Understanding and Valuing the Marine Ecosystem Services of the Northern Mozambique Channel

Final Report

Date: January 7, 2015

This document was prepared for WWF International by

Paulo A.L.D. Nunes and Andrea Ghermandi

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Northern Mozambique Channel (NMC) region 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. Moreover, 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 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.

In the face of such 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. 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degradation and depletion, they have not been compiled into a comprehensive assessment and are, by and large, outdated.

This study deals with understanding and valuing the coastal and marine ecosystem services in the NMC region with the goals to (1) providing 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. The focus of the study is on the Exclusive Economic Zone (EEZ) of the countries in the region (i.e., Mozambique, Madagascar, Tanzania, Comoros, Seychelles and France), but, where possible, the analysis is extended to contiguous areas so as to allow for the evaluation of our findings in the larger context of the Western Indian Ocean.

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 estimates of the current flow of ecosystem services values for each of the six ecosystem services. Figure ES1 summarizes the results of the economic valuation exercise, with value flows 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.

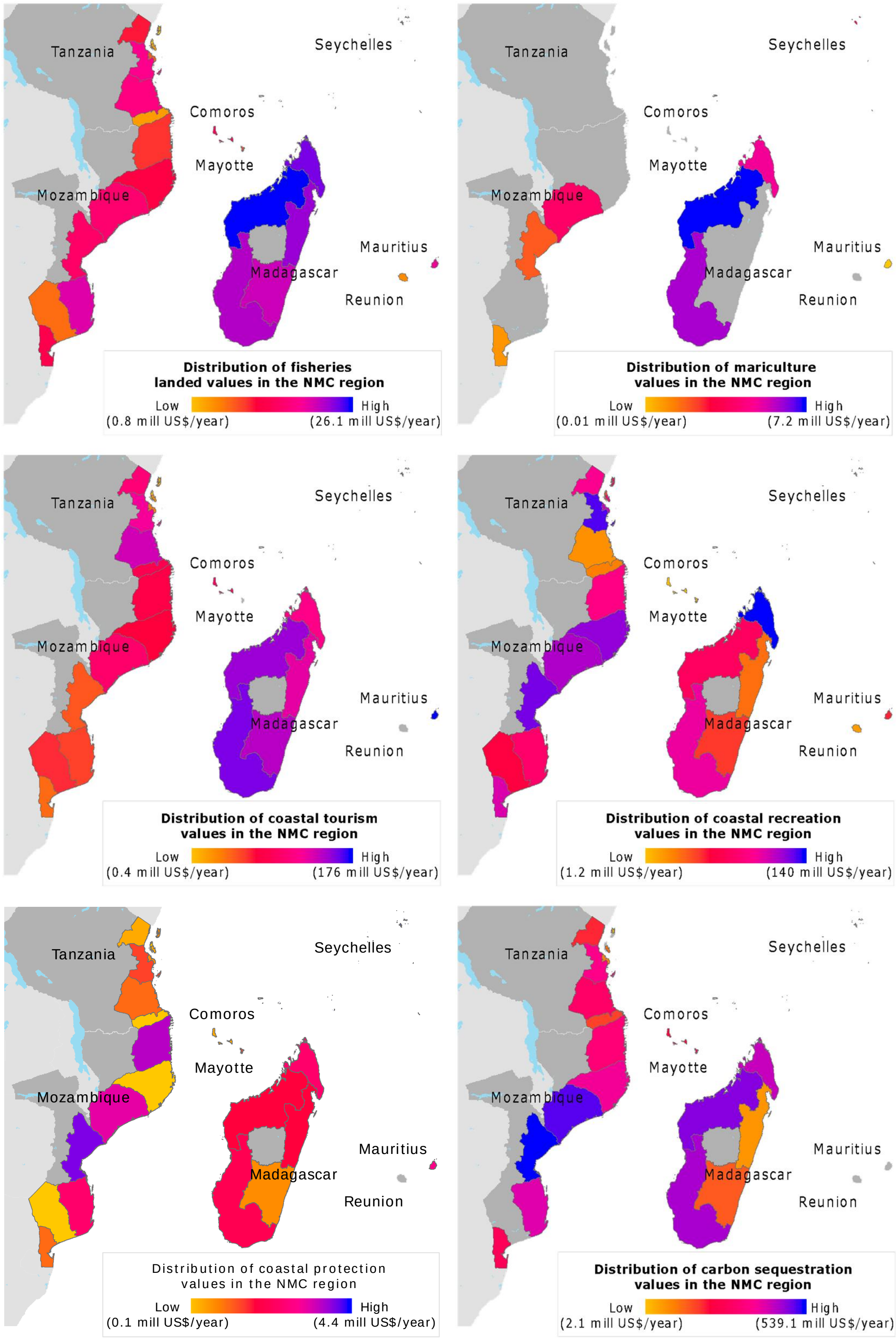


Figure ES1. Summary of estimated ecosystem service values in the Western Indian Ocean, aggregated at administrative level

The information in Figure ES1 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.

In order to further analyse the estimated flows of ecosystem service values in the context of the complex relationships established between ecosystems and human systems, 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. Figure ES2 shows the values of the composite indices for each of the countries or provinces in the Western Indian Ocean in spider diagrams.

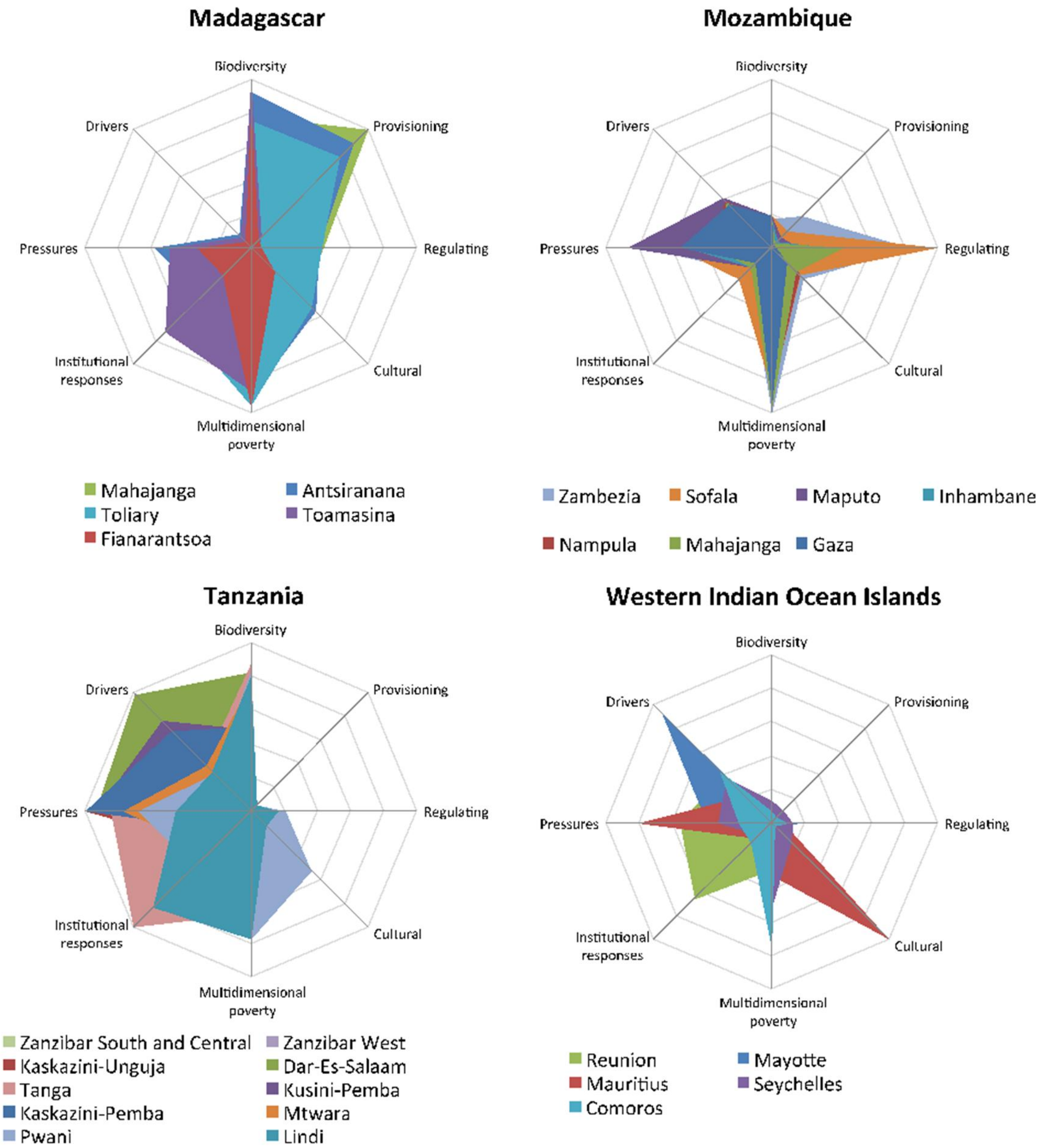


Figure ES2. Spider diagrams of composite indexes for each DPSIR component and country in the Western Indian Ocean

Rather different patterns can be identified from the analysis of Figure ES2 for the countries in the NMC region. 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 this country 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.

Mozambique, on the other hand, 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.

The findings of the study reiterate 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.

Even if primary data is wanting, it is evident from the results of the present analysis that the ecosystem goods and services that are and could be generated in the future by the NMC coastal and marine ecosystems are huge. 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 range of provisioning, regulating and cultural NMC marine ecosystem services. In this context, valuing the changes in the delivery of 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.

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.

Over the last two decades, the economic valuation of the ecosystem services has attracted increasing attention worldwide. International initiatives such as the Millennium Ecosystems Assessment, which launched its main report in 2005, and The Economics of Ecosystems and Biodiversity (TEEB), which was initiated in 2007, led by UNEP and the European Commission, have helped move forward in this field. International Organizations, such as the World Bank (2004, 2005) and UNEP (2010), have also contributed. Inspired by the TEEB initiative, many countries have produced, are producing or are planning to produce ecosystem valuation exercises. In Africa, South Africa has already conducted a country study and Liberia and Tanzania are currently conducting national studies.

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. In this context, the UNEP-led Inclusive Wealth Index (2012) emphasizes the need to estimate wealth of all types including natural capital, in order to shed light on the sustainability of economy and society. Countries willing to implement natural capital accounting (NCA) are also backed up by the World Bank's Wealth Accounting and the Valuation of Ecosystem Services (WAVES) partnership, comprising several U.N. agencies, governments, NGOs, and scholars. Currently, the WAVES initiative is helping Mozambique and Madagascar to establish natural capital accounts.

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, medium of transportation 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 report addresses the above-described questions with specific reference to the specific characteristics of the coastal and marine ecosystems in the NMC region. The layout of the report 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^{o} Latitude South near Aldabra Island in the north, to 17^{o} 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. 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.

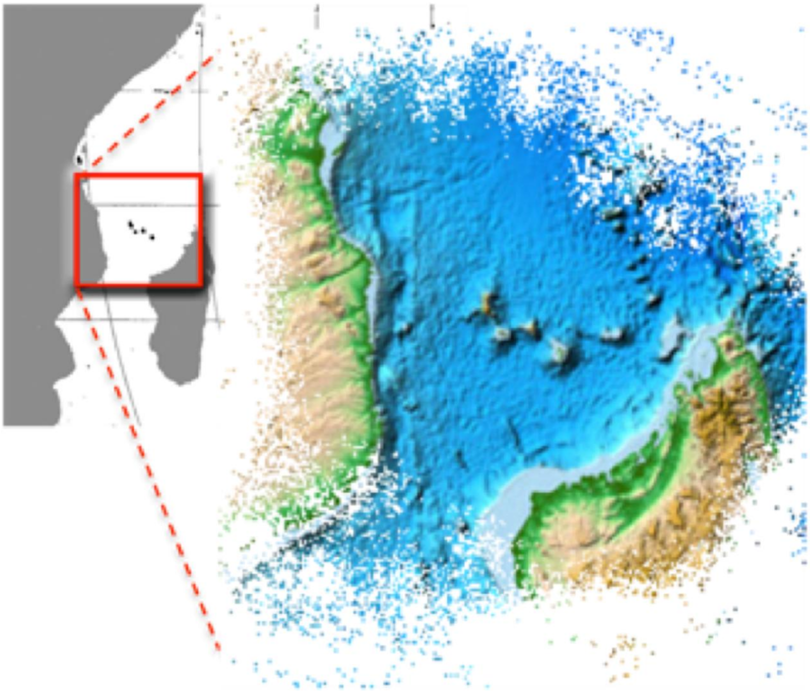


Figure 1. Geographic scope of the Northern Mozambique Channel region

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 2 shows the distribution of coral reefs, mangroves and other coastal wetland ecosystems in the NMC region. The data underlying Figure 2 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).

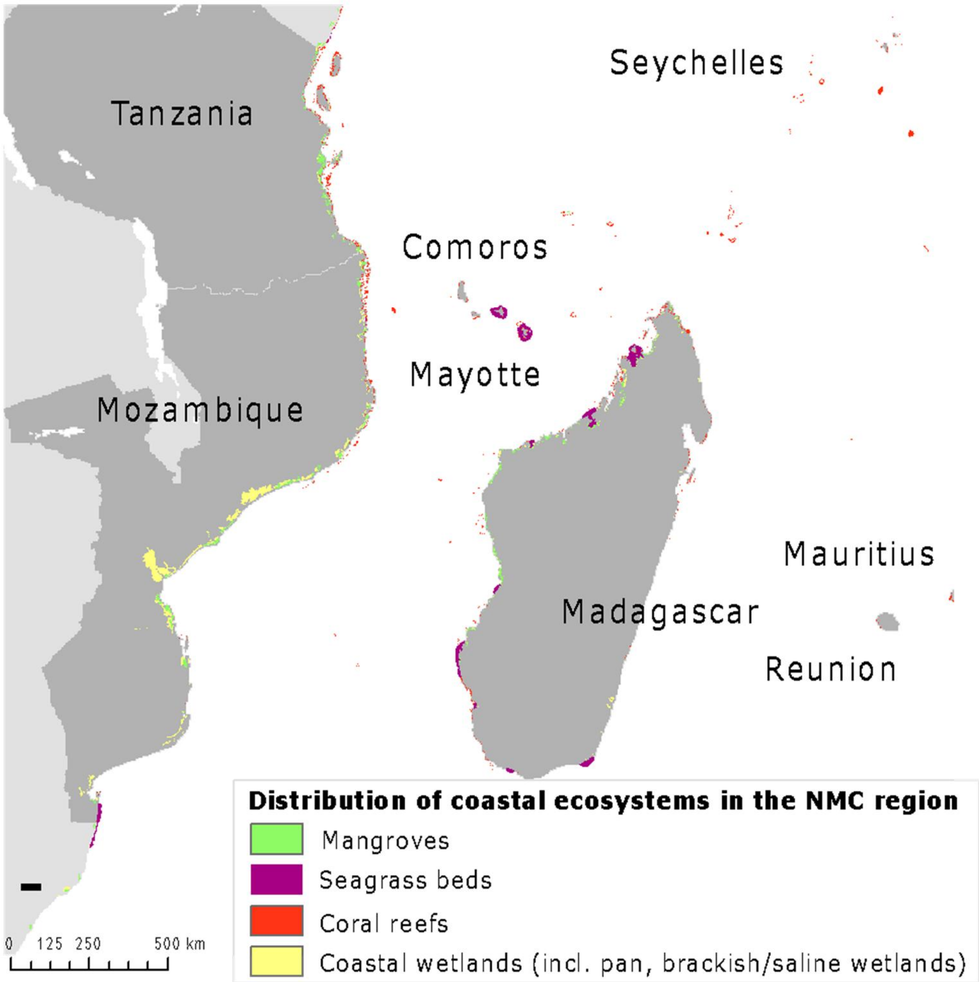


Figure 2. Distribution of coastal ecosystems and habitats in the Western Indian Ocean

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 report 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). Table 2 lists some examples of ecosystem services with a particular focus on Marine Ecosystem Services (MES), which are at the core of this document.

Table 2 Classification and examples of Marine Ecosystem Services (MES)

Ecosystem service	Illustrations/ Economic sectors
Provisioning	
Food	Food scarcity; fishing, subsistence fishing; food production mechanisms (aquaculture); navigation and marine coastal planning
Raw material	Animal feed; seabed minerals; energy resources (off-shore wind farms); oil and gas
Genetic resources	Marine biotic resources; biotechnological research; genetic manipulation
Medicinal resources	New chemicals; pharmaceutical drugs
Habitat	Physical and biological mediated habitat, land and marine coastal planning (natural parks, MPA); fishing rotation and no-take-zones
Ornamental resources	Coral and other precious minerals
Regulation and maintenance	
Climate regulation	Marine coastal planning; flooding; anthropogenic disturbance;
Coastal protection	Flooding; extreme events; sea level rise; storms; constructions
Soil formation	Flooding; extreme events; sea level rise; soil salinization and erosion
Cultural	
Recreation/Tourism	Place for relaxing, resting, refreshment; activities: e.g. walking, hiking, camping, surfing, etc.
Aesthetics	Scenery and landscape; views (real state); seascape; oil and gas pipeline construction
Science and education	Environmental education; research; excursions; field laboratories; publications
Spiritual and historic	Ethical and heritage-values

Source : TEEB (2010), adapted

The magnitude of the impact of ecosystem services on human well-being defines an economic value, which can be quantified and measured. The economic value of ecosystem services (and therefore the economic value of the benefits provided by ecosystem services on human well-being) can be assessed by economic valuation frameworks and methods.

Appendix A provides more detailed information on the concept of economic value of ecosystem services.

There exists a hierarchy of the economic valuation approaches. In fact, one is able to measure the contributory value of the ecosystems services to human-wellbeing using qualitative, quantitative or monetary valuation approaches. Qualitative valuation typically involves describing the value as well as indicating whether the value is likely to be of high, medium or low economic value (e.g. the success of a biotechnological product not yet marketed). Quantitative valuation involves describing the nature of the value in terms of relevant quantitative information (e.g. the coastal area is used by 100 fishermen, who catch 160 tons of fish per year; coastal area protection in good environmental and ES quality is of significance to 5,000 local people who have jobs in the tourism sector). Monetary valuation actually involves placing a 'monetary' or 'dollar value' on the economic activity impacted by the ES (e.g. the coastal area generates 1,400,000 USD/year from its fish and it generates about US$ 120,000,000/year for its local habitants in income). Monetary and quantitative methodologies are discussed in more detail in Appendix B.

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 Appendix C. 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.

In this study, 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 include: 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 ECOSYSTEM SERVICES AND THEIR CONTRIBUTION TO NMC ECONOMIC SECTORS

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) 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% in the same decade. 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.

[1] International tourism expenditures are expenditures of international outbound visitors in other countries, including payments to foreign carriers for international transport. (http://data.worldbank.org/indicator)

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.

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 (Figure 3). 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

	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)

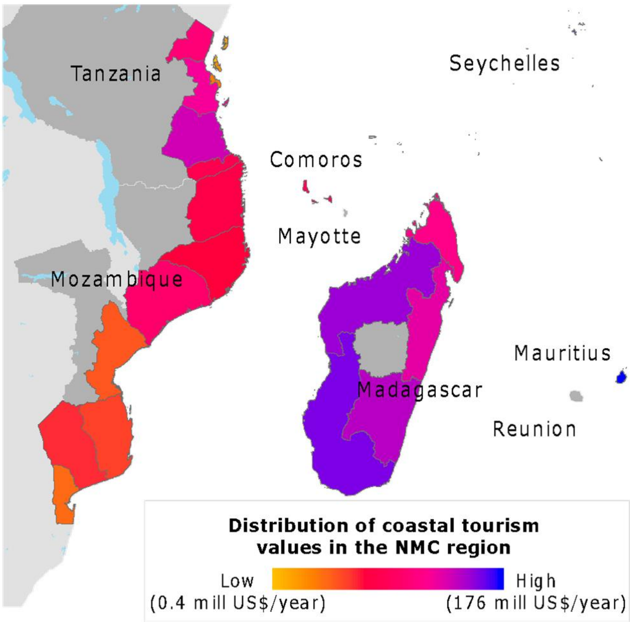


Figure 3: Distribution of coastal tourism values in the Western Indian Ocean

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 – see Table 5. 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).

Table 4: Strategic plan for approach to tourism resources in Mozambique

Resource	Strategy	Explanation
Coastal and Marine Resources	Capitalize	Mozambique's vast coastline, tropical beaches and warm waters and rich coastal and marine resources are of exceptional quality and unique in southern Africa. Mozambique should capitalize on this position in product development and marketing At the same time conservation and protection of the fragile coastal and marine resources should be a priority.
Wildlife and Nature	Develop	To be able to compete in Southern Africa markets, Mozambique must develop its nature and wildlife based tourism product. Efforts should

[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).

Resources		be focused on (re)building the resources and infrastructure, promoting investments in conservation areas, developing human resources and restocking wildlife
Cultural and Man-Made Resources	Capture	Mozambique's cultural identity, determined by its heritage, people and history, differs significantly from other countries in southern Africa and is one of the country's key tourism assets. Mozambique must cherish these differences and use them to 'flavour' its 'blue' and 'green' product lines, as well as to develop a specialized 'orange' or cultural product offering.

Sources: SPDTM 2004, 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 in Appendix C, 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; and Appendix D). 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 4). 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.

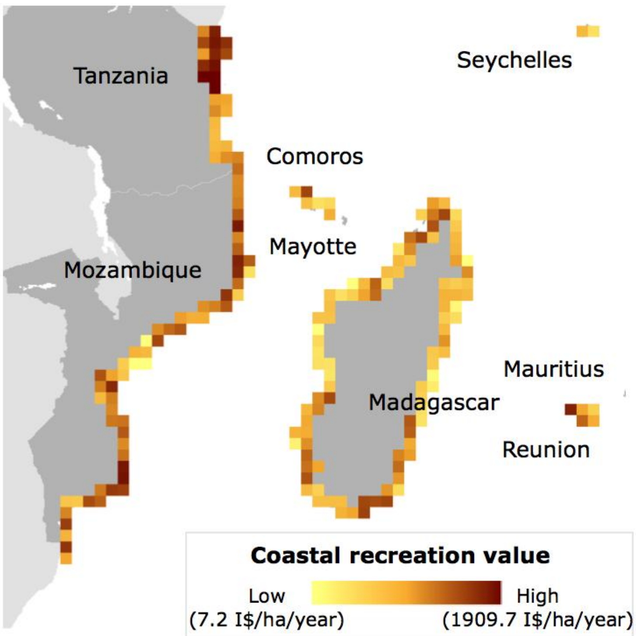


Figure 4. Map of estimated coastal recreational values in the Western Indian Ocean

The welfare contribution of the yearly flux of coastal recreation benefits in the countries making up the NMC region is estimated at 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.

[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**.

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).

3.2.3 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 5.

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

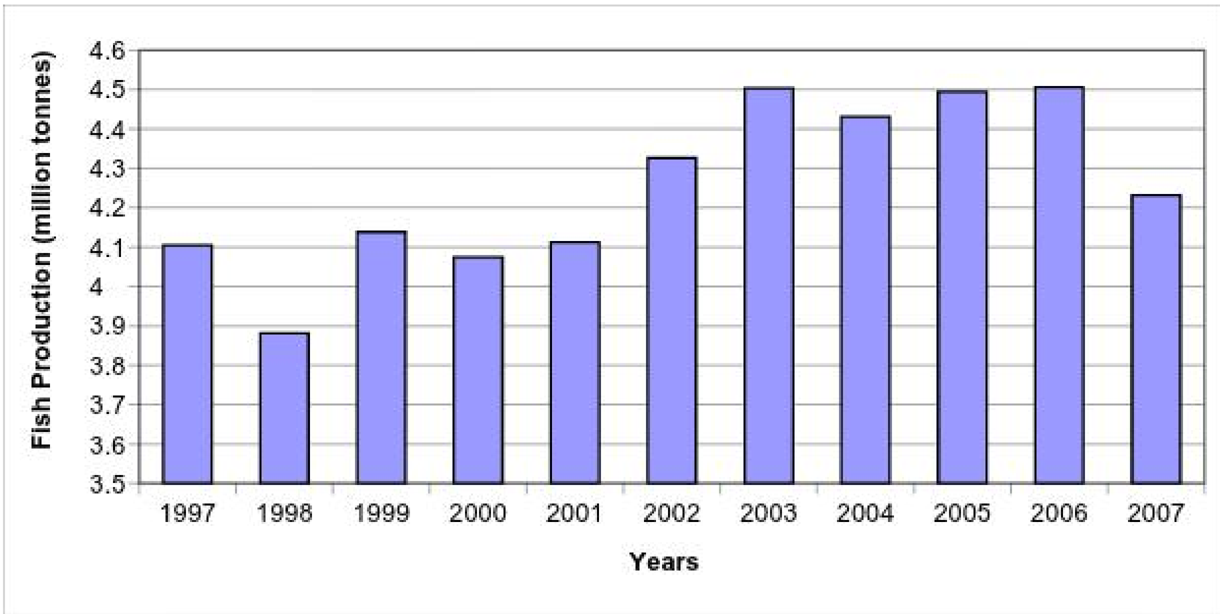


Figure 5: Total marine catch in the Western Indian Ocean
(Source: FAO Fisheries Statistics, 2009)

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 6). Figure 6 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 6 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 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.

[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 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.*

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

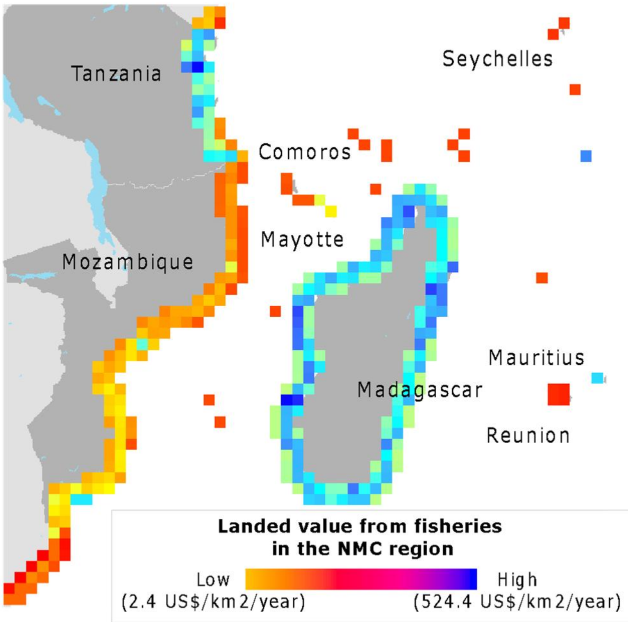


Figure 6. Map of estimated landed value from fisheries in the Western Indian Ocean

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.

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 – see Box 1 for more information.

Box 1. Economic value of small-scale fisheries: evidence from Madagascar

In a recent study, Barnes-Mauthe et al (2013) proposed an estimation of the total economic value of small-scale fisheries resources, including both commercial and subsistence values, in a remote rural region in Madagascar – one of the poorest countries in the world, with annual income per capita barely reaching PPP $950 and over 75% of all households living under the poverty threshold (World Bank, 2012a). In this study, the authors construct annual landings and characterize gear and habitat use, post-landing trends, fishing revenue, total market value, costs and net income, profitability, employment and dependence on small-scale fisheries. According to these estimations, the small-scale fisheries sector employs 87% of the adult population, generates an average of 82% of all household income, and provides the sole protein source in 99% of all household meals with protein. In particular, the study reported that 5,524 metric tons of fish and invertebrates were extracted annually by small-scale fishers in the region, primarily from coral reef ecosystems, of which 83% was sold commercially, generating fishing revenues of nearly 6.0 million USD (PPP, 2010). Furthermore, when accounting for subsistence catch, total annual landings had an estimated value of $6.9 million USD (PPP, 2010). This study demonstrates the importance of small-scale fisheries for food security, livelihoods, and wealth generation for coastal communities (applicable to the context of the NMC), and highlights the need for long-term management strategies that aim to enhance their ecological and economic sustainability. Therefore, these findings invite national and regional policy makers to re-examine existing fisheries policies that neglect this sector in the NMC area, and spur researchers to better quantify small-scale fisheries and scale-up these values to the totality of the NMC area.

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 7 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].

[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.

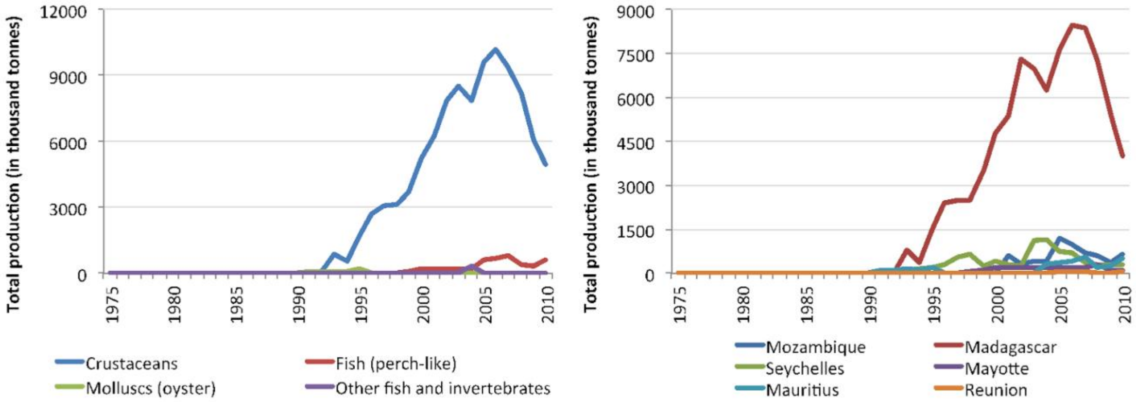


Figure 7: Mariculture production in the Western Indian Ocean in 1970-2010 by commercial species group (left) and country (right). Source: Sea Around Us Project 2011

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.

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 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, e.g. to Belgium, France and USA (Troell et al., 2009; Mmochi, 2009).

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 at 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 and Figure 8 present the estimated yearly monetary value of shrimp and seaweed mariculture in NMC countries and their geographical distribution in the region.

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**.

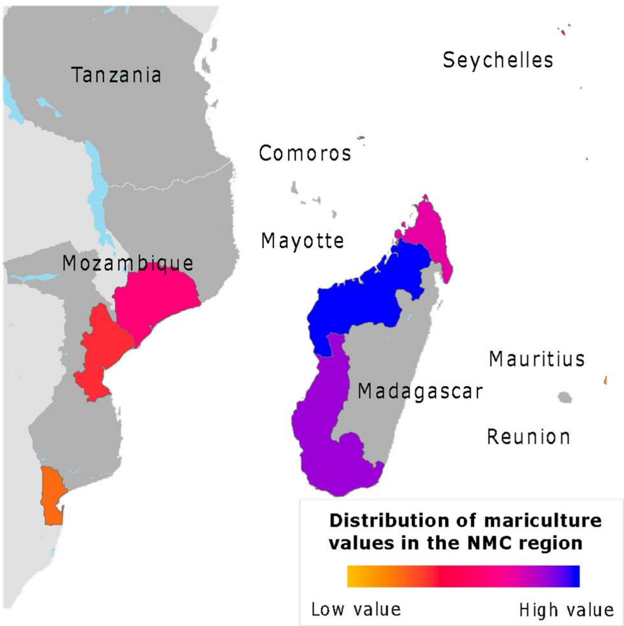


Figure 8. Geographical distribution of shrimp mariculture values in the Western Indian Ocean, at province level

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).

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 at 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 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 provided by coastal habitats in the NMC region, 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). One should note, however, that 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 the database of lakes, reservoirs and wetlands by 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.

The burial of carbon 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 at the NMC regional, national and provincial level 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 9 shows the spatial 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.

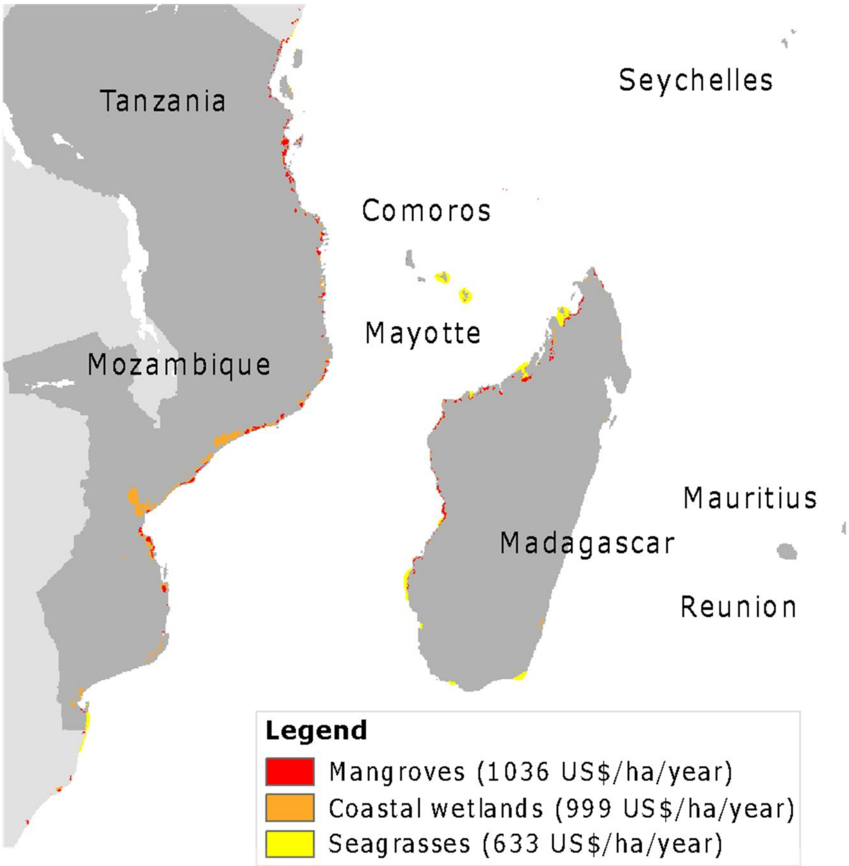


Figure 9. Spatial distribution of estimated coastal carbon storage service values in the Western Indian Ocean

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.

[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).

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 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. The reader interested in the technical details underlying the present application may refer to the technical Appendix D.

Figure 10 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 (see technical Appendix D). 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.

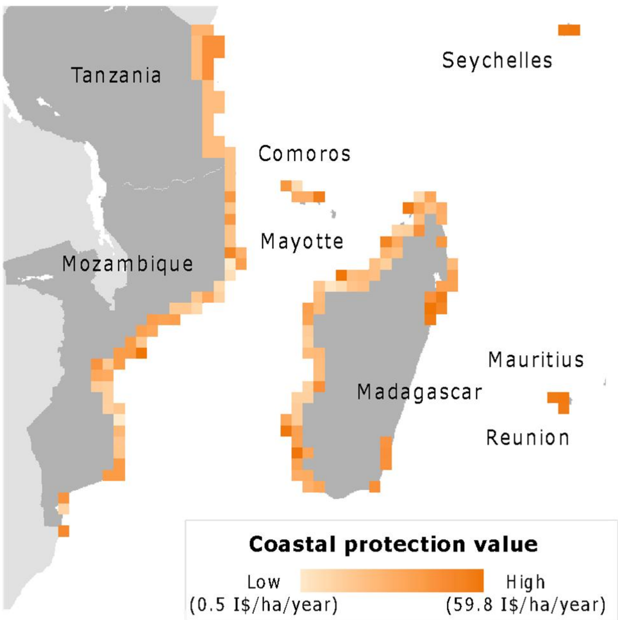


Figure 10. Map of estimated coastal protection values in the Western Indian Ocean

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.

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**.

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%).

3.6.3 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.

4 THE USE OF ECONOMIC VALUATION IN SUPPORTING POLICY DECISIONS IN THE NMC

4.1 Linking the valuation results to policy decision making

Figure 11 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 report. In Figure 11, 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 11 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.

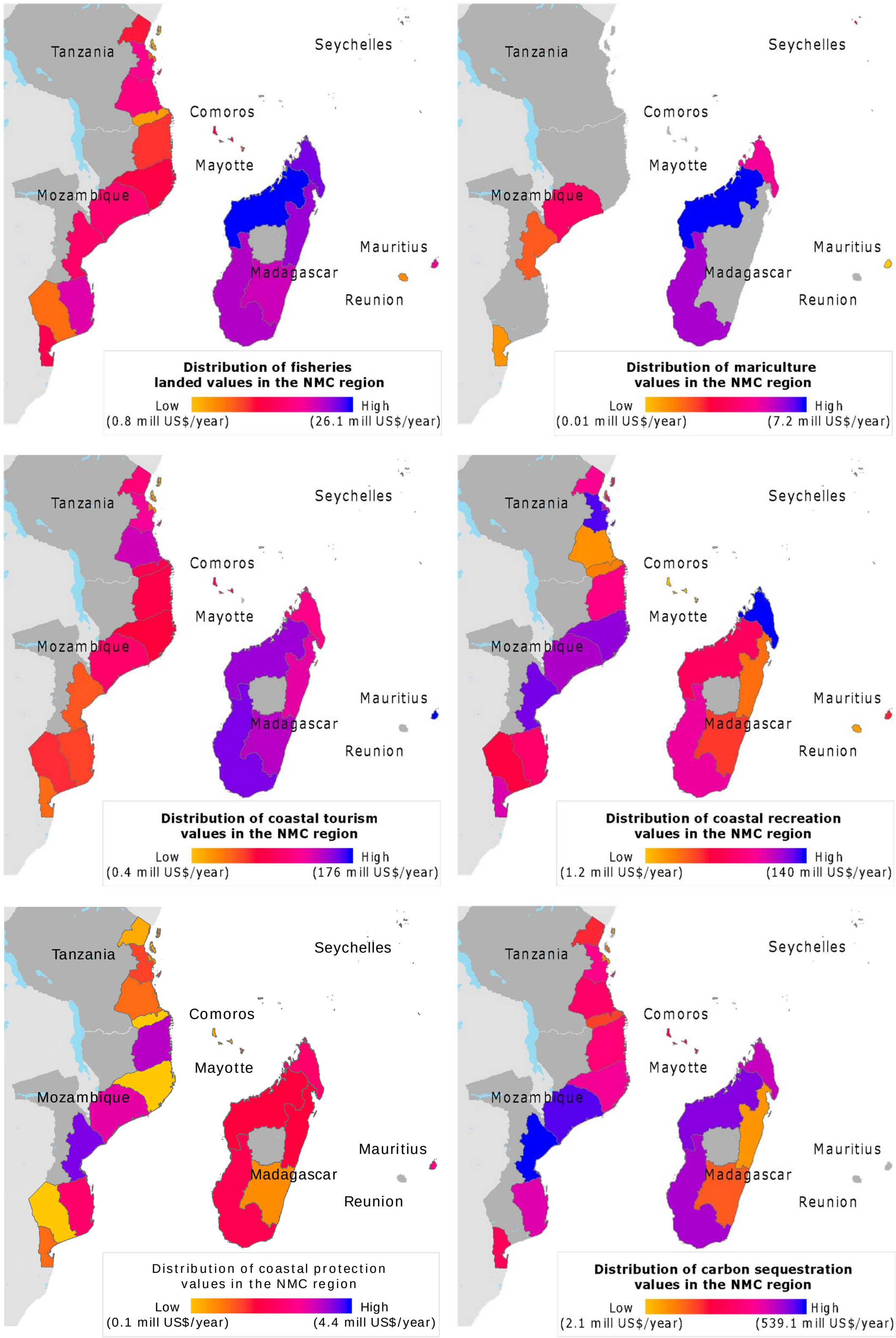


Figure 11. Summary of estimated ecosystem service values in the Western Indian Ocean, aggregated at administrative level

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.

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.

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.

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 12. For improved visualization purposes only, the values of the indexes in the figure are rescaled to range between 0 and 1.

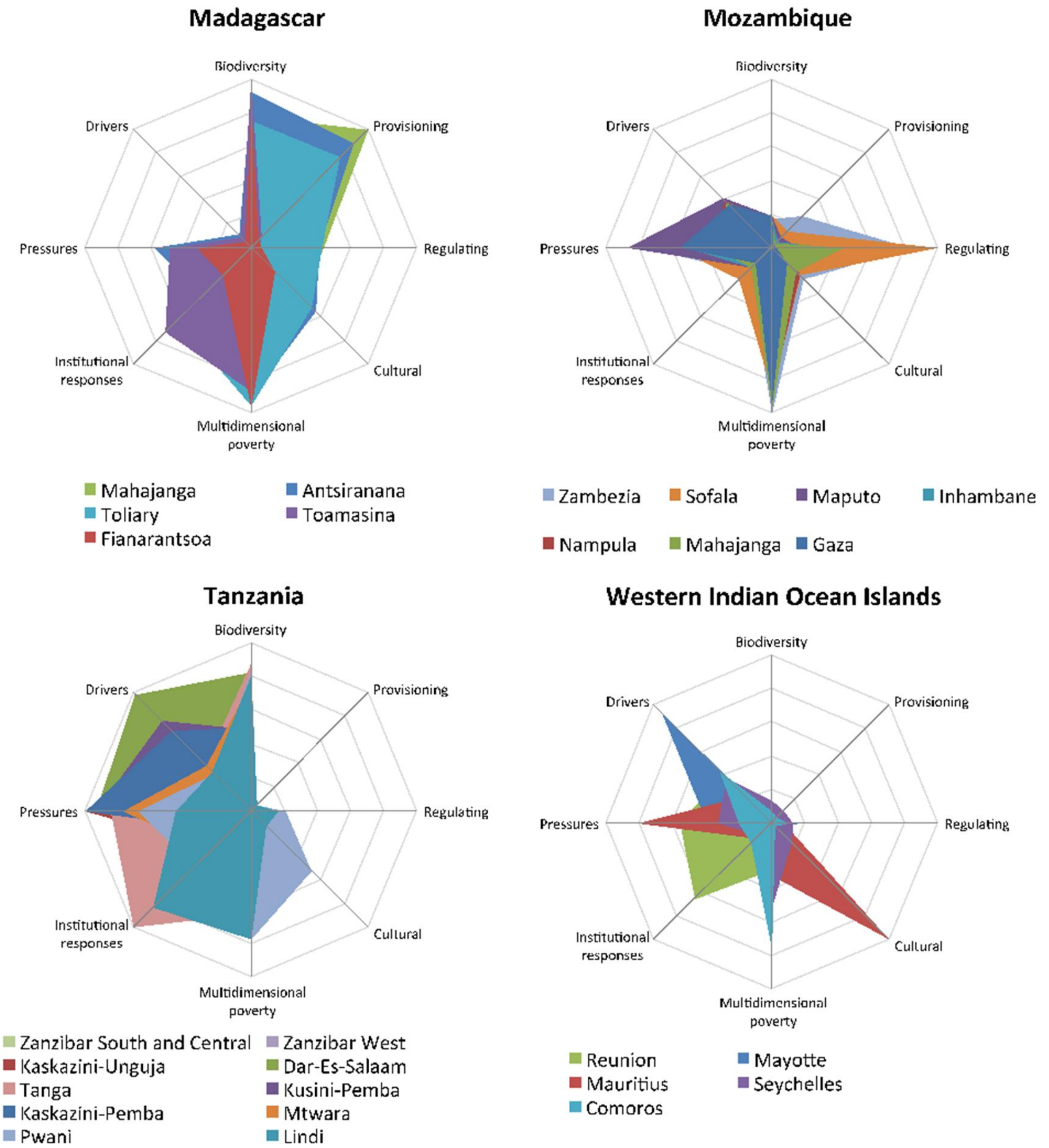


Figure 12. Spider diagrams of composite indexes for each DPSIR component and country in the Western Indian Ocean

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.

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 Appendix E.

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.

6 REFERENCES

Abbu AA, Lyimo TJ (2007) Assessment of fecal bacteria contamination in sewage and non-sewage impacted mangrove ecosystems along the coast of Dar es Salaam. *Tanzania Journal of Science* 33(1): 27-40.

Adger WN, Hughes TP, Folke SR, Carpenter SR, Rockstrom J, et al. (2005) Socialecological resilience to coastal disasters. *Science* 309: 1036–1039.

African Conservation Foundation (2013) Dynamite fishing destroying fisheries and coral reefs along the Tanzanian coast. May 16. Accessed: October 2014.

http://www.africanconservation.org/habitat-news/marine-coastal/item/dynamite-fishing-destroying-fisheries-and-coral-reefs-along-the-tanzanian-coast. Accessed: October 2014.

Andreetta A, Fusi M, Cameldi I, Cimo' F, Carnicelli S, Cannicci S (2014) Mangrove carbon sink. Do burrowing crabs contribute to sediment carbon storage? Evidence from a Kenyan mangrove system. *Journal of Sea Research* 85: 524-533.

Aquaculture Department, Ministry of Fisheries-Mozambique (2004) Shrimp Aquaculture Production Facilities Monitoring Reports.

Bandeira SO, Gell F (2003) The seagrasses of Mozambique and Southeastern Africa. In: Green EP and Short FT (eds.), World Atlas of Seagrasses, pp. 93-100. UNEP World Monitoring Conservation Centre, University of California Press, Berkeley.

Barnes-Mauthe M, Oleson KLL, Zafindrasilivonona B (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. *Fisheries Research* 147: 175-185.

Beymer-Farris BA, Bassett TJ (2012) The REDD menace: Resurgent protectionism in Tanzania's mangrove forests. *Global Environmental Change* 22: 332-341.

Bigano A, Hamilton JM, Lau M, Tol RSJ, Zhou Y (2004) A global database of domestic and international tourist numbers at national and sub-national level. Research unit Sustainability and Global Change FNU-54, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany.

Bryceson I, Beymer-Farris B (2009) Main Challenges for Coastal Aquaculture Development in the WIO Region: Who are the winners and losers? In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Burgess ND, Bahane B, Clairs T, Danielsen F, Dalsgaard S, Funder M, Hagelberg N et al. (2010) Getting ready for REDD+ in Tanzania: a case study of progress and challenges. *Oryx* 44(3): 339-351.

Burke L, Reytar K, Spalding M, Perry A (2011) *Reefs at Risk Revisited*. World Resources Institute, Washington DC, 116 pp.

Coastal Livelihoods Assessment (CLA) Report. 2010. Mozambique. ASCLME Programme Report.

Costa A, Pereira MAM, Motta H, Schleyer M (2005) Status of coral reefs in Mozambique. In: Souter D and Linden O (eds.) Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp.54-60.

Costanza R, Perez-Maqueo O, Martinez ML, Sutton P, Anderson SJ and Mulder K (2008) The value of coastal wetlands for hurricane protection. *Ambio* 37(4): 241-248.

Crooks S, Herr D, Tamelander J, Laffoley D, Vandever J (2011) Mitigating climate change through restoration and management of coastal wetlands and near-shore marine ecosystems: Challenges and opportunities. Environment Department Paper 121, World Bank, Washington, DC.

de Groot RS, Brander L, van der Ploeg S, Bernard F, Braat L, Christie M, Costanza R, Crossman N, Ghermandi A, Hein L, Hussain S, Kumar P, McVittie A, Portela R, Rodriguez LC, ten Brink P (2012) Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services* 1:50-61.

Den Haring S (2014) Effective Interpretation for Recreational Marine Resource Use in the Mombasa Marine Park and Reserve, Kenya. PhD Thesis, James Cook University, Australia

Fatoyinbo TE, Simard M (2013) Height and biomass of mangroves in Africa from ICESat/GLAS and SRTM. *International Journal of Remote Sensing* 34(2).

Fatoyinbo TE, Simard, M, Washington-Allen RA, Shugart HH (2008) Landscape-scale extent, height, biomass, and carbon estimation of Mozambique's mangrove forests with Landsat ETM+ and Shuttle Radar Topography Mission elevation data. *Journal of Geophysical Research* 113, G02S06: 1-13.

FIAS- Foreign Investment Advisory Service (2006) The tourism sector in Mozambique: A value chain analysis, volume 1. Discussion draft. March 2006.

Food and Agriculture Organizations of the United Nations (FAO) (2014) Fishery and aquaculture country profiles. Fishery and Aquaculture Department, http://www.fao.org/fishery/countryprofiles/search/en.

Garcia HJD, McCarroll Pinto-Rodrigues M, Gibbon H, Bernaudat L, Omedo G (2013) Demonstrating the adoption and linkages of global best available practices and technologies (BAPs/BATs) in reducing land based pollution in the Collaborative Actions for Sustainable Tourism (COAST) Project in Kenya, Mozambique and Tanzania. *Environmental Development* 7: 80-87.

Ghermandi A, van den Bergh JCJM, Brander LM, de Groot HLF, Nunes PALD (2010) The Values of Natural and Human-made Wetlands: A Meta-analysis. *Water Resources Research* 46, W12516, 12 pp.

Ghermandi A, Ding H, Nunes PALD (2013) The social dimension of biodiversity policy in the European Union: Valuing the benefits to vulnerable communities. *Environmental Science and Policy* 33: 196-208.

Ghermandi A, Nunes PALD (2013) A global map of coastal recreation values: Results from a spatially explicit meta-analysis. *Ecological Economics* 86:1-15.

Giri C, Muhlhausen J (2008) Mangrove forest distribution and dynamics in Madagascar. *Sensors* 8: 2104-2117.

Global Invasive Species Database, http://www.issg.org/database/welcome/. Accessed: October 2014.

Goreau T, McClanahan T, Hayes R, Strong A (2000) Conservation of coral reefs after the 1998 global bleaching event. Conservation Biology 14:5-15.

Green EP, Short FT (2003). World atlas of seagrasses. Prepared byUNEP World Conservation Monitoring Centre. Berkeley (California,USA): University of California. 332 pp.

Gulland FMD, Hall AJ (2007). Is marine mammal health deteriorating? Trends in the global reporting of marine mammal disease. *Ecohealth* 4:135–50.

Haines-Young R, Potschin M (2013) Common international classification of ecosystem services (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract No EEA/IEA/09/003.

Halafo J (2011) The Aquaculture Sector in Mozambique: Strategy, present Status, plans for Future Development and Legal Framework. In: Schoenherr and Quatmann (eds.) proceedings of the International Aquaculture Business Conference, Pemba, Mozambique, 9-10 November 2011.

Hantanirina JMO, Benbow S (2013) Diversity and coverage of seagrass ecosystems in south-west Madagascar. *African Journal of Marine Science* 35(2): 291-197.

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, Hatziolos ME (2007) Coral reefs under rapid climate change and ocean acidification. *Science* 318(5857): 1737-1742.

Hooke N (1997) Maritime casualties, 1963-1996. 2nd edition, LLP Limited, London Oil Spill Intelligence Report, 30 May 1991 & 6 June 1991.

Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall PM, Nyström M, Palumbi SR, Pandolfi JM, Rosen B, Roughgarden J (2003) Climate change, human impacts, and the resilience of coral reefs. *Science* 301(5635): 929-933.

Iltis J, Ranaivoson E (2009) A synopsis of marine aquaculture in Madagascar. In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Jindal R, Swallow B, Kerr J (2008) Forestry-based carbon sequestration projects in Africa: Potential benefits and challenges. Natural Resources Forum 32: 116-130.

Koch EW, Barbier EB, Silliman BR, Reed DJ, Perillo GME, Hacker SD, Granek EF, et al. (2009) Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. *Frontiers in Ecology and the Environment* 7(1): 29-37.

Lehner B, Döll P (2004) Development and validation of a global database of lakes, reservoirs and wetlands. *Journal of Hydrology* 296(1□4): 1-22.

Lesperance AD (2009) Mariculture development in Seychelles and other Western Indian Ocean Island States. In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Lugendo BR, Mgaya YD, Semesi AK (1999) The seagrass and associated macroalgae at selected beaches along Dar es Salaam coast. In Proc. of 20th Anniversary Conference on Advances in Marine Science in Tanzania, 28 June-1 July 1999, Zanzibar.

Lyimo TJ (2009) Microbial and nutrient pollution in the coastal bathing waters of Dar es Salaam. *Aquatic Conservation: Marine and Freshwater Ecosystems* 19: S27-S37.

Mapfumo B (2009) The development of small-scale freshwater aquaculture in Mozambique, report for EC FP7 project Sustainable Aquaculture Research Networks in Sub-Saharan Africa (SARNISSA).

McClanahan T, Sheppard CRC, Obura D (eds.) (2000) Coral reefs of the Indian Ocean: Their ecology and conservation. Oxford University Press, New York.

McGranahan G, Balk D, Anderson B (2007) The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization* 19(1): 17–37.

McLean B, Kingwill J, Govender J, Marime G (2014) Towards sustainable marine tourism in Tofo, Barra and Tofinho. Version 1. Report for Collaborative Actions for Sustainable Tourism (COAST) Project: Reef and Marine Management (RMRM) Thematic Area. http://coast.iwlearn.org/en/baps-and-bats/2014.06.24%20Moz%20Sust%20manage%20plan.pdf. Accessed: October 2014.

McLeod E, Chmura GL, Bouillon S, Salm R, Björk M, Duarte CM, Lovelock CE, Schlesinger WH, Silliman BR (2011) A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. *Frontiers in Ecology and the Environment* 9(10): 552–560.

Meeuws R (2004) Mozambique-Trade and Transport Facilitation audit. The World Bank, Washington DC.

Ministry of Fisheries (2005) Development of aquaculture sector in Mozambique: potentials and constraints for development-policy and implementation needs. (Draft for discussion). 47 pp.

Ministry of Tourism, Republic of Mozambique (2004) Strategic Plan for the Development of Tourism in Mozambique (2004-2013) Volume 1. February 2004.

Mmochi AJ (2009) Overview of aquaculture activities in Tanzania. In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Mohammed SM (2002) A review of water quality and pollution studies in Tanzania. *Ambio* 31: 617–620.

MPDC (2013) Maputo: Mozambique's biggest port. Maputo: Maputo Port. Retrieved from http://www.portmaputo.com/?wpdmact=process&did=MTguaG90bGluaw==

National Institute of Statistics 2010 National Institute of Statistics Mozambique 2010. National Accounts of Mozambique. www.ine.gov.mz.

Mwakalobo SL, Namkinga L, Lyimo TJ, Lugomela C (2013) Assessment of faecal bacteria contamination in selected coastal waters in Tanzania. *Journal of Biology and Life Science* 4(2): 63-82.

Nanyaro GF (2005). Seaweed Development Strategic Plan. Ministry of Natural Resources and Tourism Report, Dar es Salaam, Tanzania.

Nellemann C, Corcoran E, Duarte CM, Valdés L, DeYoung C, Fonseca L, Grimsditch G (eds) (2009) Blue Carbon. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no.

Nunes PALD, van den Bergh JCJM (2004) Can people value protection against invasive marine species? Evidence from a joint TC–CV survey in the Netherlands. *Environmental and Resource Economics* 28: 517–532.

Obura D (2005a) East Africa – Summary. In: Souter D and Linden O Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp. 25-31.

Obura D (2005b) Kenya – Coral reef resistance studies. In: Souter D and Linden O Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp. 35-46.

Obura DO, Church JE, Gabrie C (2012) Assessing Marine World Heritage from an Ecosystem: The Western Indian Ocean, World Heritage Papers, UNESCO.

O'Malley MP, Lee-Brooks K, Medd HB (2013) The global economic impact of manta ray watching tourism. PLoS One 8(5): e65051.

Omar I (2005) Local Expert on Aquaculture Development Report. Commonwealth Mission: Assistance to Develop an Aquaculture Policy.

Omar I, Hecht T (2009) A synopsis of the current status of mariculture in Mozambique. In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Onofri L, Nunes PALD (2013) Beach 'lovers' and 'greens': A worldwide empirical analysis of coastal tourism. *Ecological Economics* 88: 49-56.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM (2006) A global crisis for seagrass ecosystems. *Bioscience* 56(12): 987-997.

Payet R, Bijoux J, Adam PA (2005) Status and recovery of carbonate and granitic reefs in the Seychelles inner islands and implications for management. In: Souter D and Linden O Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp.132-145.

Pereira MAM, Schleyer MH (2005) A diver and diving survey in Southern Mozambique. In: Souter D and Linden O Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp.184-192.

Pierre S (2012) Point study of human impacts on vegetal cover and species diversity of seagrass in southwest Madagascar. Thesis at SIT Madagascar Biodiversity and Natural Resource Management, New York University.

Rao NS, Ghermandi A, Portela R, Wang X (2015) Global values of coastal ecosystem services: A spatial economic analysis of shoreline protection values. *Ecosystem Services* (in press).

Ribeiro F (2011) Coastal environment quality and resource species for mariculture. In: Schoenherr and Quatmann (eds.) proceedings of the International Aquaculture Business Conference, Pemba, Mozambique, 9-10 November 2011.

Sambo L (2011) The investment climate in Mozambique and the code of fiscal benefits and incentives. In: Schoenherr and Quatmann (eds.) proceedings of the International Aquaculture Business Conference, Pemba, Mozambique, 9-10 November 2011.

Sandhop LB (2013) Economic Development and Resource Boom in Southern Africa: Consequences for Port Developments in Mozambique, BA Thesis, University of Rotterdam.

Santos-Martín F, Martín-López B, García-Llorente M, Aguado M, Benayas J, Montes C (2013) Unraveling the relationships between ecosystems and human wellbeing in Spain. *PloS One*, 8(9), e73249.

Semesi S (2009) Seaweed farming in Western Indian Ocean region: A success story? In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Souter D, Linden O (eds.) (2005) Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, 283 pp.

Spalding MD, Blasco F, Field CD (Eds). 1997. *World Mangrove Atlas*. The International Society for Mangrove Ecosystems, Okinawa, Japan.

Spenceley A (2003) Managing sustainable nature-based tourism in Southern Africa: A practical assessment tool, Doctoral thesis, University of Greenwich, UK

Spenceley A, Batey E (2011) Economic case for Tourism in Mozambique, Report to USAID, Mozambique.

Suleiman M, Muhando C, Machano H, Daniels C, Tyler E, Jiddawi N, Yahya S (2005). Status of coral reefs in Tanzania. In: Souter D and Linden O Coral reef degradation in the Indian Ocean: Status Report 2005. Eurolitho, Milan, Italy, pp. 47-53.

Sutton G (2012). Port of Beira: Changing Perceptions. Maputo: Cornelder.

Tanzania Natural Resource Forum (2009). Tanzania Dynamite Fishing Monitoring Network. http://www.tnrf.org/en/dynamitefishing. Accessed: October 2014.

Tibiriçá Y, Birtles A, Valentine P, Miller DK (2011) Diving tourism in Mozambique: An opportunity at risk? *Tourism in Marine Environments* 7(3-4): 141-151.

Tol R (2009) The economic effects of climate change. *The Journal of Economic Perspectives* 23(2): 29-51.

Troell M, Hecht T, Beveridge M, Stead S, Bryceson I, Kautsky N, Ollevier F, Mmochi A (2009) Mariculture in the Western Indian Ocean region. In proc. of Workshop on Mariculture in the WIO region: Challenges and Prospects, December 2009, Zanzibar, Tanzania.

Turpie J, Wilson G (2011) Cost/benefit assessment of marine and coastal resources in the western Indian Ocean: Mozambique and South Africa. Mimeo Agulhas and Somali Current Large Marine Ecosystems Project.

UNCTAD (2013) Investment Policy Review: Mozambique. Geneva: United Nations.

UNCTAD (2013) Mozambique: Sector-Specific Investment Strategy and Action Plan. Inter Agency Working Group. Retrieved from http://unctad.org/Sections/diae_dir/docs/diae_G20_Mozambique_en.pdf

UNEP-WCMC (2006) *In the front line: Shoreline protection and other ecosystem services from mangroves and coral reefs*. United Nations Environmental Program–World Conservation Monitoring Centre: Cambridge UK.

UNEP-WCMC, Short FT (2005). Global distribution of seagrasses (version 2). Updated version of the data layer used in Green and Short (2003). Cambridge (UK): UNEP World Conservation Monitoring Centre. URLs: data.unep-wcmc.org/datasets/10 (polygons) and data.unep-wcmc.org/datasets/9 (points).

USAID 2010. Competitiveness of Mozambique's Fisheries Sector. Final Report.

van den Bergh JCJM, Botzen WJW (2014) A lower bound to the social cost of CO_2 emissions. *Nature Climate Change* 4: 253-258.

Vasseur P, Gabrie C, Harmelin-Vivien M (1988) State of coral reefs and mangroves of the Tulear Region (SW Madagascar): assessment of human activities and suggestions for management. In: Choat JH, Barnes D, Borowitzka MA, Coll JC, Davies PJ, Flood P, Hatcher BG, Hopley D, Hutchings PA, Kinsey D, Orme GR, Pichon M, Sale PF, Sammarco P, Wallace CC, Wilkinson C, Wolanski E, Bellwood O (eds.) Proceedings of the 6th International Coral Reef Symposium: Vol. 2: Contributed Papers. Townsville, Australia.

Watkiss P, Anthoff D, Downing T, Hepburn C, Hope C, Hunt A, Tol, R (2005) *Social Costs of Carbon Review – Methodological Approaches for Using SCC Estimates in Policy Assessment*. AEA Technology Environment, UK.

Williams R, Lusseau D, Hammond PS (2009). The role of social aggregations and protected areas in killer whale conservation: the mixed blessing of critical habitat. *Biological Conservation* 142:709-719.

WIOLab (2008) Transboundary Diagnostic Analysis of Land-based Sources and Activities in the Western Indian Ocean Region.

WRI, World Resources Institute (2011) Reefs at Risk Revisited, Downloadable Datasets, February 2011, http://www.wri.org/publication/reefs-risk-revisited.

Xerinda E (2011) Potential for aquaculture in Mozambique, environment conditions, and the cultivated marine and fresh water species. In: Schoenherr and Quatmann (eds.) proceedings of the International Aquaculture Business Conference, Pemba, Mozambique, 9-10 November 2011.

Zacarias DA (2010) Tourism carrying capacity assessment as a tool to support coastal management: A pilot survey at two mass tourism beaches. MSc Thesis at University of Algarve, Faculty of Science and Technology, 161 pp.

World Bank (2004) Assessing the economic value of ecosystem conservation. Pagiola S, von Ritter K, Bishop J, World Bank Environment Department Paper, 101, Washington, DC.

World Bank (2005) *Estimating the cost of environmental degradation. A training manual.* Bolt K, Ruta G, Sarraf M, World Bank Environment Department Papers, Washington, DC.

UNEP (2010) *Natural capital. The economics of ecosystems and biodiversity. Our planet*, September 2010. UNEP, Nairobi.

Armas EB, Fisker P, Naikal E (2014) How wealthy is Mozambique after the discovery of coal and gas? Measuring wealth in Mozambique using the wealth accounting framework. World Bank Working Paper 2014/01/01.

TEEB (2013) Guidance Manual for TEEB Country Studies. Version 1.0.

APPENDIX A. THE CONCEPT OF ECONOMIC VALUE OF ECOSYSTEM SERVICES

In this Appendix we present the framework that is used most often for the valuation of ecosystem services. As we will see there is no broad consensus on the underlying concepts. Often differences between scientists and economists derive from disagreements about these concepts. Hence it is important to be clear about the literary basis for the economic approach to the valuation of ecosystem services:

(1) Instrumental vs. intrinsic valuation. Many people, including various biologists and other natural scientists, do not feel comfortable with placing an instrumental value on ecosystems. The common argument is that ecosystems have value on its own, without being used by humans – also known as intrinsic value. A more extreme version of this perspective even claims that that instrumental valuation of ecosystems, often translated in monetary terms, is a nonsense exercise (see Nunes and van den Bergh, 2001). Many people, however, do accept the attribution of a monetary value to ecosystems, and their services, arguing that, like any other environmental good or service, it is an outcome of an anthropocentric, instrumental point of view, bearing in mind the benefits of ecosystems for humans in terms of its production and consumption opportunities. Two specific motivations are as follows. First, making public or private decisions that affect ecosystems implicitly means attaching a value to it. Second, monetary valuation can be considered as a democratic approach to decide about public issues. Finally, some subscribe an intermediate attitude by arguing that the monetization of ecosystems benefits is possible, but that it will always lead to an under-estimation of the 'real' value since 'primary value' of ecosystems cannot be translated in monetary terms.

(2) Monetary vs. physical indicators. Monetary valuation of ecosystem services is anchored in an economic perspective, based on biological indicators of the impacts of ecosystem services on human welfare. The economic value of ecosystems can be traced to two important sources. First, ecosystem services can serve as an input into the production of market goods. Second, ecosystem services can be interpreted as a direct contributor to individual utility or wellbeing: for example, the human pleasure derived from experiencing a marine protected area. Economic valuation of ecosystem services is based on using monetary indicators, interpreted by economists as a common platform for comparing and ranking alternative biodiversity management policies. On the other hand, physical

assessments of biodiversity value are based on non-monetary indicators. These include, for example, species and ecosystems richness indices, which have served as important valuation tools in the definition of "Red Data Books" and "Sites of Special Interest". It is not guaranteed, however, that monetary and physical indicators point always in the same direction. In this sense, they should best be regarded as complementary methods for assessing biodiversity changes. In some cases monetary values can be given to these physical indicators, bringing together the two approaches.

(3) Direct vs. indirect values. The notion of ecosystem services direct value is sometimes used to refer to the use of ecosystem services by humans for production and consumption. The term 'indirect value' refers to the relation of ecosystems in supporting and protecting economic activity by regulatory environmental services. In the literature one can also find other terms, such as 'contributory value', 'primary value', and 'infrastructure value' of ecosystems, that refer to the same notion.

(4) Levels vs. changes of ecosystem services. Much of the work done to provide monetary values of ecosystem services is structured in terms of levels – measuring the consequences of the loss of a whole set of ecosystem services or a type of ecosystem in a given location. While interesting, it is less useful as a guide to policy than values provided for small or medium sized changes in ecosystem services. These are more frequently experienced and can be avoided by taking appropriate action. At the most general level one can argue that the world's ecosystems are of infinite value because without it no economic activity would be possible. (e.g. Costanza et al. 1998). While true, such a statement has little significance to policy-makers.

(5) Holistic vs. reductionist approaches. According to a holistic perspective, ecosystem services are an abstract notion, linked to the integrity, stability and resilience of complex systems, and thus difficult to disentangle and measure. In addition, the insufficient knowledge and understanding of the human and economic significance of almost every form of life diversity further complicates the translation of physical indicators of ecosystem services into monetary values. For these reasons, economic valuation of ecosystems is regarded as a hopeless task by many scientists (e.g. Ehrenfeld 1988). The paradigm used in the economics literature takes a different view – a reductionist perspective – in which one is assumed to be able to disentangle, or separate the total value of ecosystem services into

different economic value categories, notably into use and passive use or nonuse values (Pearce and Moran 1993).

(6) Expert vs. general public assessments. Economic valuation starts from the premise that social values should be based on individual values. Therefore, when deciding for a general public valuation context, it is agreed that all individuals, from every educational level and with all types of life experiences, should be are involved in the valuation exercise. Such a valuation process benefits from clear and legitimate democratic support. Another view assumes that laypersons cannot judge the relevance and complexity of ecosystem services-ecosystems-functions relationships. Instead, judgments and evaluation of ecosystems changes in this view should be left to experts, notably biologists. An example of an intermediate 'solution' is to use experts to inform laypersons sufficiently before confronting them with special economic valuation tools. The submissions that were received and assessed represent both views.

From the above considerations it is clear that many different value perspectives can be distinguished. This means that different opinions about ecosystem services value may in fact be based on different perspectives. This does not mean that one is right and the other is wrong. Evidently however, it is crucial to understand the underlying perspective. The section clarifies this point for the subsequent evaluation of empirical valuation studies.

In this context, the economic valuation of ecosystem services is characterized with reference to the set of perspectives presented above. First, economic valuation of ecosystem services is based on an instrumental perspective of the value of ecosystems. This means that the value of ecosystem services is anchored in a human perspective interpreted as the result of an interaction between who attaches value, humans, and the object of valuation, ecosystem goods and services flows. In other words, an economic valuation subscribes to an anthropocentric value orientation, see point (1). Second, humans elicit ecosystem services value in terms of the benefits obtained from using, experiencing, and consuming ecosystem goods and services. In general terms, the value of ecosystem services can be assessed in terms of its impact on the provision of inputs to production processes, in terms of its direct impact on human welfare, as well as in terms of its impact on the regulation of the nature-ecosystem-ecological functions relationships, see point (2). Third, the economic valuation of ecosystem services is most frequently pursued through explicit ecosystem services changes, see point (3). The most important and commonly used application is to evaluate 'trade-offs' between different policy/management options. This approach typically uses cost-benefit analysis to compare the full range of costs and benefits over time associated with different options. For example, one design option for a new development may result in a loss of 5 ha of forest and 2 ha of wetland. Another option may result in the loss of 9 ha of forest. If all other things are equal, how can we rank the options and select the best option (given the policy maker objective)? From a purely economic perspective, the answer depends on the difference in aggregated 'marginal' cost of losing each ha of habitat. Ecosystem valuation can help evaluate that trade-off through converting the impacts to a single unit of currency (money), although other factors may also influence the ultimate decision. Fourth, economic valuation of ecosystem services changes is based on a reductionist approach since it is stands on the idea that one is capable of disentangling the total economic value of ecosystem services into two basic values - use and non-use – which reflect different human motivations, see point (4). Finally, the economic valuation of ecosystem services results in a monetary indicator that sits alongside physical indicators. It has a strong appeal because it can be easily fitted to benefit-cost-analysis, a fundamental tool for the design of effective and broadly accepted biodiversity management policies. One should not take that, however, to imply that only monetary indicators are relevant. In some cases policies can be made to achieve physical targets at least cost and in others to value physical targets that can then be set as policy. Thus there are important relationships between the monetary and physical targets.

A.1 The Total Economic Value framework

A well-recognized and used framework for attaching monetary values on ecosystem services is that of 'Total Economic Value'. As illustrated in Figure A1, this categorizes the different 'ecosystem services' into the following type of economic value:

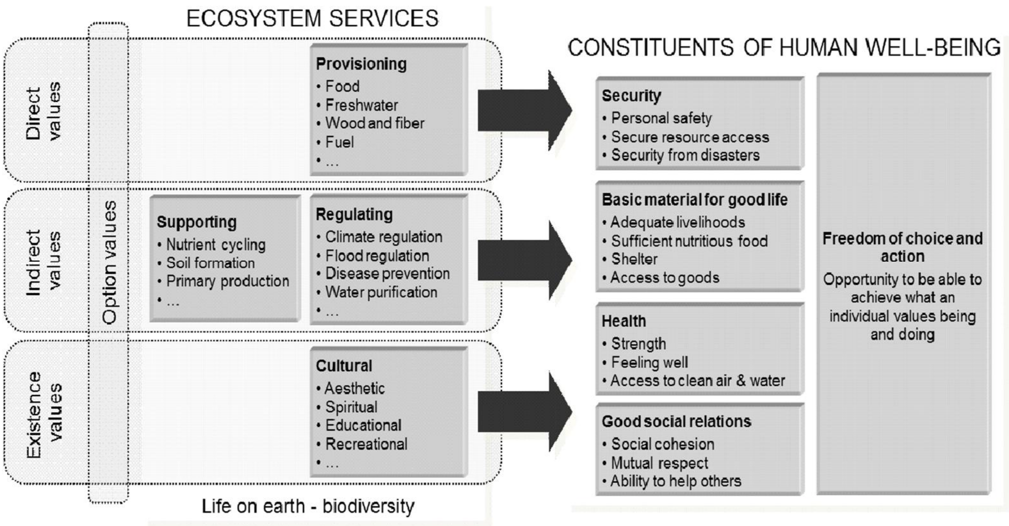
Direct use values: These include raw materials and physical products that are used directly for production, consumption and sale such as those providing energy, shelter, foods, agricultural production, water supply, transport and recreational facilities.

Indirect use values: These include the ecological functions that maintain and protect natural and human systems through services such as maintenance of water quality and flow, flood control and storm protection, nutrient retention and micro-climate stabilization, and the production and consumption activities they support.

Option values: This is the 'premium' placed on maintaining a pool of habitats, species and genetic resources for future possible uses, some of which may not be known now, such as leisure, commercial, industrial, agricultural and pharmaceutical applications.

Non-use values: This is the value of ecosystems regardless of their current or future use, for cultural, spiritual, aesthetic, heritage and biodiversity reasons. They comprise 'existence', 'altruistic' and 'bequest' values. For example, people are willing to pay to protect Caucasian tigers and rainforests even though they may never use or see them in the wild themselves. Non-use values can be significant, particularly for maintaining unique ecosystems where large populations may be willing to pay to protect them.

Figure A1: Ecosystem services and Total Economic Value



Source : TEEB (2010).

A.2 Placing a value on marine ecosystem services

Quantitative valuation (non-monetary)

Quantitative valuation of ES is not anchored in economic agent's behavior and therefore not linked to micro-economic theory. A well-known example of this approach is the ecological production function. Ecological production function is as biophysical evaluation technique and therefore is not dependent upon the socio-economic context. The valuation is expressed using non-monetary metrics. In the context of land accounting, this technique is commonly used to determining the quantity of land/coastal area, and its ecosystem type profile, in terms of the provision of ES and biodiversity that is required to offset the loss of ES form a damaged area of a similar habitat – see Table A1.

Table A1. Ecological production function

Technique	Description	Examples
Habitat equivalent analysis	This technique uses a scaling process to determine the amount of environmental compensation required based on units of habitat damaged and created.	The approach may determine that $3.5m^2$ of coral reef needs to be restored for every $1m^2$ of damaged coral reef
Ecosystem service analysis	The amount of ecosystem service compensation required is based on biophysical units of resource damaged and created.	A population of 500 trout needs to be replaced in a river damaged by a pollution incident.

Source: Own elaboration

Restoration, or even the creation, of natural habitats for the protection of biodiversity and provision of ES has also been the core of an emergent economic activity. Recently investment and development banks have been operating as ES “banks” as a tool for strengthening economic development by using ecosystem services (Han et al. 2009). The core of this banking sector is to propose a portfolio of ES investment options to the wide range of economic sectors. For example, in the process of negotiation involving a European based oil-and-gas company in the acquisition of a license to operate in the EEZ of Mozambique, this application maybe also dependent on company profile and engagement with respect of ES. In particular, the European based oil and gas company proposal may also be characterized by a significant investment in ES in Mozambique, including the support of national environmental conservation programs, e.g. supporting and respective marine biological corridors in the EEZ waters of NMC and having no vessel of the European based oil-and-gas company operating in that same corridor. This aspect will increase the degree of competiveness of the present corporate investment proposal when compared to others, if the others do not consider a similar action. Finally, when the valuation ES is focused on its impacts to human health, then we have techniques such as the loss of earnings, quality adjusted life year in addition to the cost of illness.

Monetary valuation methods

There are three main categories of monetary valuation techniques. We refer to: revealed preference approaches, cost-based approaches and stated preference approaches. Table A2 presents the full set of monetary valuation techniques, including the discussion of some examples. The only monetary valuation technique that is able to estimate the non-market benefits of ecosystem services is the contingent valuation technique and the stated choice experiment technique. They are characterized by the use of ad hoc questionnaires in which respondents are asked to state directly their preferences for the ES under valuation – for this reason these two techniques are also known as stated preferences approaches. Finally, economists may proceed with the estimation of the benefits of ecosystem services by exploring the use of valuation transfer techniques. These techniques are characterized by using monetary values from other past valuation studies and transfer the respective economic values to the new policy site under consideration.

Table A2: Monetary Based Ecosystem Valuation Techniques

Category		Technique	Description	Example
Revealed preference approaches: Look at the way in which people reveal their preferences for marine ecosystem services through market production and consumption	Production function approaches	Market prices	How much it costs to buy an ecosystem good or service, or what it is worth to sell.	The market price of fish or seafood.
		Effect on production	Relates changes in the output of a marketed good or service to a measurable change in ecosystem goods.	The reduction in fishery output as a result of clearing a mangrove or saltmarsh.
	Surrogate market approaches	Travel costs	Using information on the amount of time and money people spend visiting an ecosystem for recreation or leisure purposes to elicit a value per visit.	The transport and accommodation costs, entry fees and time spent to visit a Marine National Area.
		Hedonic pricing	The difference in property prices or wage rates that can be ascribed to the different ecosystem qualities or values.	The difference in prices between houses in the sea front compared to similar houses that do not.
Cost-based approaches: Look at the market trade-offs or costs avoided of maintaining ecosystems for their goods and services		Replacement costs	The cost of replacing an ecosystem good or service with artificial or man-made products, infrastructure or technologies, in terms of expenditures saved.	The costs of flood protection infrastructure after the loss of catchment protection forest/natural mangrove
		Mitigate or avertive expenditures	Expenditures required mitigating or averting the negative effects of the loss of ecosystem services (similar to replacement costs).	Additional infrastructure required to maintain coastal protection standards after the loss of natural mangrove areas
		Damage costs avoided	The costs incurred to property, infrastructure and production when ecosystem services which protect economically valuable assets are lost, in terms of expenditures saved.	The damage to roads, bridges, farms and property resulting from increased flooding after the loss of catchment protection forest
Stated preference approaches: Ask consumers to state their preference directly		Contingent valuation	Infer ecosystem values by asking people directly what is their willingness to pay (WTP) for them or their willingness to accept (WTA) compensation for their loss saved.	How much would you be willing to contribute towards a fund to clean up a beach?
		Choice experiments	Presents a series of alternative resource or ecosystem use options, each defined by various attributes set at different levels (including price), and asks respondents to select which option (ie sets of attributes at different levels) they prefer.	Respondents' preferences for conservation, recreational facilities and educational attributes of natural marine areas.

Source: TEEB (2010), adapted.

Table A2: Monetary Based Ecosystem Valuation Techniques (cont')

Category	Technique	Description	Example
Benefit (or Value) Transfer	Unit value (e.g. average willingness to pay values)	This technique applies average WTP values taken from other studies. Ideally these values are adjusted to account for key differences in context such as income levels and degree of impact.	The average willingness to pay of recreational visitors to one marine protected area in Madagascar applied to another similar marine area in Mozambique. Converted using difference in GDP/capita factor.
	WTP functions	This technique uses the benefit function (or 'bid' function) which is the formula that explains the WTP value in terms of key characteristics (eg environmental and socio-economic such as incomes).	Insert specific site related variables (eg average income, level of education) into the WTP bid function for visitors to a marine area/.
	Meta analysis	This technique takes the results from a number of studies and analyses them in such a way that the variations in WTP in those studies can be explained.	Analysis of many WTP studies for marine area to derive trends in the key variables affecting visitor WTP values for marine areas, to establish a suitable value or adjustments for the site to be assessed.

Source: TEEB (2010), adapted.

Table A3 provides guidance on selecting economic valuation techniques in the context of marine ecosystem services[9]. However, in many situations the choice of the technique depends on the study context and its circumstances. For example, aspects such as required estimation accuracy, and budget, data and time availability play a significant role in the choice of the economic valuation technique. However, any valuation exercise should always be casted within the mould of the economic, sociological, political and cultural characteristics and peculiarities of the study site and underlying policy management set-up within which it is located. All together these characteristics define the institutional context, determining the interaction between the society and the environment and this way impacting the selection of the valuation techniques.

Table A3: Economic Valuation Techniques for Marine Ecosystem Services

[9] See Appendix B for more detail information on the different economic valuation techniques.

Total Economic Value	Ecosystem Services		Revealed preference				Cost-based	Stated preference	Benefit transfer
			Market prices	Effect on production	Travel costs	Hedonic pricing			
Direct use	Provisioning		✓	✓					
Indirect use	Regulating			✓		✓	✓		✓
Direct use	Cultural	Recreation	✓	✓	✓	✓		✓	✓
Non use	Cultural	Existence						✓	✓

Source: own elaboration

The relationship between ES and human welfare in developing countries, and the NMC in particular, and the extent to which particular valuation tools are able to unearth this requires special attention. Therefore, the valuation study that is framed without a cognizance of NMC the characteristics – economic, sociological, political and cultural NMC characteristics and peculiarities and underlying policy management set – run the risk of being irrelevant in valuing (the change of selected) ES for informed decisions, and therefore in contributing in paving the sustainable development of the NMC country within which the study is conducted.

However, any valuation study that is proposed for application in the NMC will follow the following practical steps or organization guidelines (independently of the choice economic valuation technique):

(1) Define the scope._This step helps to scope out and define what to value and to define the boundaries of the valuation exercise.

(2) Plan the Study. This step goes into the selection of the economic valuation technique and all specific details as to how the valuation will actually be undertaken in terms of which stakeholders will be involved, to undertake what aspects, when, how long it may take and what it will cost.

(3) Undertake the Valuation. This step is the actual valuation itself. It comprises a process of other sub-steps that should be followed to undertake the valuation aspect of the ecosystem services. This involves aspects such as establishing the environmental baseline, determining the stakeholder's impacts and dependencies, assessing which ecosystem services are affected, and valuing the changes.

APPENDIX B. COMPARISON OF ECOSYSTEM VALUATION TECHNIQUES

Technique	Advantages	Disadvantages	Data requirement
Market prices	+ A readily transparent and defensible method since based on market data. + It reflects an individual's willingness to pay (WTP).	- Only applicable where a market exists for the ecosystem service and data is readily available.	Market price to buy an ecosystem product. The costs involved to process and bring the ecosystem product to market (e.g. processed timber).
Effect on production	+ If data is available, it is a relatively straightforward technique to apply.	- Necessary to recognise and understand the relationship between the ecosystem service and output of product. - Can be difficult to obtain data on both change in the ecosystem service and effect on production.	Data on changes in the output of a product. Data on cause and effect relationship (eg loss of fisheries due to loss of seagrass or coral habitat).
Travel costs	+ Based on actual behaviour (what people do) rather than a hypothetically stated WTP. + The results are relatively easy to interpret and explain.	- Approach is limited to direct use recreational benefits. - Difficulties in apportioning costs when trips are to multiple destinations or are for more than one purpose. - Considering travel costs alone ignores the opportunity cost of time whilst travelling (e.g. should a proportion of the individual's hourly salary be added?) - Some individuals may have moved house to live closer to the site, reducing their travel costs and therefore under estimating their valuation of the site.	The amount of time and money that people spend visiting an ecosystem for recreation or leisure purposes. Motivations for travel.
Hedonic pricing	+ Readily transparent and defensible method since based on market data and WTP. + Property markets are generally very responsive so are good indicators of values.	- Approach is largely limited to benefits related to property. - The property market is affected by a number of factors in addition to environmental attributes, so these need to be identified and discounted.	Usually data relating to differences in property prices or wage rates that can be ascribed to the different ecosystem qualities (e.g. a landscape view, distance to water feature).

Replace-ment costs	+ Provides surrogate measures of value for regulatory services (which are difficult to value by other means). + A readily transparent and defensible method when based on market data.	- Can overestimate values. - The technique does not consider social preferences for services or behaviour in the absence of the services. - The replacement service probably only represents a proportion of the full range of services provided by the natural resource.	The replacement costs of a proxy for the ecosystem service. This needs to be at least as effective as the ecosystem service and be the least cost alternative. Society must also have demonstrated a willingness to pay for the project.
Mitigative or avertive expenditures	+ Provides surrogate measures of value for regulatory services. + When goods are non-marketed, it can be easier to value the costs of producing benefits than the benefits themselves.	- Can overestimate values.	Data on the expenditures required to mitigate or avert the negative effects of the loss of ecosystem services.
Damaged costs avoided	+ Provides surrogate measures of value for regulatory services that are difficult to value by other means (eg storm, flood and erosion control).	- The approach is largely limited to services related to properties, assets and economic activities. - Can overestimate values.	Data on costs incurred to property, infrastructure or production as a result of loss of ecosystem services. Damages under different scenarios including 'with' and 'without' regulatory service.
Contingent valuation	+ Enables values to be captured for both use and non-use values. + Extremely flexible since it can be used to estimate the economic value of virtually anything. + Will give a much more accurate outcome than benefit transfers.	- The results are subject to numerous different bias from respondents and hypothetical in nature. - E.g. respondents may express a positive willingness to pay to promote a 'warm glow' effect, overestimating valuations. - E.g. if the cost is perceived as a government tax, respondents may express a negative willingness to pay, underestimating valuations. - Non-use values derived can still be questionable - It is resource intensive.	Data on the amounts that people would be willing to pay for an ecosystem service, or conversely, what they would be willing to accept as compensation for loss of an ecosystem service. Obtained by asking individuals to state their preference directly.
Choice experiments	+ Enables values to be captured for both use and non-use values. + Provides theoretically more accurate values for marginal changes (eg values per percent increase in coral	- The results are subject to bias from respondents, is resource intensive and hypothetical in nature. - It is resource intensive. - Can be mentally	Data on the individual preferences of people when presented with a series of alternative resource or ecosystem use options.

	cover). + Will give a much more accurate outcome than benefit transfers.	challenging for respondents to truly weigh up the alternative choices given to them in the time available.	
Benefits transfer	+ Low cost and rapid method for estimating recreational and non-use values.	- The results can be questionable unless carefully applied.	Valuations from similar studies elsewhere. Data on key variables from different studies (eg GDP per person).

Source: TEEB (2010), adapted

APPENDIX C. ANNOTATED BIBLIOGRAPHY OF VALUATION STUDIES IN NMC COUNTRIES

Ref.	Study site	Valued scenario	Economic value	Valuation method	Commissioned by (year)
[1]	Moyen Ouest (MDG)	Current values of wood extraction	(1) 41.07 US$ for export of 1 m^3 of raw wood (2) 44.53 US$ for transformation and export of 1 m^3 of raw wood (3) 14.30 US$ for transformation and selling of 1 m^3 of raw wood on local market (4) 0.16 US$/kg for export of essential oils (5) 0.22 US$/kg for fabrication and selling of products on local market (6) 0.05 US$/kg for selling bark (7) 0.20 US$/kg for medicinal products from bark and selling on local market	MP	Int. Org. (2006)
[2]	Vohitra River watershed (MDG)	Benefits of watershed protection with focus on flooding alleviation benefits of a natural park	US$ 126,700 net present value of benefits of the park	ADC	Research (1997)
[3]	Beza Mahafaly Special Reserve (MDG)	Consumer surplus from visiting the natural reserve	(1) 276 US$/person/visit with linear model (2) 360 US$/person/visit with inverse-log model	TC	Int. Org. (1993)
[4]	Mantadia National Park (MDG)	WTP for establishment of a national park and Increase in consumer surplus from improvement in tourist facilities	(1) 45.81 US$/person/trip from 10% improvement in facilities (2) 95.56 US$/person/trip from 20% improvement in facilities (3) 149.23 US$/person/trip from 30% improvement in facilities (4) 207.83 US$/person/trip from 40% improvement in facilities (5) 268.37 US$/person/trip from 50% improvement in facilities (6) 61.39 US$/person/trip WTP for establishment of the park	CVM, TC	Int. Org. (1995)
[5]	Mantadia National Park (MDG)	WTA for loss of forest products due to establishment of the park	50 USD/household/year	CVM	Research (1996)
[6]	Zambezi basin wetlands (MOZ)	Total Economic Value	(1) 1332 mill. ZMK/year for floodplain agriculture (2) 2109 mill. ZMK/year for fish production (3) 1887 mill. ZMK/year for livestock grazing (4) 70.3 mill. ZMK/year for natural products and medicine (5) 1.8 mill. ZMK/year for biodiversity	MP	Government; Int. Org. (2001)
[7]	Barotse floodplain (MOZ)	Current and present values for various ecosystem services	(1) 5.2 mill USD for groundwater recharge (present value) (2) 11.3 mill. USD for water purification (present value) (3) 4.4 mill. USD/year for cattle, crops, reeds, papyrus, palms, etc.	RP, NFI, MP	Int. Org. (1999)

			(4) 4.3 mill. USD/year for fish and wildlife (5) 400,000 USD for flood attenuation (present value)		
[7]	Lower Shire wetland (MOZ)	Current value of groundwater recharge and water purification	(1) 7.5 mill USD for groundwater recharge (present value) (2) 18.4 mill. USD for water purification (present value)	RP	Int. Org. (1999)
[7]	Zambezi river delta (MOZ)	Current value of groundwater recharge and water purification	(1) 3.2 mill USD for groundwater recharge (present value) (2) 12.7 mill. USD for water purification (present value)	RP	Int. Org. (1999)
[8]	Coutada 16 region (MOZ)	WTP for extension of Kruger National Park to Mozambique; WTA by residents for not using the forest	(1) 33.6-44.8 mill US$/year to extend Park into Mozambique (2) average WTA of 54 bags of maize / year not to use the forest	CVM, TC	Research
[9]	6 Marine Protected Areas (SYC)	(1) WTP for conservation projects (2) WTP for turtle tour (3) WTP for shark tour	(1) 4.87 US$/trip (2) 47.70 US$/trip (3) 54.73 US$/trip	CVM; PF; TC	Int. Org. (2004)
[10]	Entire Seychelles territory (SYC)	Value of biodiversity-dependent ecosystem services	(1) R 794 million from tourism revenues (2) R 3 million from entrance fees to protected areas (3) R 644 million from fisheries and mariculture (4) R 15 million from forestry (5) R 3 million from other plant and animal products (6) R 4 million from shoreline protection	MP; RP	Int. Org. (1997)
[11]	Seychelles Marine National Parks SYC)	Tourists' WTP for visits to marine park (use values)	(1) 25.61 US$/person/year Sainte Anne (2) 28.30 US$/person/year Port Launay (3) 21.63 US$/person/year Baie Ternay (4) 34.05 US$/person/year Curieuse (5) 36.65 US$/person/year Ile Coco, Ile La Fouce, Ilot Platte	CVM	Research (2000)
[12]	Various Islands (SYC)	WTP to protect from invasive alien species	52-57 euro/person/year	CVM	Int. Org. (2010)
[13]	Rufiji floodplain and delta (TZA)	Current value of extraction of natural resources	(1) 7137 USD for grass, reeds, and papyrus (2) 94,065 USD/year for salt (3) 15.7 mill. USD/year for fish and crustaceans (4) 345,524 USD/year for food, medicinal plants, palms and products	NFI	Government (2000)
[13]	Rufiji floodplain and delta (TZA)	Current value of extraction of natural resources	(1) 156,458 USD/year for fuelwood (2) 781,046 USD/year for timber, poles, products and honey	NFI	Government (2000)

			(3) 6085 USD/year for hunting of animals and birds		
[14]	Mtanza-Msona village wetlands (TZA)	Current benefits from use of natural resources and non-use values	(1) 31.5 mill. TZS/year for fishing and hunting (2) 57 mill. TZS/year for firewood and charcoal (3) 54 mill. TZS/year for grasses, reeds, medicinal plants, honey, etc. (4) 1.4 mill. TZS/year for regulating services (5) 2.4 mill. TZS/year for non-use values	MP, CVM	Government; Int. Org. (2008)
[15]	Kilombero Valley Ramsar site (TZA)	Value of water as input in agriculture	278 bill. TZS/year	PF	Government (2011)
[16]	Kilombero Valley Ramsar site (TZA)	Change in Total Economic Values from future landscape scenario	4566 TZS/household/year	CE	Government (2013)
[17]	Usangu wetland and floodplain (TZA)	Water supply for irrigated paddy and hydroelectricity	259 bill. TZS/year	NFI	Research (2005)
[18]	Pangani river basin (TZA)	Value of extracted water in different uses	(1) 108 bill. TZS/year for water supply to agriculture, domestic use, hydroelectricity (2) 114,150 TZS/household/year for harvesting of natural materials	MP	Int. Org. (2005)
[19]	Zanzibar and Mafia (TZA)	Recreational welfare loss due to coral bleaching	22-154 mill. US$/year annual welfare loss due to coral bleaching	CVM, TC	Research
[20]	Dodoma and Singida Regions (TZA)	WTP for improved management of groundwater resources and water service improvements	(1) 31.74-90.79 TZS/household/year for increased water supply (2) 28.58-68.39 TZS/household/year for water reticulation (3) 5.13-79.90 TZS/household/year for other types of improvement	CVM	Int. Org.
[21]	Serengeti National Park (TZA)	Willingness to trade off illegal hunting of bushmeat for selling in exchange for other livelihood options	(1) 36,000 TZS per week of hunting (multinomial logit model) (2) 51,000 TZS per week of hunting (random parameter logit model)	CE	Research
[22]	Eastern Arc Mountains and Cameroon Highlands (TZA)	Non-use values of wildlife and biodiversity conservation	(1) 15.90 GBP/household/year for unique and charismatic species (gorilla) (2) 9.77 GBP/household/year for unique and non-charismatic species (3) 12.78 GBP/household/year for non-unique and charismatic species (lion) (4) -0.87 GBP/household/year for non-unique and non-charismatic species (frog) (5) 4.44 GBP/household/year conserving in Eastern Arc and Cameroon Highlands	CVM	Int. Org.
[23]	Zanzibar (TZA)	Viewing coral reefs along the coast of Zanzibar via SCUBA diving or snorkeling	(1) 1.6 mill. USD/year economic losses from coral bleaching (25% of tourists diving) (2) 3.2 mill. USD/year economic losses from coral bleaching (50% of tourists diving) (3) 4.8 mill. USD/year economic losses from coral bleaching (75% of tourists diving)	CVM	Int. Org.

			(4) 2.5 mill. USD/year financial revenue from diving (25% of tourists diving) (5) 4.9 mill. USD/year financial revenue from diving (50% of tourists diving) (6) 7.4 mill. USD/year financial revenue from diving (75% of tourists diving)		
[24]	Eastern Arc Mountains (TZA)	Non-timber forest products from the tropical forest ecosystems	(1) 35,969 mill. TZS/year for firewood (2) 20,929 mill. TZS/year for charcoal (3) 220 mill. TZS/year for thatch (4) 2,202 mill. TZS/year for poles	MP	Int. Org.

Note: Valuations of coastal and marine ecosystem services are highlighted in Bold. CVM = contingent valuation method; MP = market prices; RC = replacement cost; VT = value transfer; ADC = avoided damage cost; CE = choice experiment; HP = hedonic pricing; PF = production function; TC = travel cost method; Int. Org. = International Organization; WTP = willingness to pay: WTA = willingness to accept.

References in Appendix C

[1] Andriamahefazafy (2006) Évaluation Monétaire des Actifs Environnementaux à partir d'une Approche par les Profits et Arbitrage entre Modes d'Exploitation à Madagascar. Institut de l'énergie et de l'environnement de la Francophonie, Fiche technique MOGED.

[2] Kramer, R. A., D. D. Richter, S. Pattanayak and N. P. Sharma (1997) Ecological and Economic Analysis of Watershed Protection in Eastern Madagascar. Journal of Environmental Management 49(3): 277-295

[3] Maille, P. and R. Mendelsohn (1993) Valuing Ecotourism in Madagascar. Journal of Environmental Management 38(3):213-218

[4] Mercer, E., R. Kramer and N. Sharma (1995) Rain Forest Tourism- Estimating the Benefits of Tourism Development in a New National Park in Madagascar. Journal of Forest Economics 1(2):239-269.

[5] Shyamsundar, P. and R.A. Kramer (1996) Tropical Forest Protection: An Empirical Analysis of the Costs Borne by Local People. Journal of Environmental Economics and Management 31: 129-144.

[6] Seyam, I.M., A.Y. Hoekstra, G.S. Ngabirano, H.H.G. Savenije (2001) The value of freshwater wetlands in the Zambezi basin. IHE Value of Water Research Report Series No. 7.

[7] Turpie, J., Smith, B., Emerton, L. and J. Barnes, 1999, Economic Valuation of the Zambezi Basin Wetlands, IUCN – The World Conservation Union Regional Office for Southern Africa, Harare

[8] Agostini, P. (1995) Economic Analysis of Ecologically Sensitive Areas in Developing Countries. Dissertation, University of California, San Diego.

[9] Cesar, H., P. Van Beukering, R. Payet and E. Grandourt "Evaluation of the Socio-economic Impacts of Marine Ecosystem Degradation in the Seychelles", Cesar Environmental Economics Consulting (2004)

[10] Emerton, L. "Seychelles Biodiversity: Economic Assessment", The World Conservation Union (IUCN), Prepared with the Conservation and National Parks Section, Division of Environment, Ministry of Foreign Affairs, Planning and Environment as part of the 'Seychelles National Biodiversity Strategy and Action Plan' (1997)

[11] Mathieu, L., I.H. Langford and W. Kenyo "Valuing Marine Parks in a Developing Country: A Case Study of the Seychelles", Centre for Social and Economic Research on the Global Environment (CSERGE) Working Paper GEC 2000-27 (2000)

[12] Mwebaze, P., A. MacLeod, D. Tomlinson, H. Barois and J. Rijpma (2010) Economic Valuation of the Influence of Invasive Alien Species on the Economy of the Seychelles Islands. Ecological Economics 69(12): 2614-2623.

[13] Turpie, J.K. (2000) The Use and Value of Natural Resources of the Rufiji Floodplain and Delta, Tanzania. Rufiji Environment Management Project Technical report No. 17.

[14] Kasthala, G., A. Hepelwa, H. Hamiss, E. Kwayu, L. Emerton, O. Springate-Baginski, D. Allen and W. Darwall (2008) An integrated assessment of the biodiversity, livelihood and economic value of wetlands in Mtanza-Msona Village, Tanzania. IUCN Tanzania Country Office Report.

[15] Musamba, E.B., Y.M. Ngaga, E.K. Boon, R.A. Giliba, A. Sirima and L.I. Chirenje (2011) Journal of Agricultural Science 2(1): 17-27.

[16] Mombo, F.S. (2013) A new institutional economics approach to evaluate management options for wetlands: the case of Kilombero Vallery wetlands in Tanzania. PhD Dissertation, University of Gent, Belgium.

[17] Kadigi, R.M.J., N.S. Mdoe, B.A. Lankford, S. Morardet (2005) The value of water for irrigated paddy and hydropower generation in the Great Ruaha, Tanzania. In Lankford, B. A.; Mahoo, H. F. (Eds.). Proceedings of East Africa Integrated River Basin Management Conference, Sokoine University of Agriculture, Morogoro, Tanzania.

[18] Turpie, J.K., Y.M. Ngaga, F.K. Karanja (2005) Catchment Ecosystems and Downstream Water: The Value of Water Resources in the Pangani Basin, Tanzania. IUCN Water, Nature and Economics Technical Paper No. 7

[19] Andersson, J. (2007) The Recreational Cost of Coral Bleaching - A Stated and Revealed Preference Study of International Tourists. Ecological Economics 62(3-4): 704-715.

[20] Kaliba, A.R.M., D.W. Norman, Y-M. Chang (2002) Willingness to Pay to Improve Domestic Water Supply in Rural Areas of Central Tanzania: Implications for Policy. International Development Research Centre, Nairobi Office.

[21] Moro, M., A. Fischer, M. Czajkowski, D. Brennan, A. Lowassa, L.C. Naiman, and N. Hanley (2013) An Investigation Using the Choice Experiment Method into Options for Reducing Illegal Bushmeat Hunting in Western Serengeti. Conservation Letters 6(1): 37-45

[22] Morse-Jones, S., I. Bateman, A. Kontoleon, S. Ferrini, N. Burgess and K. Turner (2010) Stated preferences for tropical wildlife conservation amongst distand beneficiaries: charisma, endemism, scope and substitution effects. Ecological Economics 78: 9-18.

[23] Ngazy, Z., N. Jiddawi and H. Cesar (2004) "Coral Bleaching and the Demand for Coral Reefs: A Marine Recreation Case in Zanzibar" in the Economic Valuation and Policy Priorities for Sustainable Management of Coral Reefs edited by Mahfuzuddin Ahmed, Chiew Kieok Chong and Herman Cesar.

[24] Schaafsma, M., S. MorseJones, P. Posen, R. D. Swetnam, A. Balmford, I. J. Bateman, N. Burgess, S. A. Chamshama, B. Fisher, T. Freeman, V. Geofrey, R. Green, A. S. Hepelwa, A. Hernández-Sirvent, S. Hess, G. C. Kajembe, G. Kayharara, M. Kilonzo, K. Kulindwa, J. F. Lund, S. S. Madoffe, L. Mbwambo, H. Meilby, Y. M. Ngaga, I. Theilade, T. Treue, P. Van Beukering, V. G. Vyamana and R. K. Turner (2011) The Importance of Local Forest Benefits: Valuation of Non-Timber Forest Products in the Eastern Arc Mountains in Tanzania. Working Paper 0967-8875, CSERGE, School of Environmental Sciences, University of East Anglia.

APPENDIX D. TECHNICAL DETAILS OF VALUE TRANSFER METHODOLOGY

The aim of this section is to provide the reader with the technical background required to understand the details of the value transfer analysis performed for the assessment of the coastal recreation and coastal protection services. Value transfer involves obtaining an estimate for the value of ecosystem services through the analysis of a single study or group of primary valuation studies that have been previously carried out to value similar goods or services in similar contexts (Liu et al., 2012). The transfer itself refers to the application of derived values and other information from the original study site to a policy site, in this case the coastal region of the NMC. This study implements meta-analytical value transfer, i.e., resulting from the statistical analysis (meta-regression) of a collection of previous individual primary valuation studies. Among transfer techniques, this has emerged as particularly suitable to scale up values that have been estimated for localized changes in individual ecosystem sites and to assess the value of changes in multiple ecosystem sites within a large geographic area such as a country or an administrative region (Brander et al., 2012).

D.1 Valuation of coastal recreation service

For the analysis of coastal recreation values, we rely on a global database of non-market valuations of the recreational services of coastal and estuarine ecosystems[10]. It includes 253 distinct value observations from 79 primary valuation studies, including both studies in the peer-reviewed scientific literature as well as unpublished working papers, theses and reports. Estimates of non-use values (e.g., existence, option and bequest values) are excluded from the analysis. Recreational activities in the database include both extractive uses (e.g., recreational fishing, shellfishing, and hunting) and non-extractive uses (e.g., swimming, sun-bathing, boating, wind-surfing, bird-watching, snorkeling, and diving). Valued ecosystems in the dataset are located in 34 countries, with the largest number of observations coming from the USA (82 observations). Fourteen observations from five African countries are included in the database, with only one study from the NMC region

[10] Further details on the dataset and analysis reported here are provided in Ghermandi and Nunes (2013).

(Ngazy et al., 2005). All the studies in the dataset use stated or revealed non-market valuation techniques (contingent valuation, choice experiments, travel cost method, and contingent behavior). Six types of coastal ecosystem types are considered: sandy beaches and coral reefs (which jointly correspond to slightly less than half of all observations), estuaries, coastal marshes and lagoons, mangroves, and ecosystems that are a mosaic of different coastal biomes.

GIS tools were used to characterize the geographic extent of each of the valued coastal ecosystems and the geographic, socio-economic and climatic context in which the valued ecosystems are located. The collected information on study, site and context characteristics was used in the context of the estimation of the following meta-regression model:

$$\ln(y_i) = a + b_V X_{Vi} + b_S X_{Si} + b_C X_{Ci} + u_i \qquad (1)$$

where $ln(y_i)$ is the natural logarithm of the endogenous variable measured in 2003 US$/ha/year (PPP); the subscript i is an index for the value observations; a is a constant term; b_V, b_S and b_C are vectors containing the coefficients of the explanatory variables X_V (including valuation study characteristics), X_S (site characteristics), and X_C (context characteristics).

To ensure the robustness of the results to changes in model assumptions, we considered different model specifications and used Huber-White/sandwich estimators, which are robust to modest departures from normality and heteroskedasticity. The econometric results of the estimation of the model parameters and relative diagnostics are presented in Table D1.

Table D1. Estimated meta-regression model of per-hectare recreational values

Variable	Coefficient	95% confidence interval		p-value
Constant	-7.987	-14.510	-1.465	0.017
CV – open ended	-0.944	-1.713	-0.174	0.016
TCM – zonal	1.862	1.089	2.635	0.000
TCM – individual & RUM	0.937	0.377	1.497	0.001
Contingent behavior	-1.639	-2.432	-0.847	0.000
WTP for improvement	0.863	0.326	1.400	0.002
Unpublished	-1.312	-1.870	-0.754	0.000
Year of primary data	0.144	0.106	0.182	0.000
Estuary	1.050	-0.228	2.328	0.107
Beach	1.860	1.087	2.632	0.000
Reef	1.667	0.826	2.507	0.000
Recreational fishing	1.697	0.956	2.439	0.000
Non-extractive recreation	3.387	2.585	4.188	0.000
GDP per capita (ln)	0.470	0.051	0.889	0.028
Population density (ln)	0.454	0.156	0.751	0.003
Low human development	1.972	1.367	2.577	0.000
Anthropogenic pressure (ln)	-0.239	-0.327	-0.150	0.000
Travel time to nearest city (ln)	-0.534	-0.984	-0.085	0.020
Marine biodiversity	0.290	0.144	0.437	0.000
Heating degree months	-0.008	-0.016	0.001	0.092

Note: Regression with robust standard errors; N = 253; R-square = 0.719; adj. R-square = 0.696; Root MSE = 1.583; Shapiro-Wilk test, p-level = 0.193; the dependent variable in the regression is expressed in log-units.

In order to perform the spatial value transfer, a series of layers representing each one of the geo-referenced moderator variables were prepared with consistent projection, spatial resolution and extension. The original layers were re-projected in the geographic coordinate system WGS1984 and converted to raster layers with a cell dimension of 0.5°. The spatial variables in the model were evaluated at the level of each grid cell. Regarding non-spatial variables, 2009 was selected as the reference year. Due to the coarse geographic resolution of the map, any grid cell is likely to reflect a composite of the ecosystem types. We assume thus in the transfer function that any grid cell represents a mix of different ecosystem types. For the ecosystem service types, for which information at the policy sites is lacking, we assume the average characteristics of the study sites in the dataset. For the set of methodological explanatory variables, the data sample mean was used in the transfer function.

Following the assumptions described in Ghermandi and Nunes (2013), we rely on the areal extension (in ha) and average coastal recreation value (in US$/ha/year) in a swath of 2 kilometers landwards from the coastline for the aggregation of the spatially distributed value in each of the administrative provinces and countries making up the NMC region.

D.2 Valuation of coastal protection service

For the valuation of the coastal protection service, we rely on a global database of primary valuations of the coastal protection service of mangroves, coastal wetlands and coral reefs[11]. The dataset includes 92 observations from 52 independent valuation studies, including both studies in the peer-reviewed scientific literature as well as unpublished working papers, theses and reports. The observations are distributed rather homogeneously among the three ecosystem types (30 observations for mangroves, 36 for coral reefs, and 23 for coastal wetlands). In total, studies from 27 countries are included.

GIS tools were used to characterize the geographic, socio-economic and climatic context in which the valued ecosystems are located. The collected information on study, site and context characteristics was used in the context of the estimation of the following meta-regression model:

$$\ln(y_i) = a + b_1 X_{1i} + b_2 X_{2i} + b_3 X_{3i} + b_4 X_{4i} + u_i \qquad (1)$$

where $ln(y_i)$ is the natural logarithm of the coastal ecosystem services measured in 2003 US$/ha/year (PPP); the subscript i is an index for the value observations; a is a constant term; b_1, b_2, b_3 and b_4 are vectors containing the coefficients of the explanatory variables X_1 (including valuation study characteristics), X_2 (site characteristics), X_3 (context characteristics), and X_4 (regional binary variables). The regression analysis uses the Ordinary Least Squares (OLS) technique with robust standard errors. Heteroskedasticity and multi-collinearity are controlled for. The econometric results of the regression for the best-fit model are presented in Table D2.

[11] Further details on the dataset and analysis reported here are provided in Rao et al. (2015).

Table D2. Estimated meta-regression model of per-hectare coastal protection values

Variable	Coefficient	p-value
Constant	2.997	0.280
Replacement cost	0.563	0.380
Damage cost avoided	0.644	0.237
Contingent valuation	3.062	0.002
Size (log)	-0.316	0.001
Mangroves	-1.473	0.067
Coral reefs	-0.652	0.376
GDP/capita (log)	0.772	0.007
Low impact development	-1.515	0.011
Number of storms	0.056	0.049
Wind speed	-0.056	0.040
Mangroves*wind speed	0.026	0.431
Coral reefs*wind speed	0.076	0.016

Note: OLS regression with robust standard errors; N = 90; R-square = 0.445; $F(12,77) = 7.26$, p-value < 0.01; the dependent variable in the regression is expressed in log-units.

After estimating the model parameters, the meta-regression model described above was applied as a benefit transfer value function to provide an estimate of the values of the investigated ecosystem types in areas where primary valuation results are not available. First, the spatially explicit, continuous, explanatory values used in this analysis were calculated for all coastal areas, using the global data sets described in Section 4 to infer the distribution of the three considered coastal habitats. The spatial resolution of the spatial layers was equal to 0.5°. The value transfer function was applied only in those grid cells where at least one of the three ecosystem types is present. For the non-spatial regional information, a proportion based on the studies used in the meta-analytic regression was calculated and included. After estimating a unit average value in each grid cells (in US$/ha/year), an aggregated ecosystem service value estimate was calculated in each grid cell of the raster map multiplying by aggregate area of each of the three ecosystem types. This was estimated based on the information contained in the spatially explicit databases of the distribution of mangroves, coral reefs and coastal wetlands.

Appendix E. Econometric estimation results

Table E1: Coastal Tourism (Segmented) Demand

Specification	Number of Observations	(International Coastal Arrivals) "R-Squared"	(Domestic Coastal Arrivals) "R-Squared"
Equation 1	124	0.67	0.48
Equation 2	124	0.79	0.78
Equation 3a	124	0.42	0.49
Equation 3b	124	0.55	0.53
		International Coastal Arrivals	Domestic Coastal Arrivals
Equation 1: (Log) Coastal Arrivals			
(Log) Total Expenditures		0.37***	0.03***
(Log) Number of UNESCO Sites		1.27***	0.07*
(Log) Number of Coastal Protected Areas		1.44***	0.30*
(Log) Beach Length		0.24*	2.47***
Constant		8.02***	4.41*
Equation 2: (Log) Total Expenditures			
(Log) Destination GDP per Capita		0.86***	0.87***
Population Density on the Coast		0.08	0.03
Constant		0.81	0.70
Equation 3a: (Log) Beach Length			
(Log) Annual Average Precipitation		-0.20*	- 0.26*
(Log) Harbour		-0.58***	-0.62***
Constant		2.77	1.02
Equation 3b: (Log)Number of Coastal Protected Areas			
(Log) Annual Average Temperature		0.69***	0.70***
(Log) Annual Average Precipitation		-1.08***	-1.06***
Biodiversity Index Mammals		0.11*	0.01***
Biodiversity Index Birds		0.08***	0.09***
(Log) Reef Area		0.30*	0.37*
(Log) Wetlands Area		0.23***	0.23***
Constant		2.99***	3.00*

*** =statistically significant at the 1% level; * =statistically significant at the 5% level.

Source: Onofri and Nunes (2013).

These estimates show and quantify the impact of ecosystem services on coastal (nation and international) touristic arrivals. In particular, coastal protected areas and beach length play a significant role in the characterization of coastal touristic attractiveness in Mozambique. In both cases, the results can be interpreted as a benefit (here measured in monetary terms, through a market choice that in turns reveals/signals a preference) received from the consumption of the destination country. This result signals a higher availability to pay for coastal destinations from international tourists (because of higher money and time availability, or higher benefits derived from the consumption of coastal tourism).The estimated coefficients for the variable "beach length" are, as expected, positive in both cases and statistically significant, demonstrating that domestic and international arrivals positively depend on the beach dimension of the selected destination. This result confirms the mainstream empirical literature results. An important determinant of tourism destination choice is the presence of sandy beaches. Previous studies have demonstrated that a country's coastline and beach length positively influence the number of national tourist arrivals (Bigano et al., 2007, Maddison 2001). In addition, annual average precipitation (climate related variable) and harbour dimensions (economic activities) negatively affect the attribute beach length, which, in turn, is a fundamental determinant of both domestic and international arrivals in the countries. It is important to highlight that the magnitude of the estimated coefficients for "beach length" is much larger, and more statistically significant, for domestic tourists. This result might be interpreted as a stronger preference for the "beach segment" from domestic tourists. The estimated coefficients for the variable number of UNESCO sites are positive and statistically significant for both international and domestic tourists' arrivals. This result follows Hamilton (2004) findings. However, the magnitude of the estimated coefficient for international tourists is much larger than the one for domestic tourists. The same holds for the estimated coefficient for the variable (logged) coastal protected areas. This might signal, in line with the previous result, a stronger preference for the natural and cultural segment of coastal tourism from international tourists. The variables that indicate the coastal habitat abundance[12] and

[12] Habitat abundance is defined as the share of a country's surface covered by a particular habitat type; here the surface covered by coral and coastal wetland. This indicator is also considered important in the description of a country's biodiversity profile since habitat distribution, together with its spatial landscape patterns, are strongly linked to the overall condition of ecological resources (O'Neill et al., 1997). Furthermore, coastal wetlands and reefs, together with forests, are well-studied ecosystems for which good quality data are available and their role in the hosting and conservation of biodiversity is widely acknowledged.

coastal habitat diversity do exert a significant influence on the country's extent of protected areas. The estimated coefficients for the biodiversity indexes, bird and mammal species diversity in the destination country, and (logged) reef and coastal wetland areas are positive and statistical significant and, in turn, affect the number of coastal protected areas. Climatic variables can also have an impact on the number of protected areas. In particular, the estimated coefficient for the (logged) annual average precipitations negatively impact the areas designated with protected status. Interestingly, average annual temperature positively affects the existence of protected areas. The selected climatic, environmental and biodiversity related variables affect the number of protected coastal area by country, which, in turn, affects tourist arrivals in coastal destinations. In sum, we have "distinguished" two horizontal differentiated touristic demand segments worldwide and found they are characterized by different reservation price levels. International tourists choose destinations because they have a preference for the cultural and natural segment of the coastal tourism. This, in turn, depends on the destination country's coastal habitat abundance and diversity. Domestic tourists have a preference for the beach characteristics, in particular beach length. This in turn depends on anthropogenic pressure, built environment and climatic variables. In addition, the "greens" estimated coefficient for the variable "total expenditures" presents a much higher (marginal) impact on (international) arrivals than in the case of the "beach lovers"/domestic tourists.