000	-
	Mahajanga	7,200	-
	Toliary	6,800	-
Seychelles		1,500	-
	Amirantes Alphonse Coetivy	1,500	-

Note: Administrative regions and countries in the NMC region are highlighted in **Bold**.

It is important to note, however, that fisheries and mariculture play a role in NMC countries' economies and societies that goes well beyond the commercial value of the produced and exported species. Mariculture may be a key factor in improving food security and opportunities for socio-economic development and poverty alleviation (e.g., as a source of proteins, income and jobs). It is estimated that a total of 95,000 people are directly employed in fisheries and aquaculture sector in Mozambique (Ministry of Fisheries, 2004; Omar, 2005), 90 percent of whom in the artisanal sector and that, in 2004, commercial shrimp farming provided employment for 1,492 people (Aquaculture Department, 2004; FAO, 2014). Extensive, subsistence seaweed farming in Mozambique is practiced by estimated 2,200 people (FAO, 2014). Respectively, 80 and 30 percent of the producers and workers employed in processing the product of seaweed farming are women (Aquaculture Department, 2004). In Tanzania, reportedly more than 90 percent of seaweed farmers are women and more than 20,000 people are involved with seaweed farming in Zanzibar (Nayaro, 2005; Semesi, 2009). In Madagascar, seaweed and prawn farming provide jobs to, respectively, 256 farmers (primarily in Nosy Ankao Island) and 5,670 farmers and industrial employees (Iltis and Ranaivoson, 2009; Semesi, 2009).

3.4.3 Discussion

Due to the favorable climatic conditions, low levels of pollution, low human population densities, and the existence of wild native species (e.g., giant tiger prawn, Indian white prawn, kuruma prawn, and speckled shrimp) there is a high potential for aquaculture to play a much larger role in the economy of the NMC region in the future (FAO, 2014).

Current estimates suggest that along the entire 2,780 km of Mozambique's coastline, 77,592 hectares of land are available for mariculture in ponds, 32,194 hectares for cultivation in floating cages and 10,591 hectares for the cultivation of seaweed, without

conflicting with populated areas or protected nature reserves (Xerinda, 2011; FAO, 2014). The total area identified as suitable for finfish and prawn mariculture in Tanzania is estimated in 3,000 hectares (Mmochi, 2009).

The different typologies of the coastal environment in the south, center-north and north Mozambique coastline are likely to favour different type of mariculture development (Ribeiro, 2011). Shrimp ponds are typically located on estuarine intertidal mud flats in proximity of mangrove forests, which prevail in the south and center-north, and may thus represent a threat to this habitat if expanded. All shrimp farms in Mozambique treat their effluent using settlement ponds and mangroves as natural biofilters (FAO, 2014) with little known consequences of the ecological impacts on such ecosystem. Moreover, prawn farms, such as in Mafia island in Tanzania, tend to be abandoned after few years of operation, with foreign corporations moving to new areas and leaving the original sites behind as a polluted and impoverished land (Bryceson and Beymer-Farris, 2009). From this perspective, the experience with environmental and social management of shrimp farming in Madagascar is a more positive one, with mangroves not being threatened by ponds since the latter are constructed exclusively on salt flats (Iltis and Ranaivoson, 2009). For comparison, a similar scenario is observed in Kenya. Due to the high tidal range (4 m), the lower half of the range tends to be covered by mangroves and the upper one by salt flats. Constructing ponds in the salt flats benefits thus from the protection of the mangrove trees while, on the other hand, constructing in the mangrove zone requires very high and expensive man-made walls (D. Obura, personal communication). Marine seashore and bays, either rocky or coralline, are more favorable for finfish, seaweeds and bivalves (Ribeiro, 2011). In Mozambique, potential conflicts may emerge in the north coast, which is rich in these habitats, with the developing natural gas and oil industry in locations such as the Bay of Pemba, where mariculture ventures may come to clash with the current exploration and, potentially, future exploitation of natural gas and oil resources (Schoenherr and Quatmann, 2011).

With regards to tourism, according to FAO (2014) there is currently little competition in the areas suitable for mariculture development in Mozambique. Bryceson and Beymer-Farris (2009), however, observed how the expansion of coastal tourist hotels in Tanzania has caused many seaweed farmers to lose access to farming areas in the intertidal zone and drying areas on the upper shoreline. It seems likely that such conflicts between tourism and mariculture development may increase with the further expansion of the two sectors.

Bryceson and Beymer-Farris (2009) identify in farming of molluscs (e.g., oysters, cockles and mussels) and fish farming of algal/detritus-feeders (e.g., mullet, milkfish) and herbivores (e.g., rabbit-fish) a more sustainable solution for the mariculture sector compared to shrimp and seaweed farming. This is due to the small-scale of these systems, low use of chemicals, low frequency of disease outbreaks, and better options for wastes recirculation and reuse.

3.4.4 Institutional framework and stakeholders

Due to the high potential for development of this activity, both freshwater and coastal aquaculture rank among the top priorities on the agenda of governments in the region, such as in Mozambique and Seychelles (Halafo, 2011; Lesperance, 2009). In the past, assistance has also been provided by non-governmental, inter-governmental organizations (such as FAO and UNDP), and foreign governments such as France, in Mozambique, and Japan, in Mauritius and Madagascar (Mapfumo, 2009; FAO, 2014; Lesperance, 2009).

The regulatory framework for development of aquaculture and mariculture in Mozambique primarily involves assistance from the Ministry of Agriculture and the Ministry

of Fisheries (through its Institute of Aquaculture Development) in the form of training and extension services (Mapfumo, 2009). The current government strategy revolves around the Aquaculture Development Strategy 2008-2017, which was approved by the Council of Ministers in 2007, and focuses on increasing the production by encouraging clustering of smallholder farmers, establishing large farms – with the additional benefit of catalysing the development of smallholder farmers – and attracting (foreign) investors with an eye on export markets (Mapfumo, 2009). The Government strives to pursue such objectives through a policy that involves incentives to (foreign) investments, such as general and specific fiscal benefits, as well as a favourable legal and taxation framework (Sambo, 2011).

In Madagascar, the prawn farming industry has been regulated by the Shrimp Aquaculture Master Plan since 2007. This aims at promoting sustainable small-scale and family-based prawn culture and has so far been successful at promoting more environment-friendly practices than in other NMC countries (Iltis and Ranaivoson, 2009; Lesperance, 2009).

3.5 CARBON SEQUESTRATION IN COASTAL ECOSYSTEMS

3.5.1 Characterization of current state

The benefits of the regulating service of carbon sequestration provided by terrestrial, coastal and marine ecosystems are expressed in the form of mitigation of climate change. Coastal ecosystems are increasingly recognized for their important role in sequestering and storing carbon dioxide from the atmosphere: such service is generally referred to under the term “blue carbon” (Nellemann et al., 2009). Among vegetated coastal habitats, mangroves, salt marshes and seagrasses are known to be substantially more efficient per unit area than terrestrial forests in burying carbon dioxide (McLeod et al., 2011). Table 11 presents the average carbon burial rate estimated by McLeod et al. (2011) for each of these three ecosystem types.

Table 11 Estimated average global carbon burial rate by vegetated coastal habitats

Ecosystem	Carbon burial rate (±SE) (tC/ha/year)
Salt marshes	2.18 ± 0.24
Mangroves	2.26 ± 0.39
Seagrasses	1.38 ± 0.38

Source: Adapted from McLeod et al. (2011). SE = standard error

Pendleton et al. (2012) show how the loss of these ecosystems does not simply involve foregoing the carbon sequestration service performed by these ecosystems, but may also result in the release of large quantities of carbon that were previously stored in the soil. Globally, the annual release of carbon dioxide by land-use changes in coastal ecosystems is estimated at 0.45 Pg/year, equivalent to 18.5 billion US$/year in economic cost due to increased climate change (Pendleton et al., 2012). The majority of this release is attributed to a loss in mangroves (53%) and seagrasses (33%), while the remainder is due to losses in tidal marshes (14%).

Per unit area, mangroves provide on average the highest carbon sequestration services, with salt marshes being close second. Carbon is buried in mangrove forests mainly through the sedimentation of carbon-rich mud, with intertidal mudflats - often lying seawards to mangrove forests – possibly accumulating more carbon than the mangroves themselves

(Andreetta et al., 2014). Other factors in the carbon retention processes in mangroves include carbon exchanges with the ocean, root-to-soil carbon transfer, and various processes linked to the macrobenthos (e.g., crabs) (Andreetta et al., 2014). In the context of the NMC countries, the largest extent of mangrove forests is found in Mozambique (3,054 km^2), followed by Madagascar (2,059 km^2) and Tanzania (809 km^2) (Fatoyinbo and Simard, 2013). Mangroves in Madagascar are located almost exclusively on the west coast. In Mozambique, mangroves are found along the entire coast, constituting the third largest mangrove area in Africa. In terms of biomass, Fatoyinbo and Simard (2013) estimate that the largest biomass per hectare is found in Tanzania (136 ton/ha), followed by Madagascar (121 ton/ha) and Mozambique (101 ton/ha). Fatoyinbo et al. (2008) find no correlation between mangrove biomass or height and latitude in Mozambique, although the average biomass per hectare shows substantial variation between provinces, ranging from 207 ton/ha in Gaza and 67 ton/ha in Inhambane (Table 12).

Table 12. Estimated mangrove height and biomass by province in Mozambique

Province	Average height (±SD) (m)	Biomass (ton/ha)	Total biomass (ton)
Maputo	3.7 (±2.7)	72	964,101
Gaza	15.9 (±7.9)	207	70,810
Inhambane	4.0 (±4.4)	67	2,238,038
Sofala	4.8 (±3.3)	84	9,187,137
Zambezia	5.8 (±3.2)	97	7,874,952
Nampula	4.7 (±2.5)	84	3,247,788
Cabo-Delgado	6.3 (±2.9)	102	2,841,468

Note: Provinces within the boundaries of the NMC region are highlighted in **Bold.** SD = standard deviation. Source: Adapted from Fatoyinbo et al. (2008).

3.5.2 Economic significance of coastal carbon sequestration in the NMC

For the assessment of the value of carbon sequestration regulating service, we rely on the average carbon burial rates by McLeod et al. (2011) and the distribution of the three aforementioned coastal ecosystems as derived from high-resolution spatial datasets. For seagrasses, we use the global distribution of seagrasses produced by UNEP-WCMC (Green and Short, 2003; UNEP-WCMC, 2005). The area coverage of seagrasses in the NMC region has not yet been adequately assessed (Hantanirina and Benbow, 2013; Pierre, 2012): the area extent used in this study may thus represent an underestimate of the distribution of this habitat. For mangroves, we rely on the World Mangrove Atlas compiled by UNEP-WCMC in collaboration with the International Society for Mangrove Ecosystems (Spalding et al., 1997). The distribution of coastal wetlands and salt marshes is derived from Lehner and Döll (2004). For the purposes of this study we extracted the “Coastal wetlands” and “Pan, brackish/saline wetland” categories from the global database to characterize the distribution of coastal wetlands and salt marshes in the NMC region. Particular attention is paid to avoid double-counting mangroves from the Spalding et al. (1997) database and coastal wetlands in the same grid cell. Given that some of the investigated coastal habitats are not land-based (e.g., seagrasses) and considering that administrative provincial divisions are not defined in the coastal waters, for the calculation of the aggregated area of coastal habitats at the level of provinces we rely on a 20 kilometer wide buffer from the shoreline, running perpendicularly to the land-based administrative subdivision.

Carbon burial by coastal habitats translates into a benefit for society by reducing the concentration of greenhouse gases in the atmosphere that are responsible for climate change. A micro-economic valuation of the benefits of blue carbon storage may thus rely on prices per unit of carbon, multiplied by ecosystem-specific carbon burial rate per unit of area. Aggregated values of blue carbon storage can be estimated based on calculation of the total area of each of the three ecosystems in the administrative region of concern. The appropriate monetary measure per unit of carbon is the social cost of carbon. The social cost of carbon captures the net present value of the cumulative, worldwide impact of one additional ton of carbon emitted to the atmosphere today over its residence time in the atmosphere, typically 100 years or longer (Watkiss et al., 2005). The social cost of carbon can be interpreted as the value of resulting climate damages, measured at the margin. Since the benefits of carbon sequestration and storage are not limited to a specific region but are felt globally, the social cost of carbon does not have spatial variation.

Monetary estimates of the social cost of carbon are the outcome of Integrated Assessment Models (IAMs), which capture the complex linkages between greenhouse gas emissions, greenhouse gas atmospheric concentrations, temperature change and monetary costs of climate change damage to society. A number of models and approaches have been applied in the literature to the estimation of the social cost of carbon, resulting in a wide range of magnitudes (Tol, 2009). Recently, van den Bergh and Botzen (2014) took a critical look at the current range of published estimates of the social cost of carbon, and particularly at cost categories that omitted from prior studies, discounting, and uncertainties about damage costs and risk aversion. They conclude that most previous estimates grossly underestimate the true social cost of carbon. In this study we rely on their proposed lower bound value of 125 US$/ton$CO_2$ for climate policy appraisal. Figure 6 shows the distribution of the values of carbon sequestration and storage by mangroves, coastal wetlands and seagrasses in the NMC region, as calculated with the above-described procedure. Table 13 presents the respective values aggregated at the provincial level across the region.

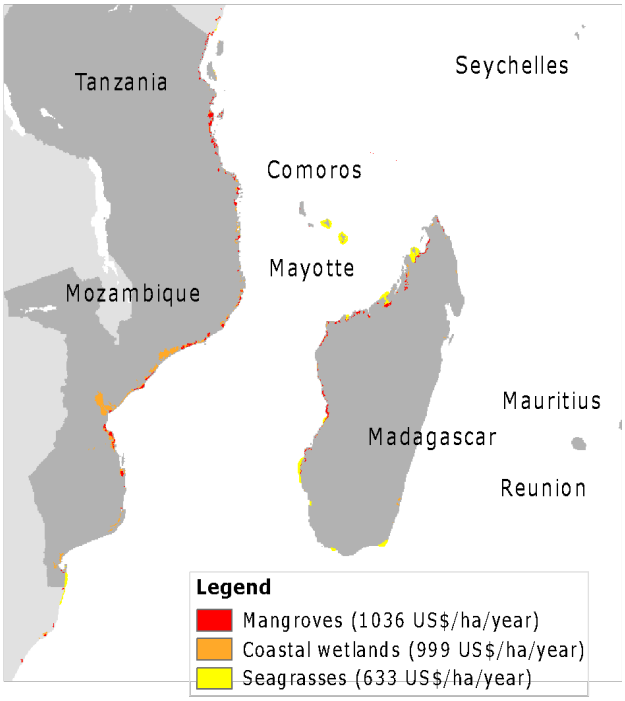

Figure 6. Estimated coastal carbon storage service values in the Western Indian Ocean

Table 13. Estimated yearly monetary value of "blue carbon" storage in NMC countries

Country	Province	Salt marshes (million US$/year)	Mangroves (million US$/year)	Seagrasses (million US$/year)	Total value (million US$/year)
Comoros		0.0	0.2	80.8	80.9
Madagascar	**Antsiranana**	28.1	57.9	111.9	197.9
	Fianarantsoa	20.7	0.0	0.0	20.7
	Mahajanga	66.9	192.6	90.8	350.2
	Toamasina	3.9	0.0	0.0	3.9
	Toliary	20.2	79.4	163.7	263.3
Mayotte		0.0	1.0	93.6	94.6
Mozambique	**Cabo-Delgado**	59.5	57.2	2.1	118.8
	Gaza	0.0	0.0	0.0	0.0
	Inhambane	99.9	47.8	0.3	147.9
	Maputo	56.6	5.5	40.6	102.8
	Nampula	77.0	59.0	0.0	136.0
	Sofala	472.7	66.4	0.0	539.1
	Zambezia	383.3	84.8	0.0	468.0
Seychelles		0.0	3.6	0.0	3.6
Tanzania	Dar-es-Salaam	3.3	4.6	0.0	7.9
	Kaskazini-Pemba	2.1	0.0	0.0	2.1
	Kaskazini-Unguja	0.0	0.0	0.0	0.0
	Kusini-Pemba	0.0	0.0	0.0	0.0
	Lindi	32.8	72.1	0.0	104.9
	Mtwara	4.1	20.3	0.0	24.4
	Pwani	12.9	115.8	0.0	128.7
	Tanga	3.5	21.2	0.0	24.7
	Zanzibar South and Central	8.4	0.0	2.5	10.9
	Zanzibar West	0.0	0.0	0.0	0.0

Note: Administrative regions and countries within the boundaries of the NMC region are highlighted in **Bold**.

3.5.3 Discussion

Mangrove ecosystems in the NMC region face challenges primarily due to conversion to other land uses (e.g., agriculture, aquaculture and urban) and forest degradation due to logging (Giri and Muhlhausen, 2008). In Mozambique, widespread losses of mangrove cover have been reported between 1972 and 2002 for the Zambezia province (about 745 km^2 lost over the thirty-year period, or almost half of the once extensive coverage) and, to a lesser extent, in Sofala and Nampula (Fatoyinbo et al., 2008). Along the entire coast and in Mozambique in particular, shellfish collection is a major cause of loss of seagrass habitat, due to the sediment digging and trampling it involves (Bandeira and Gell, 2003). Giri and Muhlhausen (2008) estimated that the extent of mangroves in Madagascar has declined by 7% between 1975 and 2005. Within the broader Mozambique Channel region, major land use changes are reported in Bombekota Bay, Mahajamba Bay, Ambanja, along the Tsiribihina river, and in Cap St Vincent. Discharge of untreated or only partially treated domestic sewage constitutes an additional and growing human disturbance for mangroves and seagrasses, whose ecological impacts are still poorly understood (Lugendo et al., 1999).

The implementation of payment for ecosystem services schemes targeting blue carbon sequestration in coastal areas region represents an important opportunity for the NMC region, as it may provide a win-win situation for environmental conservation and funding sustainable development through financial inflows (Wendland et al., 2010). Out of the 23 carbon sequestration projects in Africa that are listed by Jindal et al. (2008), six are located

in countries of the NMC region. These include three projects in Tanzania[8] (The International Small Group and Tree Planting Program, Commercial Plantation Project, The Participatory Environmental Management Programme), one in Mozambique (Nhambita Community Carbon Project), and two in Madagascar (Andasibe-Mantadia Biodiversity Corridor, Reforestation on degraded land for sustainable food production of woodchips). Although none of the six project is focusing on coastal ecosystems, this signals the opportunities for carbon sequestration programs in the NMC region, East Africa being the leading destination for carbon sequestration investors within Africa (Jindal et al., 2008). Several of the projects are reported to have produced significant benefits to local communities both in the form of cash incomes and non-timber forest benefits.

3.5.4 Institutional framework and stakeholders

The Emissions from Deforestation and Forest Degradation (REDD+) mechanism is a widely accepted international policy foundation for ecosystem-based management, which has been proposed as a blueprint for the management of blue carbon sinks (Crooks et al., 2011; Nellemann et al., 2009). Being the only country in the NMC region that benefits from a full UN-REDD National Program (www.un-redd.org), the literature on forestry-based carbon sequestration in the NMC region has focused in particular on Tanzania. Burgess et al. (2010) describe the real-world challenges faced by Tanzania in implementing REDD+. These include the lack of adequate baseline forestry data, which prevents reliable carbon accounting, a crucial pre-requisite on which to base blue carbon financing projects. In the context of the application of REDD+ schemes to mangrove forests in Tanzania, Beymer-Farris and Bassett (2012) warn against the shift in resource control and management from local, forest-reliant communities to global actors and proponents of REDD+ schemes on the basis that narratives that frame local communities as "part of the environmental problem" often misrepresent the role of local villagers. Among the additional challenges to be faced by carbon sequestration projects in Africa, Jindal et al. (2008) include: overcoming a lack of investments by international donors in the least developed countries; reducing transaction costs for negotiating, contracting, implementing and monitoring a project; guaranteeing secure property rights and land tenure; improving governance and political stability at national and local level; and building institutional capacity.

Among the most important non-institutional stakeholders, one should mention the international marine conservation organization Blue Ventures (http://www.blueventures.org/), which is currently involved in promoting community-based tropical marine conservation of blue carbon habitats as well as the promotion of eco-tourism in Madagascar, particularly in the southwestern regions (e.g., village of Andavadoaka).

3.6 COASTAL PROTECTION

3.6.1 Characterization of current state

Coastal wetlands, mangroves and near-shore coral reefs provide crucial benefits to coastal communities by protecting them from flooding and storm surges, both seasonal and idiosyncratic storm events. The benefits from this ecosystem service may include prevention of loss of life, damage to housing, infrastructure and food sources, and prevention of

[8] Of the three listed projects, the first two are joint programs with Uganda and Kenya (The International Small Group and Tree Planting Project) and Uganda (Commercial Plantation Project).

saltwater intrusion. This has been shown to be particularly important in the case of poor, vulnerable communities, which recent research shows to be often the most critically dependent on the provision of ecosystem services, among others due to their limited options to replace foregone services by natural ecosystems with man-made options (Ghermandi et al. 2013; McGranahan et al. 2007).

Four main types of coastal habitats present in the NMC region are understood to provide significant services for coastal protection: these are coral reefs, mangroves, coastal wetlands and seagrasses. Mangrove forests protect inland communities and freshwater resources from saltwater intrusion during storms, and protect near shore settlements from erosion, their roots helping to hold the sediment in place and slowing down water flow (Orth et al. 2006). Coral reefs and mangroves also minimize the impact of storms by reducing wind action, wave action and currents and coral reef structures buffer shorelines against waves, storms and floods (Adger et al. 2005). Wetlands and seagrasses found in coastal areas often function as storm buffers, dissipating both storm energy and wave energy (Costanza et al. 2008; Orth et al. 2006).

The aforementioned coastal habitats are widely distributed within the NMC region. For the present analysis we rely on high-resolution spatial distribution provided by the following sources: for mangroves, we use data from the World Mangrove Atlas (Spalding et al., 1997); for coastal wetlands we rely on the database of lakes, reservoirs and wetlands (Lehner and Döll, 2004); for coral reefs, we rely on the results of the Reefs at Risk Revisited study (Burke et al., 2011). Due to a lack of primary valuations in the literature regarding the coastal protection values of seagrasses, this coastal habitat is not included in the present analysis.

3.6.2 Economic significance of coastal protection in the NMC

To the best of our knowledge, no primary valuation study on the monetary value of the coastal protection services of coastal ecosystems is available in the NMC region. Due to the lack of primary data and following the rationale exposed in the section on coastal recreation, we rely in this section on the application of a meta-analytical value transfer methodology in combination with GIS tools to provide a first estimate of the spatially explicit values of such service in the region. The value transfer exercise relies on the methodology and results described by Rao et al. (2015) to provide average, per hectare values of the coastal protection services of mangroves, coastal wetlands and coral reefs.

Figure 7 maps the spatial distribution of the estimated flows of coastal protection values in the NMC region. The yearly flow of welfare benefits is estimated to range between 0.5 and 59.8 US$/ha/year in 2013 dollars and corrected for purchasing power parity. When interpreting such results, the reader should consider that they represent average values of the coastal habitats in the region, without consideration of the fact that coastal protection services tend to be highest in proximity of the shoreline and progressively (and, in general, non-linearly) decrease with the distance from it (Koch et al., 2009).

The economic values reported in the map are determined by the combination of the local values of the different explanatory variables that are included in the meta-regression model (Rao et al., 2015). These include: GDP per capita, human development, climatic variables such as temperature, storms frequency, and average wind speed. As expected, the modelled values tend to increase with GPD per capita of the local population, local human development, number of storms and wind speed.

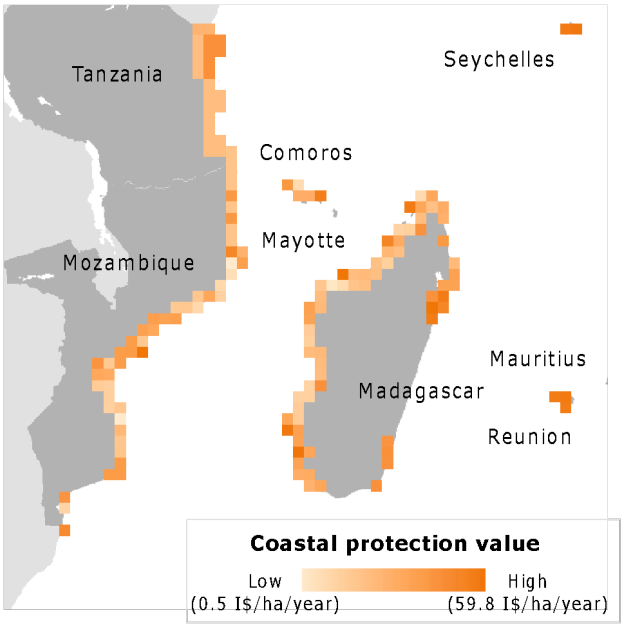

Figure 7. Map of estimated coastal protection values in the Western Indian Ocean

The overall aggregated monetary estimate of the coastal protection value of coral reefs, mangroves and coastal wetlands in the NMC region amounts to 27.4 million US$/year (2013, PPP), while the average hectare of coastal habitat in the region is valued at 9.8 US$/ha/year (2013, PPP) as far as coastal protection services are concerned. Table 14 shows the value estimates aggregated by country and administrative province.

The highest per-hectare values are found in the Seychelles, followed by the Toamasina province of Madagascar and the Mauritius Islands. At the other side of the range, the lowest values are found in several NMC regions, such as Nampula, Mahajanga, Lindi, Mtwara and Pwani. The majority of coastal protection values are accrued by coral reefs (54%).

3.1.1 Discussion

Many of the pressures and challenges described in the previous sections for mangroves, coral reefs and coastal wetlands apply to the provision of coastal protection services as well. In general, when reefs and mangroves are damaged or destroyed (for instance, due to land use conversion), the absence of this natural buffer has been shown to increase the damage to coastal communities from normal wave action and violent storms. Moreover, the structural integrity of coral reefs has also been shown to affect their effectiveness as buffers to storm surges (UNEP-WCMC 2006). No conflict exists between the provision of coastal protection and that of other ecosystem services.

Table 14. Estimated yearly monetary value of coastal protection in NMC countries

Country	Province	Average unit value (US$/ha/year, PPP)	Coral reefs (million US$/year, PPP)	Mangroves (million US$/year, PPP)	Salt marshes (million US$/year, PPP)	Total value (million US$/year, PPP)
Comoros		5.4	0.21	0.00	0.00	0.21
Madagascar	**Antsiranana**	6.7	0.91	0.37	0.19	1.47
	Fianarantsoa	13.1	0.05	0.00	0.27	0.32
	Mahajanga	3.2	0.24	0.59	0.21	1.04
	Toamasina	22.5	0.89	0.00	0.09	0.97
	Toliary	5.6	0.70	0.43	0.11	1.24
Mayotte		12.1	0.61	0.01	0.00	0.62
Mozambique	**Cabo-Delgado**	11.1	1.59	0.61	0.66	2.86
	Gaza	10.5	0.07	0.00	0.00	0.07
	Inhambane	10.6	0.00	0.49	1.06	1.55
	Maputo	7.1	0.01	0.04	0.41	0.45
	Nampula	0.8	0.05	0.04	0.06	0.16
	Sofala	6.0	0.00	0.38	2.83	3.22
	Zambezia	5.5	0.03	0.45	2.10	2.58
Seychelles		33.3	5.44	0.12	0.00	5.56
Tanzania	Dar-es-Salaam	13.9	0.23	0.06	0.05	0.34
	Kaskazini-Pemba	13.9	0.40	0.00	0.03	0.43
	Kaskazini-Unguja	6.7	0.10	0.00	0.00	0.10
	Kusini-Pemba	13.9	0.32	0.00	0.00	0.32
	Lindi	3.2	0.19	0.22	0.10	0.52
	Mtwara	3.2	0.07	0.06	0.01	0.15
	Pwani	3.2	0.23	0.36	0.04	0.63
	Tanga	3.2	0.12	0.07	0.01	0.20
	Zanzibar South and Central	13.9	0.20	0.00	0.12	0.31
	Zanzibar West	6.7	0.07	0.00	0.00	0.07

Note: Administrative regions and countries within the boundaries of the NMC region are highlighted in **Bold**.

4 ECONOMIC VALUATION TO SUPPORT POLICY DECISIONS IN THE NMC

4.1 Linking the valuation results to policy decision making

Figure 8 summarizes the results of the economic valuation exercise of the selected provisioning, regulating and cultural coastal and marine ecosystem services in the NMC region, which was presented in Section 3 of the paper. In Figure 8, the ecosystem service values for which spatially explicit estimates were derived are aggregated at the level of provinces for the coastal area of the three largest countries in the region (i.e., Madagascar, Mozambique, and Tanzania) and at the country level for the island states (i.e., Comoros, and Seychelles) and French overseas department of Mayotte. In order to avoid potential issues with double-counting of benefits, the estimated values for each of the six ecosystem services are presented and discussed separately.

The information in Figure 8 can provide guidance for policy-makers who, for instance, may be interested in identifying the areas that deliver the highest estimated flows of ecosystem service values. Such information can be useful for identifying priority areas, which may be selected for nature conservation projects or for further more in-depth analysis (e.g., as target sites for primary economic valuations of selected ecosystem services). High provisioning service values, for instance, appear to be concentrated along the west coast of Madagascar, along with high coastal tourism and carbon sequestration values. High regulating service values are estimated for several regions in Mozambique (e.g., Sofala and Zambezia). Cultural service values are highest in Mauritius, the Antsiranana and Toliary provinces of Madagascar, and Pwani province in Tanzania.

The analysis of the estimated flows of ecosystem service values is more informative if put in the context of the complex relationships established between ecosystems and human systems in each of the investigated areas. In the following section we provide a multidimensional analysis of dependence and vulnerability to changes in marine ecosystem services combining the estimated values with a series of other indicators.

4.2 Building vulnerability maps with the use of economic valuation

We use the Driver-Pressure-State-Impact-Response (DPSIR) framework to investigate the complex relationships between marine ecosystem services and the wider environmental and human systems in the NMC region. In the DPSIR framework, Drivers are the demographic, economic, cultural, socio-political or technological driving forces that underlie the Pressures exerted by human activities on the environmental system (such as habitat loss and degradation, overexploitation, climate change, pollution and nutrient load, and invasive alien species). These modify the State of the environmental systems leading to Impacts thereupon. Such Impacts may elicit policy Responses to adapt to the environmental changes or mitigate them.

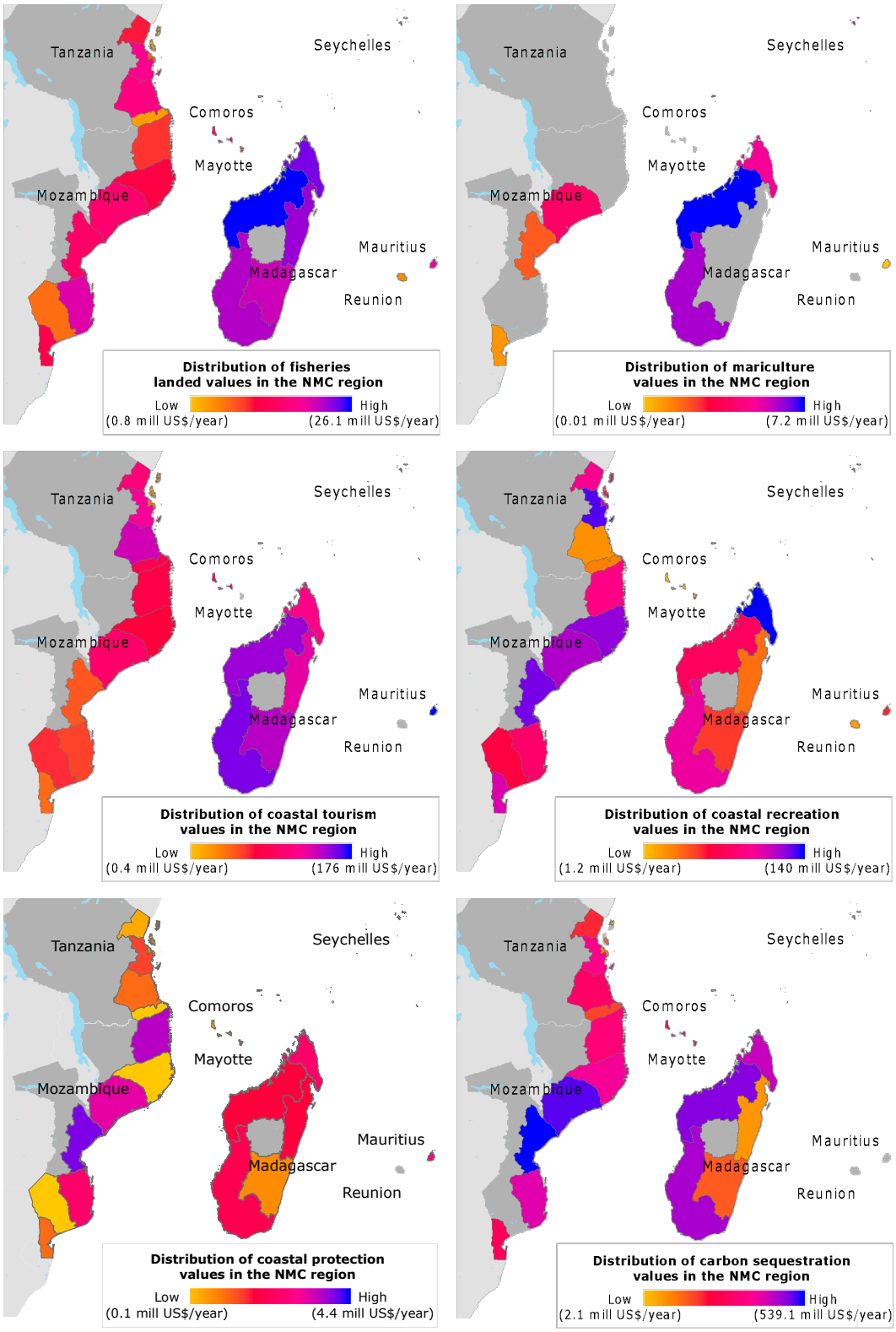

Figure 8. Summary of estimated ecosystem service values in the Western Indian Ocean, aggregated at administrative level

Following Santos-Martin et al. (2013), we adapted the DPSIR framework to analyze the connections among biodiversity loss, ecosystem services, human wellbeing and society's responses to preserve the ecosystem service flow. We consider six categories of indicators:

(1) biodiversity; (2) ecosystem service value flows; (3) multidimensional poverty; (4) institutional responses; (5) pressures; (6) drivers. Each of the categories includes one or more sub-categories and between three and eleven distinct indicators, at the province level or country level where more detailed information is not available, which were derived from official publications of national public institutes (such as National Institutes of Statistics, Ministries of Health, etc.) or reports to international organizations or initiatives (such as USAID, or United Nations in the framework of the Millennium Development Goals initiative). The criteria for selection of the indicators included being understandable and widely accepted for NMC stakeholders, being expressed in quantitative units, and being available for each of the countries or provinces in the region of investigation. Table 15 provides an overview of the 32 selected indicators, their unit of measurement and the level of aggregation at which information is available.

To ensure comparability, the indicators were first standardized to range between 0 and 1, following the normalization procedure used in the calculation of the Human Development Index (hdr.undp.org/sites/default/files/hdr_2013_en_technotes.pdf) and using the maximum and minimum sample value for each of the indicators. Subsequently, the individual indicators are aggregated in composite indices for each of the components of the DPSIR framework. Separate composite indexes are calculated for each of the categories of ecosystem services (i.e., provisioning, regulating and cultural). In order to reduce the compensability of poor performance in specific indicators with high values in other indicators, we use the geometric mean as the aggregation rule for each component, except for the multidimensional poverty index for which the Storie index is used to ensure that a high value of the composite index corresponds to a high level of poverty rather than a high wellbeing level. The logarithm of the GDP per capita is used in the calculation to reflect the decreasing marginal impact of income on welfare (see also calculation of the Human Development Index).

The values of the composite indices for each of the countries or provinces in the region of investigation are presented in spider diagrams in Figure 9. For improved visualization purposes only, the values of the indexes in the figure are rescaled to range between 0 and 1.

From the analysis of the spider diagrams emerge rather different mappings across the selected countries in the NMC region. For example, from a statistical viewpoint the results can be analysed from three main countries, Madagascar, Tanzania and Mozambique plus the set of the Western Indian Ocean islands, including the Comoros, Mauritius, Seychelles and French islands of Mayotte and Réunion. From this perspective, the spider diagram informs of four distinct patterns: we can see that Madagascar is well extended over the vertical axis of the diagram, which reflects the concomitant presence of the highest level of biodiversity richness and multidimensional poverty in this country. A high level of development in the exploitation of provisioning services (fisheries and mariculture) is also observed. Tanzania occupies the majority of the left side of the diagram, indicating that the coastal provinces of Tanzania are, on one hand, exposed to the highest pressures and drivers of environmental change but, on the other hand, benefit from the highest level of institutional responses (e.g., creation of MPAs). The low value of the composite indexes corresponding to ecosystem service values indicate a strong potential for improved environmental management and better capturing of the benefits that can be provided by the local coastal and marine ecosystem, for instance in the form of improved opportunities for coastal recreation. There is no correspondence in the cultural and regulating services.

Table 15. Province and national-scale indicators for the categories of the DPSIR framework

Group	Class	Indicator	Level of aggregation	Unit
Biodiversity		Total endemic species	Country	Number
		Plant species	Country	Number
		Biodiversity index	Province	-
Ecosystem services	Provisioning	Fishery	Province	Mill US$/year
		Mariculture	Province	Mill US$/year
	Regulating	Sequestration	Province	Mill US$/year
		Protection	Province	Mill US$/year
	Cultural	Tourism	Province	Mill US$/year
		Recreation	Province	Mill US$/year
Multidimensional poverty	Material	GDP per capita (log)	Province	US$/capita/year, PPP
		Population below poverty rate*	Province	% population
		Employment rate	Province	% population
	Health	HIV positive*	Province	% population
		Infant mortality rate (5q0)*	Province	Number per 1000 live births
	Security	Access to improved water	Province	% population
		Access to improved sanitation	Province	% population
		Political stability and absence of violence	Country	-
	Freedom	Literacy rate (15 & over)	Province	% population
		Adolescent birth rate*	Country	Number per 1000 women
	Social	Gini coefficient*	Province	-
Institutional responses		Marine protected areas	Country	% territorial waters
		Terrestrial protected areas	Province	% total area
		Proposed protected areas	Province	Number
	Pollution	Nutrients in coastal waters	Province	Ton/km2/year
	Fishing	Threatened fish species	Country	Number
	Climate change	Area below 5m elevation	Province	% total area
	Species introduction	Invasive species	Country	Number
	Habitat destruction	Agricultural & urban land use	Province	% of terrestrial area
Drivers	Demographic	Human population density	Province	Inhabitants/km2
		Fertility rate	Province	Total fertility rate
	Economic	Annual GDP growth	Country	% avg last 5 years
	Cultural	Urbanization	Mixed	% total

Note: * indicates that the additive reciprocal of the indicator is used in the calculations.

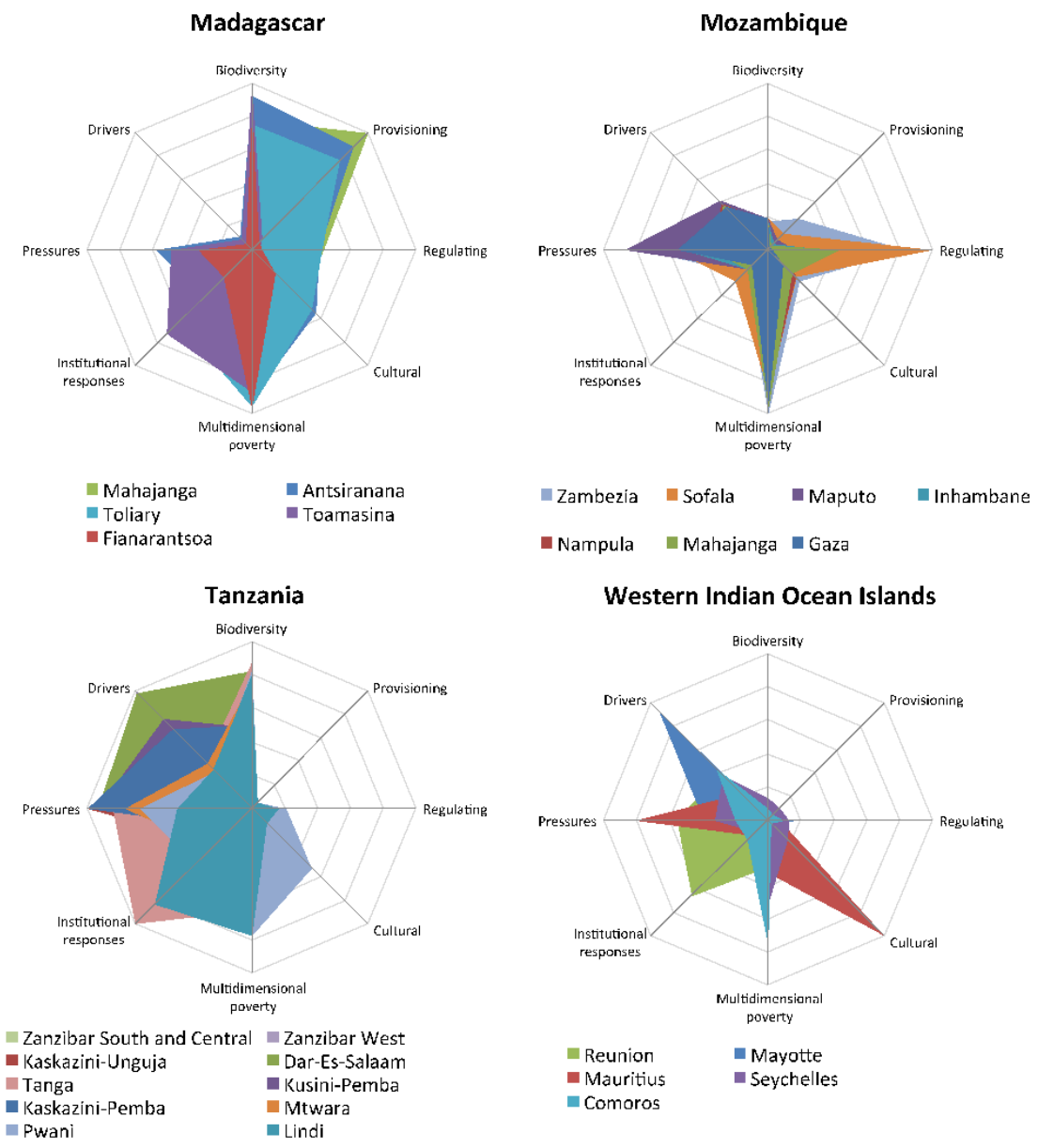

Figure 9. Spider diagrams of composite indexes for each DPSIR component and country in the Western Indian Ocean

On the other hand, Mozambique occupies a thin region in center of the diagram, with the exception of the regulating services and the multidimensional poverty index, reiterating the importance of these two individual dimensions. Mozambique is also characterized by a high level of pressure, in particular in the province of Maputo, capital of the country. The islands in the broader Mozambique Channel region appear to be substantially differentiated across the various dimensions but are in general characterized by a low level of biodiversity richness and ecosystem service values, with the exception of cultural services in Mauritius.

Such empirical results reiterate the diversity of the area under study, the need to collect better data and the provision of the adequate analytical tools that decision-makers need to evaluate trade-offs and this way inform development decisions. Of particular interest for

policy-makers and other stakeholders is the possibility to explore the implications of the results presented in the spider diagrams in terms of identifying within-country differences, for instance with the purpose of selecting or prioritizing provinces for improved environmental protection or for further more in-depth investigation.

4.3 Estimation of the costs of policy inaction scenario: illustration from the coastal tourism sector

Coastal tourism constitutes a significant economic sector in the NMC region. We might wonder what spurs coastal tourists and how is the demand for coastal tourism determined. The work by Onofri and Nunes (2013) addressed the issue. The authors examine worldwide coastal destination choice using a comprehensive global dataset at the country level, for both domestic and international tourists. This data includes a systematic profile of the countries' coastline with respect to economic and natural environments, such as marine biodiversity related indicators. Tourist demand is modelled using a system of simultaneous structural equations estimated by a 3SLS routine. The authors identify two tourist demand segments, denoting different preferences for the worldwide coastal destinations. International tourists have a higher reservation price and choose their coastal destination because they have a strong preference for the cultural and natural environments. This, in turn, depends on the destination of country's coastal habitat abundance and marine biodiversity. Alternatively, domestic tourists have a preference for beach characteristics, in particular beach length. This in turn depends on anthropogenic pressure, the built environment and climatic variables. Empirical results are presented in Ghermandi and Nunes (2014). Estimation results, when applied to NMC region and in the scenario of an absence of an integrated conservation policy program for this same region shows us that:

- 1% decrease of the number of coastal protected areas (MPAs) causes 1.44% decrease in international arrivals and 0.3% decrease in domestic arrivals for the NMC region.
- 1% decrease of the number of UNESCO sites causes 1.27% decrease in international arrivals and less than 0.1% increase in domestic arrivals for the NMC region.
- 1% decrease of the beach length causes 0.24% decrease in international arrivals and 2.47% decrease in domestic arrivals for the NMC region.

In addition, such a policy inaction scenario with respect to management of MPAs / UNESCO sites or beach fragmentation is associated to significant welfare losses, which are here translated in terms of decrease in tourism attractiveness and number of international of arrivals in the coastal areas of the countries in the NMC region. Indirect impacts of policy inaction scenario with respect to the conservation of “coastal protected areas” will bring additional negative impacts on the number of coastal arrivals, via the following mechanisms:

- **wetland areas:** wetland areas increase the *productivity* of the coastal protected area in the coastal tourism sector; in particular, in the presence of a policy inaction scenario an 1% decrease of wetland areas will generate 0.33% decrease in **international arrivals** and 0.07% decrease **domestic arrivals** for the NMC region.
- **biodiversity index for birds/mammals:** biodiversity index for birds/mammals increases the *productivity* of the coastal protected area in the coastal tourism sector; in particular, in the presence of a policy inaction scenario a 1% decrease of the biodiversity index for birds/mammals will generate 0.12%/0.16% decrease in

international arrivals and 0.03%/0.01% decrease in **domestic arrivals** for the NMC region.

- **reef area:** reef area increases the *productivity* of the coastal protected area in the coastal tourism sector; in particular, in the presence of a policy inaction scenario a of 1% decrease of the reef are will generate 0.43% decrease in **international arrivals** and 0.11% decrease in **domestic arrivals** for the NMC region.

Furthermore, we can also measure indirect impacts of "beach length" on the number of coastal arrivals taking into account the location/characteristics of the beach under consideration, including:

- development of coastal infrastructure decreases the *productivity* of beach length in the coastal tourism sector; in particular, in the presence of a policy inaction scenario an of 1% increase of coastal infrastructure **(e.g. harbours)** will generate 0.14% decrease in **international arrivals** and 1.53% decrease in **domestic arrivals** for the NMC region.

Finally, we can infer from this econometric model that climate change also presents significant impacts on the coastal tourism flows in the NMC region, including:

- **Annual average temperature:** annual average temperature impacts the *productivity* of the coastal protected area in terms of its impact on the coastal tourism sector: in the scenario of 1% increase of **average annual temperature** will generate 0.99% increase in **international arrivals** and 1.01% decrease in **domestic arrivals** for the NMC region.
- **Annual average precipitation:** annual average precipitation impacts the *productivity* of the coastal protected area in terms of its impact on the coastal tourism sector: in the scenario of 1% increase of **average annual precipitation** will generate 1.56% decrease in **international arrivals** and 1.53% decrease in **domestic arrivals;** for the NMC region.

For this reason, it is important to have in mind that climate change impacts may be cumulative to the policy inaction scenario, and therefore amplifying the negative welfare impacts – here measured in terms of a decrease in international and domestic arrivals for the NMC region.

4.4 Policy recommendations

The policy lesson driven by the empirical analysis recommends the creation of coastal/marine protected areas as one of the possible drivers (together with the preservation of pristine environment at the beach) for the growth of coastal tourism worldwide and in Mozambique. In this perspective, the Primeiras and Segundas have been approved as an MPA in Mozambique making this diverse ten-island archipelago Africa's largest coastal marine reserve. Comprising ten islands off the coast of northern Mozambique and featuring abundant coral and marine turtle species, the protected area will cover more than 1,040,926 hectares. WWF has worked for eight years to secure this important marine reserve, which has been threatened by overfishing and unauthorized tourism. Located in the northern region of the country, between Nampula and Zambezia Provinces, the declaration of the Primeiras and Segundas environment protection area represents the second major conservation area to be declared within the last two years. The archipelago includes the most robust and diverse coral community in Mozambique. It is rich in mangroves, marine life, deep underwater canyons and large seagrass beds. Due to cold nutrient-rich upwellings, the archipelago has been spared so far from coral bleaching, a

common problem in other coral-rich areas, making these some of the most globally productive and important reefs on the planet. In this perspective, following Spenceley and Batey (2011) coastal tourism can have fundamental impacts on biodiversity conservation for a number of reasons, including the following:

- Coastal tourism can generate revenue in areas of high biodiversity such as protected areas (PA), and help make them economically viable. Both use- and non-use values are potentially recoverable from PAs;
- Coastal tourism can raise public support for conservation since it can provide environmental education to visitors and local people. Tourism can also generate direct employment and catalyse economic opportunities for local people. Beneficiaries may consequently perceive a direct value from biodiversity, which may provide incentives to conserve natural areas;
- Coastal tourism based on natural resources can theoretically be sustainable if its impacts are managed and mitigated. Other industries based on non-renewable resources have a limited life span that may only continue until the exploited resource is exhausted (e.g. mining).

5 CONCLUSIONS

Understanding and valuing the marine ecosystem services of the Northern Mozambique Channel has a considerable latent potential to improve their stake in the global economy and to alleviate to some extent poverty, most notably in the coastal zone. Better use of marine natural resources with marine ecosystem services value-adding rather than export of raw materials is also one clear opportunity. It is also evident that the ecosystem goods and services that could be generated are huge – even if the data is wanting. Some of the economically "richest" ecosystems occur throughout the region and improved management and use of those resources needs to be fully pursued.

A good example lies in tourism development. Clearly, each of the NMC countries has great tourist potential, especially related to the coastal and marine environment. Generally the same attractions are on offer, ranging from beach vacations to more intrepid diving and fishing. In some cases, the attractions have special attributes, including unique MPAs, biodiversity hotspots such as in Madagascar and Seychelles, and rich cultural heritage such as in Mozambique. While this enhances the regional attraction to tourists, it also adds to competition between countries for tourist arrivals. Surprisingly, few of the countries appear to attach much importance to domestic tourism, which is a big economic driver in many parts of the world.

Fisheries of the NMC region are already providing substantial benefits, not only to national budgets but also to the millions who access these resources as subsistence or artisanal fishers. Improved benefits may well be possible but these will depend on the effective interaction and joint development action plans among the different countries of the NMC with the neighboring regions, including South Africa, as well as better management and control over access by foreign fisheries. These two factors are clearly a key objective that will be best achieved if done with regional collaboration. A clear need also exists to improve fisheries and socio-economics data collection and sharing in the region. Many of the reports consulted contain conflicting data thus making it difficult to establish the reliability of much essential information.

Ultimately, securing substantial and reliable ecosystem goods and services requires a comprehensive understanding of the drivers of economic value change and how these interact with the different marine ecosystem services under consideration, including provisioning, regulating, and cultural/recreational/tourism services of NMC ecosystems. Ascribing values to these services can be used as a tool for decision making and evaluating trade-offs where these are necessary as well as identifying the winners and losers associated to each of the trade-offs. No matter how variable the natural environment may be, most of the impacts on marine ecosystem services on the well-being of people living in the NMC region depend largely on the level of informed decision making. In this context, valuing the change of marine ecosystem services is a crucial step towards informed decisions, which in turn is a fundamental pillar towards any technical advice regarding the most appropriate policy or management scenarios as foundation for the development and implementation of the broader NMC initiative recommendations.

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