Republic of Mozambique
Ministry of Sea, Inland Waters and Fisheries

SPATIAL PRIORITIZATION ANALYSIS TO SUPPORT MARINE PROTECTED AREA EXPANSION IN MOZAMBIQUE

By The Wildlife Conservation Society & National Institute for Fisheries Research

JUNE 2021

Published by:

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Citation: Jones, K., Duarte, E., Grantham, H., Costa, H.M., Sidat, N., Sitoe, J., Van Beuningen, D., Bennet, R., Afonso, P., Agy, B., Montanha, C., Suege, I. & Harris, L.R. Spatial Prioritization Analysis to support Marine Protected Area expansion in Mozambique. Wildlife Conservation Society Mozambique and National Institute for Fisheries Research. Maputo, Mozambique. 2021 56pp.

Acknowledgements:
We are very grateful to the Ministry of Sea, Interior Waters and Fisheries, in particular to the board of the National Institute for Fisheries Research (IIP), the National Administration of Fisheries (ADNAP) and the National Directorate of Maritime and Fisheries Policies (DIPOL) for all support and information provided. We are also thankful to the other Ministries and Institutions that made available or that had gathered the information that allowed this work to be undertaken. We thank all the members of the coordination group established during this project for their valuable contributions, as well as the other institutions and specialists who were invited to the discussion meetings: Ministry of Land and Environment-MTA (Manuel Mutimucuio), National Directorate of Environment-DINAB (Ana Paula Francisco, Anselmo Gaspar, Sidonia Muhurro, Alexandre Bartolomeu), National Administration of Conservation Areas- ANAC (Armindo Araman and Mohamed Harun), ADNAP (Hadija Mussagy), DIPOL (Moniz Munguambe, José Ariscado,), National Petroleum Institute- INP (Guilhermina Honwana, Nazario Bangalane) RARE (Atanasio Brito, Edson José, Angelica Dengo, Alice Pires), Conservation International-CI (Karen Allen and Shannon Murphy), African Parks (Pablo Shapira), Eduardo Mondlane University- UEM (Adriano Macia, Célia Macamo, Noca Furaca), Centro Terra Viva- CTV (Cristina Louro), Pedagogic University-UPM (Benjamim Bandeira), Ponta do Ouro Partial Marine Reserve- POPMR (Gladys Nhangumele), IUCN (Maria Matediane, Cremildo Armando), FAO (Erudito Malate), BIOFUND (Denise Nicolau), WWF (Alima Taju, Eduardo Videira, Dalila Sequeira, Milton Jose Xavier), Natural History Museum (Almeida Guissamulo), National Institute of Hydrography and Navigation- INAHINA (Célia Magaia, Rezia Taiela, Flavio Almeida), Universidade de Cadiz (Yara Tibiriçá), Tartarugas para o Amanhã (Jess Williams) and Peace Parks Foundation. We would also like to thank to the whole team that is currently developing the Mozambican National Marine Spatial Plan (Plano de Ordenamento do Espaço Marítimo – POEM) for all the support provided, particularly to Teresa Gamito for the very profitable discussions that were held throughout the process. We would also like to acknowledge the contribution of Kerry Sink and Domitilla Raimondo from the South African National Biodiversity Institute (SANBI) for all the motivation and information provided to support this project. Our sincere thanks to the Master students of the students at the Bren School of Environmental Science & Management, Class of 2021, of the University of California, Santa Barbara, namely Anna Abelman, Courtney Krone, Erin Restig, Rachel Rhodes and Vanessa Rathbone for all the support provided, namely on data collection, organization and cleaning, on the spatial analysis conducted for sharks and rays, which were key for the development of this project, and also for the communication materials developed. Finally, we would like to thank Dr. Linda Harris from the Nelson Mandela University for the review, discussions and contributions provided throughout the process. This project was made possible with support from donors to the WCS Marine Protected Area Fund (MPA Fund) and the Norwegian Agency for Development Cooperation (NORAD).

Photo credits:
Erwan Sola cover, p4, p17, p24; Naseeba Sidat p9, 10 left; Hugo Costa p10 right, p13; Dave van Beunigen p11 top; BLT p12; Wild Times Safaris p21; Jon Hanson p25; WWF/Carlos Drews p27; Marc Stalmans p29; WCS p44.

EXECUTIVE SUMMARY

Recognizing the importance of marine ecosystems for the survival and well-being of the population, the Mozambican government has committed to meet several national and international conservation targets, with a view to increasing the protection of marine biodiversity that is poorly represented in the current network of Marine Protected Areas (MPAs). The current network of MPAs covers around 2.2% of the Economic Exclusive Zone (EEZ), falling short of the 10% target defined in the Aichi 2020 Biodiversity Targets, as well as the 5% by 2025 defined in target 11A of the National Biodiversity Strategies and Action Plans (NBSAP), and the 30% by 2030 established in the High Ambition Coalition (HAC).

There is an urgent need and desire to expand the national network of MPAs, and several additional areas have already been identified as potential protection sites. However, to make an informed decision on the expansion of MPAs, a robust analysis considering marine biodiversity and socio-economic activities in the ocean was required. As such, a program to develop scenarios to guide the government in the strategic expansion of MPAs in Mozambique was developed in September 2020. This program has been implemented through a joint partnership between WCS-Mozambique, and the National Institute for Fisheries Research under the Ministry of Sea Inland Waters and Fisheries (MIMAIP) using funding from the WCS Marine Protected Area Fund (MPA Fund).

Through this process, a coordination group was created comprised of institutions from MIMAIP, Ministry of Land and Environment (MTA), other ministries and civil society organizations, with the purpose of becoming the forum to discuss aspects related to the expansion of the MPA network. This coordination group conducted a comprehensive review of published and grey literature to identify data on marine biodiversity and human activities in the ocean. Using this data, priority areas for potential MPA expansion were identified by: i) mapping ecosystems, species and other important areas; ii) understanding human uses of Mozambique's EEZ, and iii) combining these data to identify new MPA priorities. The conservation planning software ***prioritizr*** was used to explore three different MPA expansion scenarios, namely: **scenario A**, covering 7-8% of Mozambique's EEZ; **scenario B**, covering 10-12% of the EEZ; and **scenario C**, expanding protection to 30% of the EEZ. These scenarios were based on Mozambique's international conservation commitments, such as the Aichi Targets and the High Ambition Coalition.

In scenario A, MPA priority areas are concentrated mainly in coastal areas and along the continental shelf, which are the most biodiverse waters in Mozambique. In scenarios B and C, increased targets for offshore ecosystems led to the selection of many remote areas in the southern and central parts of Mozambique's EEZ. Importantly, this spatial prioritization provides an evidence-based approach to identifying conservation priority areas, but does not decide about where to establish MPAs. Final MPA design requires a more comprehensive process, including more intensive stakeholder feedback, expert review, feasibility assessments, and more.

While the results of this analysis can be improved when more data becomes available, the government now has appropriate information to make informed decisions about how to expand the MPA network to achieve the protection goals to which the country has committed under the various conventions and initiatives. Considering that the National Marine Spatial Plan (POEM) is already finalized and approved, Mozambique now has an excellent opportunity to use the results of this analysis to help guide the expansion of its National Network of Marine Protected Areas.

Figure 0. Mangrove Forest os Quipaco Bay, Cabo Delgado

CONTENTS

SECTION 1. **INTRODUCTION**

1.1 Background

Mozambique harbours a wide variety of marine and coastal ecosystems from mangroves to coral reefs, through seamounts and coastal dune systems. The Mozambican government recognizes the importance of these ecosystems and has committed to meeting several national and international conservation targets, such as those of the Convention on Biological Diversity (CBD), through the 2015-2035 National Biodiversity Strategy and Action Plan (NBSAP).

The current Marine Protected Area (MPA) network covers about 2.2% of the EEZ, falling short of the 10% 2020 Aichi Biodiversity Targets, which Mozambique has ratified (Figure 1). Furthermore, the NBSAP aims to protect 5% of the marine ecosystems by 2025, and in 2019 Mozambique committed to the High Ambition Coalition (HAC) initiative 30/30, which intends to protect at least 30% of its land and sea by 2030.

Many ecosystems and species are, in fact, still poorly represented and protected under the current MPA network. There is a recognized need and will to further expand the national network of MPAs, and several additional areas have been identified as potential sites for protection. For example, the Wildlife Conservation Society Mozambique (WCS), in partnership with the Government, has implemented a project to identify Key Biodiversity Areas (KBAs) according to the recent 2016 IUCN Global Standard, and four marine and nine coastal KBAs were mapped (WCS, Government of Mozambique and USAID, 2021). Due to their importance, these areas could potentially receive formal protection in the future. Nonetheless, to make an informed decision about MPA expansion, the Government needs to rely on robust, scientific information, comprising both biological/environmental and socio-economic elements.

The country faces difficulties in meeting the targets mentioned above and several factors hamper the sound development of an adequate framework to pursue these objectives, such as i) the existence of multiple targets from different conventions, and ii) the lack of financial and scientific information for the identification and management of protected areas.

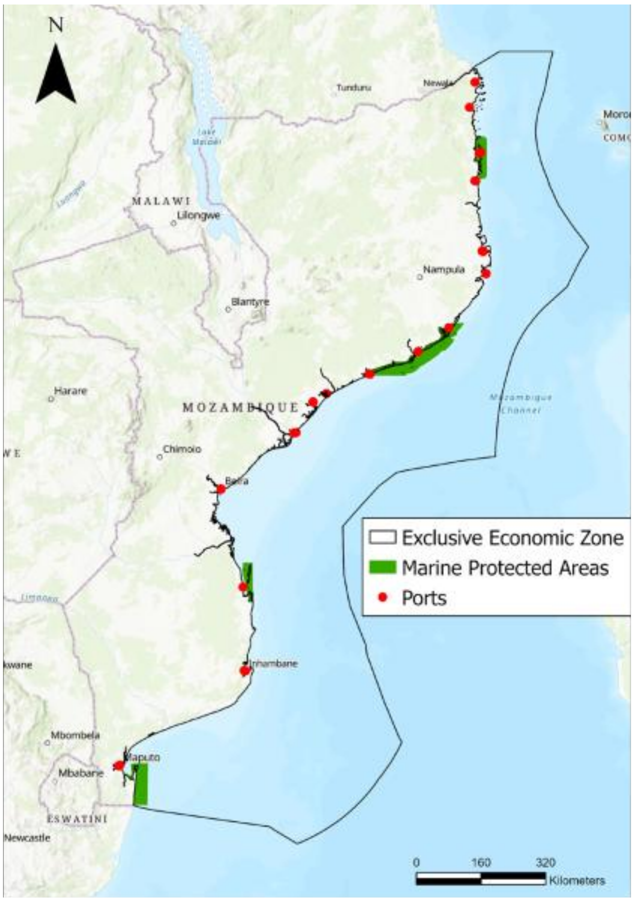


Figure 1. Map of Mozambique, its Exclusive Economic Zone, main Ports and Marine protected areas

1.2 Objectives

The present document is the result of a process established by the WCS and the National Institute for Fisheries Research (IIP) with the goal of **creating a framework where adequate institutional mechanisms and technical tools exist to support the process of MPA network expansion towards the achievement of national and international targets**. The specific objectives are as follows:

- Establish a coordination group composed of relevant national stakeholders to support the current process.
- Identify appropriate areas where efforts can be directed to establish new and/or expand existing MPAs.
- Inform the national Marine Spatial Planning (MSP) process by providing data layers to be incorporated in a wider analysis.

SECTION 2. **MOZAMBIQUE'S MARINE ENVIRONMENT**

Mozambique is located along the southeast coast of Africa, bordered by the Republic of Tanzania to the north, South Africa to the south, and the Comoros Islands, Madagascar, and Mayotte to the east (República de Moçambique, 2021a). The Mozambican Exclusive Economic Zone (EEZ) is estimated to cover around 562,000 km^2 (República de Moçambique, 2021a), but the delineation of the official boundaries has not yet been finalized and is pending negotiations with Madagascar, France and South Africa (República de Moçambique, 2021a).

The country's climate ranges from subtropical in the south to tropical in the north, characterized by two very distinct seasons: a cold, dry season from May to September and a hot, wet season from October to April. The sea surface temperature for the entire EEZ ranges between 23.9 and 28.9 °C, and is generally higher in the northern part of the Mozambique Channel (Johnsen *et al.*, 2007).

The coastline of Mozambique is about 2,700 km long. Thanks to this extensive, diverse and relatively pristine coastline, Mozambique has exceptional conditions for the occurrence of a great diversity of habitats (Pereira *et al.*, 2014). Coastal and near-shore habitats include mangrove forests and marshes, coastal dunes, sandy beaches, muddy and rocky shores, coral reefs, estuaries, bays, and seagrass beds that provide suitable habitat for many species, including threatened species such as turtles, dugongs, and many others. In addition to these coastal ecosystems, the deep-water pelagic and seabed ecosystems make up the majority of the country's EEZ (UNEP-Nairobi Convention and WIOMSA, 2021).

Unique to Mozambique is its extremely wide and flat continental shelf area. This shelf covers around 19% of Mozambique's EEZ (104,300 km^2), forming a unique marine system that is extremely productive and very important for fisheries. The largest and most important continental shelf areas in Mozambique's EEZ are the Sofala Bank in the central part and the Delagoa Bight in the south (Figure 2).

2.1 Marine and coastal habitats and ecosystems

The Mozambican marine environment is characterized by a great diversity of ecosystems. Based on Tinley (1971), the Mozambican coastline can be divided into three sections with distinct geomorphological characteristics, each supporting a diversity of marine ecosystems:

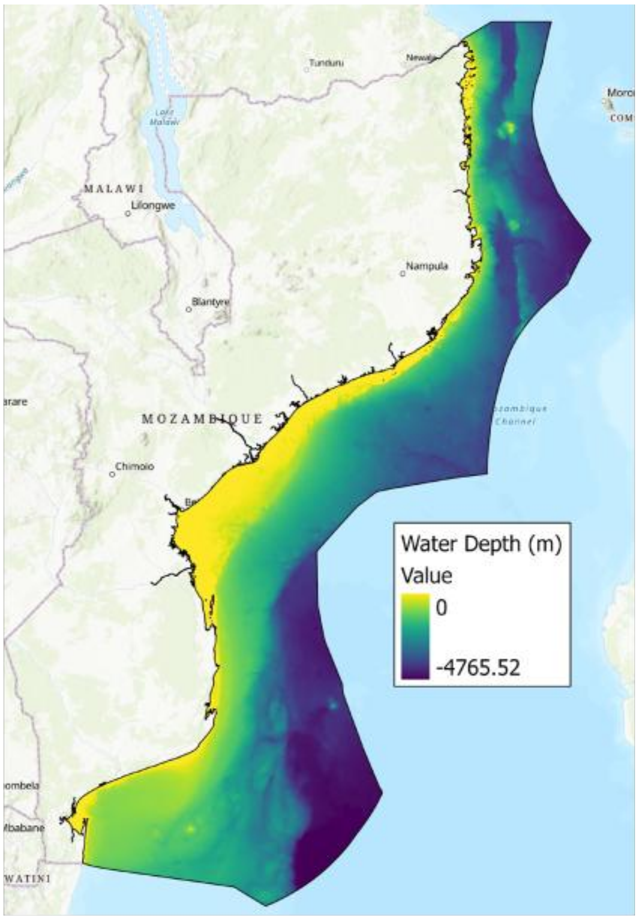


Figure 2. Bathymetry of Mozambique

(i) The southern coast (parabolic dunes coast) from Ponta do Ouro to the Bazaruto Archipelago: A dune coast, dominated by sandy beaches, vegetated parabolic dune systems as high as 125 m and brackish coastal lagoons of high biodiversity, some of which are also important tourism attractions. Where lagoons are open to the ocean, large estuary areas occur which support seagrass meadows. Corals colonizing sandstone reef formations are typical, and soft coral species are more predominant than hard reef building species. Sandy beaches throughout this coast provide optimal nesting habitat for marine turtles.

(ii) The central coast (swamp coast) from the Bazaruto Archipelago to Angoche: A characteristically swampy, with shallow muddy beaches, rich organic fluvial sediments. More than 24 rivers discharge in this section supporting extensive mangroves, soft-sediment intertidal habitats, large swamps and estuaries. The continental shelf is very wide reaching up to 140 km around Beira. High turbidity limits extensive coral reefs formations along this section of coast. The swamp coast is particularly important for more than 73 species of waterbirds, including several vulnerable and threatened species and fishery industry, particularly prawn fisheries.

(iii) The northern coast (coral coast) from Pebane to the Rovuma estuary bordering Tanzania: This section is characterized by fringing, barrier and island reefs, clear and warm waters. These reefs are mainly formed by calcium carbonate-secreting organisms (mainly corals) and extremely important for biodiversity and physical protection of the coast from erosion induced by wave energy..

Some of the main ecosystems that are found in the Mozambican marine environment, such as coral reefs, mangrove forests, seagrass beds, parabolic dunes and oceanic waters, are briefly described below.

Mangrove Forests

Mangroves are important coastal ecosystems that provide economic and environmental benefits for a large part of the population living in the coastal areas (Pereira *et al.*, 2014). Mangrove forests are among the most productive areas of the planet, and are also considered the most effective carbon sinks (Obura *et al.*, 2012). In Mozambique they cover an area of about 2,259 km^2 and are distributed along the entire coastline, although they are more abundant in the central region, in the provinces of Sofala and Zambézia (Shapiro, 2018), and occur mostly in the deltas and estuaries of major rivers (Barbosa *et al.*, 2001).

Figure 3. Mangrove forest from Pomene National Reserve

Mozambique's mangrove forests are considered the most diverse in the African continent (Griffiths, 2005). At the national level there are nine species of plants that form mangrove forests (Barbosa *et al.*, 2001), although the diversity can be much higher if all the associated plants species found in the adjacent and transition zones are taken into account. Major threats to these ecosystems include logging, deforestation for agriculture and salt production, pollution by oil and gas, reduced freshwater flows, and uncontrolled population migration and coastal industrial development (Pereira *et al.*, 2014, Republica de Moçambique, 2021b,c).

Dunes, Shores, Estuaries and Bays

Dune ecosystems are present along the coastline of Mozambique, most notably in the southern region (Massinga and Haton, 1996). In this region, parabolic dunes extend for over 850 km along the shoreline and characterize the coast from Bazaruto Island to Ponta do Ouro (Tinley, 1985; Louro, 2005; República de Moçambique, 2021b, 2021c). These systems are generally composed of two different dune types: primary dunes, which are more coastal, recent, dynamic and smaller; and secondary dunes, which are more inland, stable and older. In ecological terms, parabolic dunes are considered important reservoirs of biodiversity (Louro, 2005). They allow the development of typical floristic communities that support the coastal dune forest and provide essential habitats for several groups of animals including nesting sites for marine turtles and coastal and migratory birds (Louro, 2005; República de Moçambique, 2021). These dune systems are also an outstanding tourist attraction (Louro, 2005; República de Moçambique, 2021b, c).

Besides sandy beaches that are very common along the entire coastline, Mozambique also has a significant stretch of rocky shores that are mainly distributed along the coral coast in the north and the parabolic dune coast in the south. However, apart from some localized studies, little attention has been paid to the rocky shores in Mozambique. Besides macroalgae, not much is known about the biodiversity, exploitation and conservation status of these areas. However, it is well known that rocky shores play an important role in coastal protection and also serve as nursery grounds and permanent habitat for several commercially important species. In certain areas like Xai-Xai and Ponta do Ouro Partial Marine Reserve, rocky shores provides important resources for the subsistence of local communities (Pereira *et al.*, 2014).

Due to an extensive drainage network that includes about 100 major river basins and several rivers, Mozambique also has large estuarine areas, mostly funnel-shaped or delta-front topographies. The estuaries of large rivers like the Zambezi, Púnguè, Buzi and Save are all in the central part of Mozambique, Consequently, it is a highly productive area due to nutrient-rich runoff, and supports large populations of important species such as shallow water shrimp.

Mozambique is also home to a number of notable bays, such as Maputo Bay, which together with the Sofala Bank forms a major fishing area that contributes significantly to Mozambique's economy. Other bays on the Mozambican coast include Pemba Bay, Fernão Veloso Bay, Conducia Bay, and Memba Bay near Nacala (Pereira *et al.*, 2014).

Figure 4. Top: Rocky shore at Tofo Beach, bottom: Coastal dunes in the Ponta do Ouro Partial Marine Reserve

Coral Reefs

Coral reef ecosystems are found mostly in the north of the country, although they occur to a lesser extent in the rocky reef zones of the south. The central coast is generally inhospitable to coral reef growth given the muddy nature of the habitat (Macamo, 2019). Coral reefs harbour a rich diversity of associated fauna, including molluscs, echinoderms (sea urchins, sea stars and sea cucumbers), algae and reef fish (Macamo, 2019). They are estimated to cover an area of about 1,400 km2 (Allen Coral Atlas, 2020). In terms species, these reefs are considered among the most diverse in the East African region, although at the national level 76% are under threat (Obura *et al.*, 2012). Fishing pressure, destructive gear use, pollution, inappropriate tourist activity, oil and gas exploration and coastal erosion are among the main drivers of immediate and potential risk to coral reef conservation.

Figure 5. Coral reefs from northern Mozambique

Seagrass beds

Seagrass beds are a very important ecosystem on the coast of Mozambique. Nationally they cover an area of about 439 km^2 and occur mainly in the intertidal zone (República de Moçambique, 2021b). The largest seagrass beds are found in Cabo Delgado, Inhambane and Maputo Province. Eleven species are found in Mozambique, and the Maputo Bay area has the largest global coverage of eelgrass (Zostera capensis), a Vulnerable species on the International Union for Conservation of Nature's (IUCN) Red List (República de Moçambique, 2021c).

This ecosystem is recognized for having high productivity, its key role in nutrient cycling and carbon sequestration, and for serving as habitat, nursery, feeding and breeding areas for several marine species, including those of commercial interest and others of conservation interest, such as dugongs and green turtles (Pereira *et al.*, 2014, Duarte *et al.*, 2012; Obura *et al.*, 2012).

Oceanic waters

From an oceanographic point of view, Mozambique's marine area reaches around 4,000 meters in depth, and is one of the most relevant areas for oceanic circulation on the South African coast (ASCLME, 2012; República de Moçambique, 2021b). The Mozambique Channel is one of the routes that feeds the Agulhas Current through the South Equatorial Current, where upwelling of cold, nutrient-rich waters creates an oceanic environment rich in biological resources (Lamont *et al.*, 2014, Obura *et al.*, 2019).

In this context, this ocean environment has high potential value, particularly for the fishing industry (Obura *et al.*, 2019). From an ecological point of view, the pelagic environment is rich in iconic species, many of them top predators and threatened species such as cetaceans, sharks and sea turtles. However, studies on the deep-water benthic ecosystems that occur over this vast area are rare and these habitats currently remain practically unknown.

2.2 Marine and Coastal Species

With regard to marine and coastal biodiversity, over 6,000 species have been recorded in Mozambique (Froese and Pauly, 2019; UNEP, 2019; República de Moçambique, 2021b,c). According to the IUCN, at least 1,976 of the species occurring in Mozambique's marine waters are on the Red List of Threatened Species, including 139 species categorised as Vulnerable or above (IUCN, 2019). A total of 301 marine species, of which 242 are corals, are listed under the CITES convention (UNEP, 2019).

Regarding marine mammals, at least 34 species have been recorded in Mozambican waters, including 30 cetaceans, which generally use these waters every year as wintering and breeding grounds (Findlay *et al.*, 2011). Some species are of conservation concern, such as the blue whale (*Balaenoptera musculus*) and the Indian Ocean humpback dolphin (*Sousa plumbea*), both of which are Endangered species. It is important to note that Mozambique is also one of the last places in the Western Indian Ocean holding a viable population of Vulnerable dugongs (*Dugong dugon*).

Five of the seven existing marine turtle species are present in Mozambican waters, distributed along the entire coast. Several turtle nesting areas are recognized (Sitoe *et al.*, 2015; República de Moçambique, 2021b,c), making Mozambique a key country for turtle conservation in East Africa and the globe

Figure 6. Humpback whale

(McLellan et al., 2012). All turtle species present in the country are classified as threatened by the IUCN (IUCN, 2019) and are protected either by national laws or international conventions such as CITES and the Bonn Convention (Warnell et al., 2013). Most notably, the regional population of leatherback turtles (*Dermochelys coriacea*) in Mozambique is Critically Endangered (Wallace et al. 2013), and the global population of hawksbill turtles is also Critically Endangered (Mortimer & Donnelly 2008).

Figure 7. Loggerhead turtle, one of the 5 marine turtle species that occur in Mozambique

Regarding birds, more than 130 coastal and marine species have been reported in the national territory, of which 37 are considered seabirds (BirdLife International, 2019). From a conservation perspective, the most important species include albatrosses (*Thalassarche chlororhynchos, T. carteri*), Cape Gannet (*Morus capensis*), and Cape Cormorant (*Phalacrocorax capensis*), all of which are Endangered, as well as other migratory birds, such as pelicans (*Pelecanus onocrotalus, P. ruescens*).

The Mozambique Channel is also a global hotspot for shark and ray species richness, endemism, and evolutionary distinctiveness, with over 146 different species identified to date (Abelman *et al.*, 2021). Key species include the mantas (*Mobula sp.*), hammerhead sharks (*Sphyrna sp.*), white sharks (*Carcharodon carcharias*) and whale sharks (*Rhincodon typus*). Sharks and Rays are the most threatened group of marine species in Mozambique, with sawfishes (*Pristis sp.*), short-tail nurse sharks (*Pseudoginglymostoma brevicaudatum*), and Guitarfish (*Rhynchobatus sp.* and *Rhina ancylostoma*) all Critically Endangered according to the IUCN (2019). In places like Tofo or the Bazaruto Achipelago, aggregation sites for species like whale sharks and manta rays also act as an important tourist attraction (Rohner *et al.*, 2014; Pereira *et al.*, 2014; Reeve-Arnold *et al.*, 2016).

The diversity of habitats present along the coastline also allows for a high number of bony fish species (Balidy *et al.*, 2007). Nearly 2,200 species have been recorded in Mozambique (WoRMS, 2019), of which about 862 are considered reef species (Froese and Pauly, 2019). Bony fishes are the main marine resource exploited nationally, and in oceanic waters there are a number of species with high commercial value, such as tuna. In the context of conservation, there are a number of bony fish species of special concern: Seventy-four Seabream (*Polysteganus undulosus*), which is Critically Endangered; napoleon pipefish (*Cheilinus undulatus*); Sky Emperor (*Lethrinus mahsena*); and Red Steenbras (*Petrus rupestris*) that are all Endangered, as well some vulnerable seahorse species (*Hippocampus spp.*) also listed on CITES (República de Moçambique, 2021b,c).

Mozambique's coral reef biodiversity is recognized as among the most diverse on the African continent (Obura *et al.*, 2012) with at least 430 species of Anthozoan corals referenced in the global biodiversity databases (WoRMS, 2019). According to the IUCN Red List (2019), 45 coral species are considered Vulnerable (mostly in the genus Scleractinia). Corals are also the marine group with the highest representation in CITES Appendices I and II (UNEP, 2019).

Additionally, about 1,690 species of marine molluscs and 730 species of crustaceans are currently documented for the Mozambique coast (WoRMS, 2019). These species play a crucial role in the ecosystem balance, and some species such as crustaceans (shrimp, crabs and crayfish) and molluscs (octopus, cuttlefish, squid, clams, oysters and mussels), are especially important to fisheries.

2.3 Human uses

Approximately 60% of Mozambique's population, about 17 million people, live within the coastal zone (Pierce *et al.*, 2008; Benkenstein, 2013), and many of these people rely on coastal and marine ecosystems for food and income. As such, Mozambique's marine ecosystems support a variety of different human activities, including fishing, mining, oil and gas activities, aquaculture, port infrastructure and transport, tourism and recreation, scientific research, cultural heritage etc. Below we briefly describe some of the main human uses on the Mozambique's marine environment.

Port infrastructure

Mozambique has three major ports in Nacala-a-Velha, Beira and Maputo, that are served by ocean-going vessels and connected through railroads to the interior of Southern Africa. These ports require periodic dredging of access channels, which can negatively impact biodiversity through sedimentation. Expansions and modernizations of smaller ports (Mocímboa da Praia, Pemba, Angoche, Moma, Pebane, Quelimane, Vilanculos, Inhambane) are planned, as well as construction of new ports along the coast (Palma, Afungi, Memba, Macuse, Techobanine, and Chongoene) (República de Moçambique, 2021b, c).

Figure 8. Beira's port among the largest ports in Mozambique

Fishing

Fishing is an important pillar of Mozambique's economy, and is vital for the survival of coastal communities. Fishing is practiced by local populations along the entire coast of Mozambique, mostly as subsistence or artisanal fishing, with intense semi-industrial and industrial fishing occurring in some areas further offshore. The most important fisheries for the

Figure 9. Artisanal fishermen in northern Mozambique

Mozambican economy are the surface shrimp fishery; deep-sea crustacean fishery; small pelagic fishery; demersal fish fishery; and the tuna and related species fishery (República de Moçambique, 2021b). Fishing is generally permitted throughout the EEZ, except for within some MPAs and other specific areas reserved for fisheries management (República de Moçambique, 2021b).

The most productive and fished areas in Mozambique are found at the confluence of the main river basins that drain to the sea (Zambezi basin and Limpopo basin), particularly on the Sofala Bank and Maputo Bay (FAO 2019). Total catch from industrial and semi-industrial fisheries is about 24,000 tons per year, whereas the artisanal catch is around nine times larger. The value of the industrial and semi-industrial fisheries is about 1.8 billion meticais, while the artisanal fisheries is about 5-7 times larger (República de Moçambique, 2020).

Mozambique's artisanal fishing sector (Figure 9) involves more people than industrial fishing, and therefore has the greatest social importance and development potential. It represents an essential basis of subsistence for many coastal communities, most of which depend on fishing and related activities, along with subsistence agricultural activities. The 2012 artisanal fisheries census indicated the existence of 290,000 artisanal fishers. The dominance of artisanal fishing is also evident based on the number of licenses issued, with 13,000 artisanal fishing licenses and only 315 semi-industrial/industrial licenses (República de Moçambique, 2020).

Despite being far less widespread than artisanal fishing, industrial and semi-industrial fishing is more technologically developed, having specialized mainly in the export market (e.g., shrimp and prawns), contributing directly to the improvement of the country's trade balance (República de Moçambique, 2021b,c).

Mining

The increasing discovery of mineral resources in Mozambique, especially those near the coastline, has awakened a great potential for growth and development in Mozambique's economy as a whole. The likely mineral resources that occur in the coastal zone are of industrial application, and with most of the existing mining concessions allocated for heavy minerals, limestone, and construction materials (República de Moçambique, 2021b,c).

In general, mining concessions are concentrated along the coast of Nampula and Zambezia provinces. In other provinces, such as Cabo Delgado, Inhambane and Maputo, most concessions and licences are found inland, and so are unlikely to impact the marine environment directly. There are currently no records of mining activity occurring directly in the ocean (República de Moçambique, 2021b).

Oil and Gas

Mozambique has a high potential for oil and gas production, particularly petroleum and natural gas. Currently there are seven active concessions in the maritime space, totalling about 30,000 km2, distributed along the provinces of Cabo Delgado, Nampula, Zambézia, Sofala and Inhambane. These activities are aimed at identifying the potential deposits of oil and gas, as well as their appraisal for development and production in new reservoirs (República de Moçambique, 2021b, c). The greatest potential for marine oil and gas production is in the offshore region in the north of the country (Rovuma Basin).

Tourism and Recreation

Mozambique has great tourism potential based on its natural and cultural resources, including marine wildlife, outstanding beaches, tropical islands, coral reefs, and clear waters. As such, tourism in Mozambique is predominantly based on natural resources, with a strong focus on tourism along the coastline. Mozambique's coast attracts national, regional, and international tourists looking for destinations with quality accommodation and maritime activities linked to fishing, observation of marine megafauna, diving, sport fishing, among others (República de Moçambique, 2021b,c).

Cultural and Archaeological Heritage

On the Mozambique coast, important civilizations developed in ancient times, whose growth was largely based on trans-oceanic navigation. The achievements of these civilizations over the centuries have given rise to an important heritage that is now an invaluable resource that should be preserved and enhanced (República de Moçambique, 2021b). There are a range of archaeological sites, forts, old port facilities, and shipwrecks along the coast that are testimonies to ancient society's participation in the trade and navigation of the Indian Ocean and the traditional daily activity linked to the sea since millennia ago. More than 300 shipwrecks from different periods are inventoried along the Mozambican coast, with a particularly high density in the area surrounding Mozambique Island in the northern region of the country (República de Moçambique, 2021b).

SECTION 3. **INTRODUCTION TO MARINE SPATIAL PLANNING AND SPATIAL PRIORITIZATION ANALYSES**

3.1 Marine spatial planning

Marine spatial planning (MSP) is a process that brings together multiple ocean users to make informed and coordinated decisions about how to use marine space and marine resources sustainably. MSP can help resolve current and potential future conflicts between users, and identify effective conservation strategies. It is particularly useful to help delineate conservation-orientated management, like MPAs. To do so, spatial data are used to help identifying where and how different marine areas are used, and what natural resources and biodiversity exist there. Through the planning process (Figure 10), planners can quantify the cumulative effect of maritime industries on marine biodiversity, seek to make industries more sustainable, and proactively minimize conflicts between multiple industries wanting to utilise the same ocean area. The intended result is a more coordinated and sustainable approach as to how the ocean is used, which will promote economic development but while ensuring marine ecosystems and biodiversity remain healthy (White *et al.* 2012).

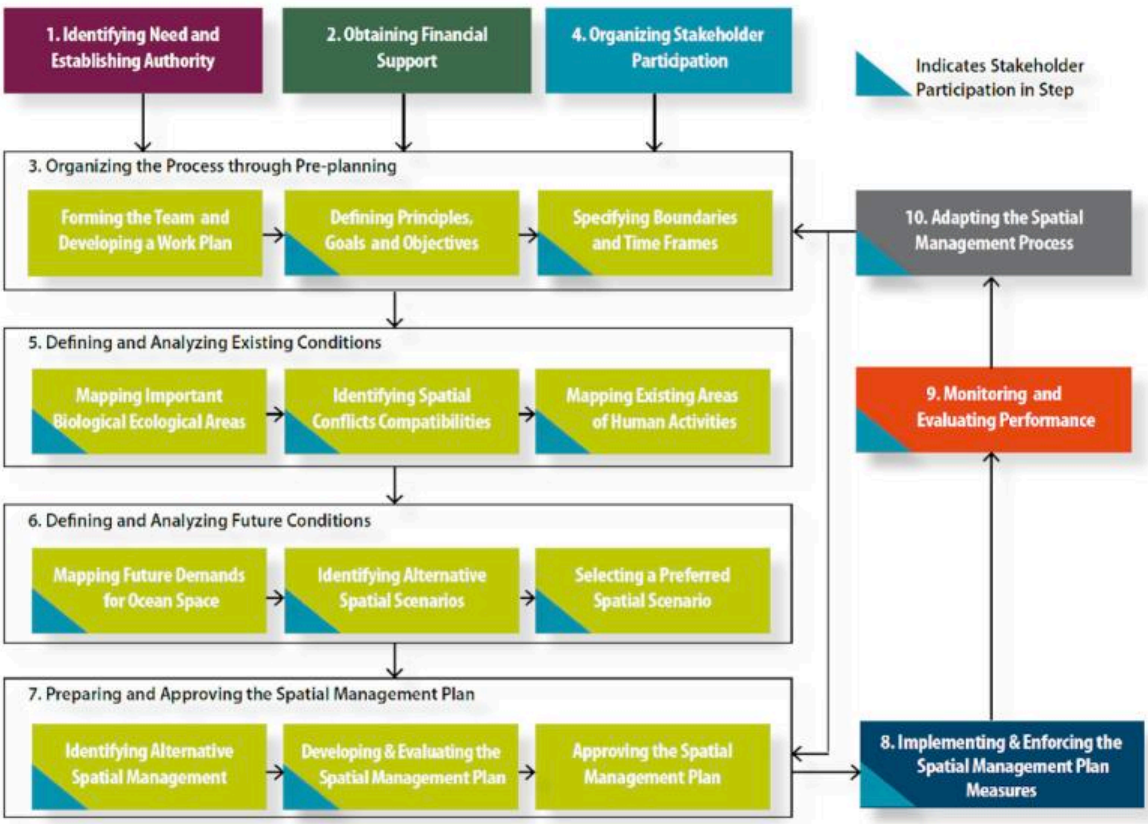


Figure 10. General outline of Marine spatial planning

3.2 Spatial prioritization analysis

A key aspect of MSP involves spatially prioritising where different marine activities can occur. Many activities can be spatially incompatible, e.g., industrial fishing and nature conservation, and MSP can help decide on appropriate areas for different activities. One of the most common uses for spatial planning analyses is to decide on the location of MPAs and other forms of conservation and sustainable resource management that regulate other ocean uses in order to conserve biodiversity and have sustainable community resource use and industries. Importantly, while some MPAs can be strictly managed to prevent all extractive activities (e.g., fishing, mining), many allow sustainable levels of artisanal fishing and other low-impact activities, e.g., SCUBA diving.

Because the overall area of the ocean that can be protected is often limited, as are the resources to manage these areas, MSP processes often aim to design MPA networks that achieve conservation goals in an efficient manner. This process, known as systematic conservation planning, is a process that aims to achieve representation and persistence of biodiversity in an efficient portfolio of priority areas (Margules and Pressey, 2000). The major steps, adapted from Margules and Pressey (2000), are:

1. Ensure stakeholder engagement throughout process
2. Understand context of planning region
3. Identify conservation goals and objectives for the planning region
4. Compile data characterizing the region (e.g. biodiversity and human uses) in the planning region
5. Review existing conservation areas
6. Prioritize additional conservation areas
7. Get feedback on prioritized areas
8. Make recommendations

The remainder of this document summarises how these steps were followed to generate scenarios for MPA expansion in Mozambique.

SECTION 4. **MARINE SPATIAL PLANNING IN MOZAMBIQUE**

The Government of Mozambique, through the Ministry of the Sea, Inland Waters and Fisheries (MIMAIP), having the National Directorate of Marine Policies (DIPOL) as a focal point and involving a multidisciplinary team, finalized the National Marine Spatial Planning (POEM). This work began in June 2019 and embodies the existing legal and policy provisions, namely the Policy and Strategy for the Sea (POLMAR) and the Regulation that establishes the Legal Regime for the Use of the National Marine Space (REJUEM), approved by Decree No 21/2017 of 24 May, applicable to "all the marine areas under national jurisdiction, under the terms defined by the United Nations Convention on the Law of the Sea". In general terms, the marine spatial planning process in Mozambique aims to:

- Promote sustainable and efficient economic exploitation of the sea and of marine resources and ecosystem services, ensuring the compatibility and sustainability of the various uses and activities developed in the sea, while taking into account inter and intra-generational responsibility in the use of the national marine space.
- Ensure the preservation, protection and recovery of natural values, biodiversity and coastal and marine ecosystems, the maintenance of the good environmental status of the marine environment, and the prevention of risks and the minimization of the effects resulting from natural disasters, climate change or from human action.
- Ensure the legal security and transparency of the procedures used in attribution of titles for private use of maritime space, and allow the exercise of information and participation rights.

The POEM is complementary to the National Plan for Territorial Development (PNDT) and it should promote sustainable and integrated development, based on an intelligent and responsible planning of the potential uses, activities and roles existing in Mozambique's maritime space. It should also allow for the resolution of conflicts that may exist between the development of different uses, activities and functions, such as tourism, fishing and the establishment of protected areas. Furthermore, the generation of information and knowledge within the coastal zones and maritime space as an indirect result of the POEM will be a benefit for technological and scientific development. Increased knowledge and appreciation of underwater archaeological heritage and marine biological resources is also expected, among many other benefits that will be achieved through the implementation of this MSP.

4.1 Key national, regional and international policies

Since 1981, Mozambique has ratified several international conventions related to biodiversity conservation. In a marine context, the most relevant are the Convention on Biological Diversity (CBD), the Convention on the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa Region (Nairobi Convention), Convention on the Conservation of Migratory Species of Wild Animals (CMS - Bonn Convention), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the African Convention on the Conservation of Nature and Natural Resources (Algiers Convention), the Indian Ocean Tuna Commission (IOTC) and more recently, the High Ambition Coalition (30x30) initiative.

These conventions and initiatives have resulted in a number of recommendations and commitments among member states, such as the need to increase and strengthen protected areas, reduce and prevent of biodiversity loss, and ensure sustainability of resource extraction (e.g. fishing). In this context, Mozambique has been making efforts to achieve its commitments through the creation, implementation and consolidation of conservation areas, in order to promote the sustainable use of biological resources in order to ensure their preservation for future generations.

At the national level, the most relevant legislation regarding marine conservation includes the Law for the Protection, Conservation and Sustainable Use of Biological Diversity (known as the Conservation Law, Law 5/2017 of 11 May) and the Fisheries Law (Law 22/2013 of 1 November), which deals specifically with fisheries and closed seasons. The former provides the general framework for the categories of conservation areas, roles and articulation of different agencies, as well as biodiversity conservation in general. It is also worth noting that Mozambique has recently approved the new regulation on maritime fisheries (REPMAR), which clarifies how the Community Fishing Councils (CCPs) – the principal bodies managing local fisheries – can become legally recognized entities. Once recognized, CCPs can designate community-managed fishing areas allowing local fishers to decide what gear types can be used, and establish no-take zones or temporary closures (Abelman *et al.*, 2021).

In general, the success of these laws is reliant on the capacity of the government to enforce them, and in Mozambique, a lack of resources contributes to poor enforcement of marine conservation policies (Rosendo *et al.*, 2011). In addition, enforcement varies for coastal versus offshore fisheries, as well as between neighbouring countries such as South Africa, Tanzania, and Kenya (Abelman *et al.*, 2021). Motivation to enforce fisheries regulations can also be tenuous given how heavily many people in Mozambique rely on fisheries for their livelihoods (Abelman *et al.*, 2021).

4.2 Existing Protected Areas

Protected areas are essential for biodiversity conservation and are key components of any conservation strategy, both nationally and internationally (República de Moçambique, 2021). In Mozambique, conservation areas are governed by the Law for the Protection, Conservation and Sustainable Use of Biological Diversity (Law No. 5/2017 of 11 May), regulated by Decree No. 89/2017. This law defines the basic principles and standards for the classification of conservation areas, as well as for their integrated management and administration to support the sustainable development of Mozambique. The National Administration of Conservation Areas (ANAC), created by Decree No. 9/2013 of 10 April, is responsible for the strategic, political and operational activities of the Mozambique's conservation areas. Through the Presidential Decree 2/2017 of 10 of July, the Ministry of Sea, Interior Waters and Fisheries (MIMAIP) was assigned the role of i) proposing policies, legislation and strategies to the development of the marine conservation areas; ii) ensuring the management of the marine conservation areas in liaison with the competent authorities.

Conservation areas in Mozambique, either terrestrial or marine, are currently standardized into the following categories:

- **Total conservation areas:** Where the extraction of natural resources is not allowed. The relevant categories for the marine environment are: (i) Integral Nature Reserve, (ii) National Park and (iii) Cultural and Natural Monument.

- **Conservation areas of sustainable use:** Where a certain level of natural resources extraction is allowed but subject to a management plan. The relevant categories for the marine environment are: (i) Special Reserve, (ii) Environmental Protection Area, (iii) Community Conservation Area, (iv) Sanctuary, and (v) Municipal Ecological Park.

The gazetting of individual conservation areas in the country is achieved through specific decrees sanctioned by the Council of Ministers. Each specific decree states the overarching reason for the proclamation and general restrictions to be imposed on fisheries and marine resource-related activities, although these are further detailed in the specific management plans (UNEP-Nairobi Convention and WIOMSA, 2021).

Currently, all conservation areas in general – and MPAs in particular – are inadequately resourced in terms of staff, infrastructure and financing (UNEP-Nairobi Convention and WIOMSA, 2021). Most MPAs also lack management procedures and tools (including management, monitoring and research, communications, and business plans), as well as the appropriate science to support them (Pereira and Fernandes, 2014). A number of ecosystems and species (e.g., seagrass beds, mangroves, dugongs, manta rays and sharks) are poorly represented in Mozambique's current MPA network. The concept and implementation of non-formal protection of marine areas, which could be classified as Other Effective Conservation Measures (OECMs) by communities and/or local authorities, is still in its infancy in Mozambique (UNEP-Nairobi Convention and WIOMSA, 2021), but has now room to progress with the formal acknowledgment of Community-Managed Fishing Areas, under the new REPMAR (UNEP-Nairobi Convention and WIOMSA, 2021).

Marine and Coastal Protected Areas in Mozambique

Nine of Mozambique's conservation areas cover the marine and coastal environment, but only six can effectively be considered MPAs: (i) Quirimbas National Park, (ii) Bazaruto Archipelago National Park, (iii) Sanctuary of Cabo de São Sebastião (adjacent to the Bazaruto Archipelago National Park), (iv) Ponta do Ouro Partial Marine Reserve, (v) Environmental Protection Area of the Archipelago of the Primeiras and Segundas Islands, and (vi) Maputo Environmental Protection Area incorporating the Maputo National Park (Formaley Ponta do Ouro Partial Marine Reserve and the Maputo Special Reserve on land).

It is also important to highlight other conservation areas along the coastline, which incorporate key coastal ecosystems such as mangroves, estuaries and coastal dunes, namely the Marromeu Special Reserve, and Pomene Special Reserve. The following table (Table 1) shows the different coastal and marine conservation areas, including their extent, respective IUCN categories, legal framework, main biodiversity features, and main threats and risks. Figure 12 shows a map of Mozambique's marine and coastal conservation areas, highlighting their total extent and marine area.

Figure 11. Mejumbe Island, Quirimbas National Park

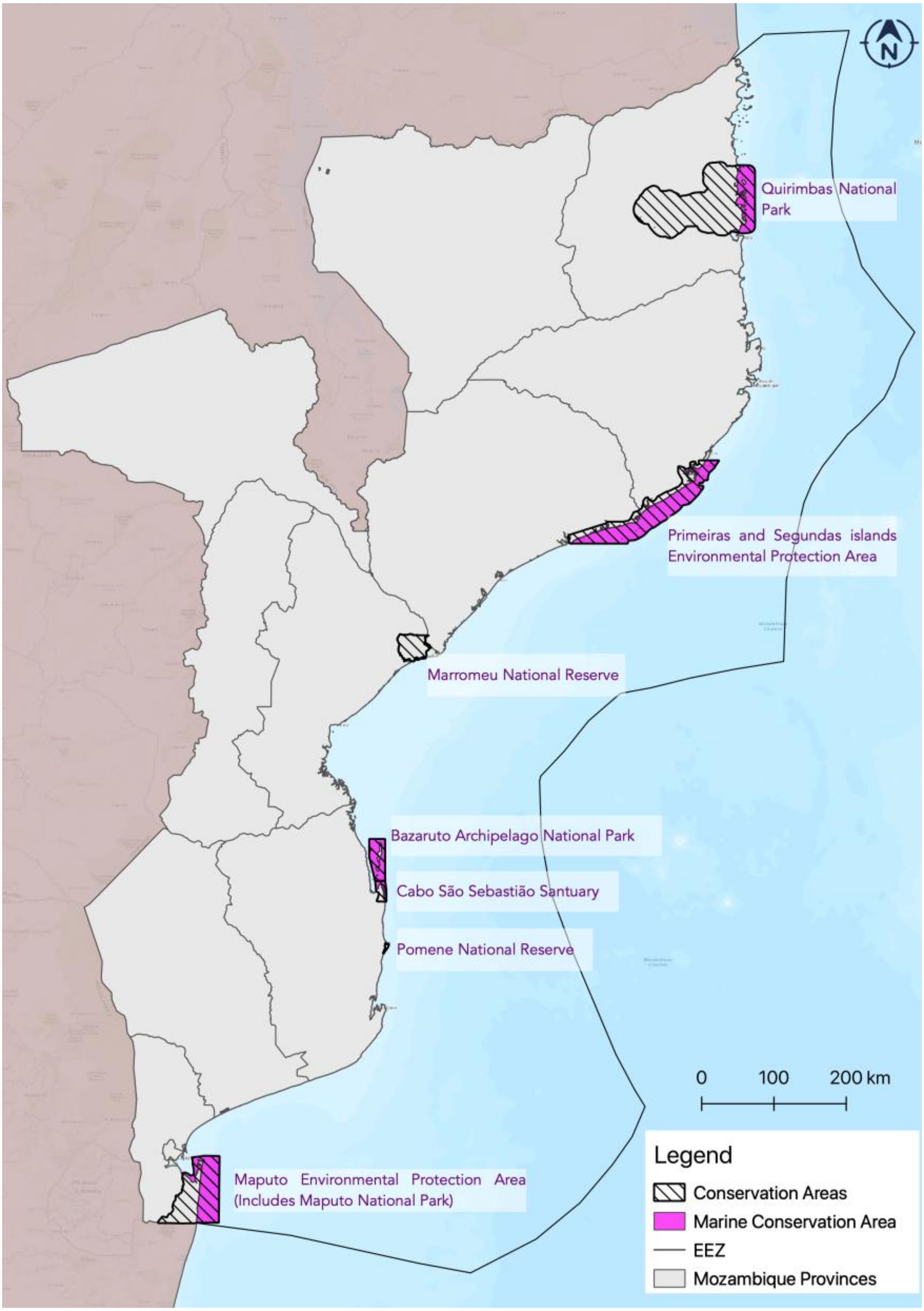


Figure 12. Location of the Mozambican coastal and Marine Conservation Areas

Table 1. Mozambique's coastal and marine Conservation Areas and their main characteristics

Marine and Coastal protected Areas	IUCN level	Management regime and entities	Legal framework	Total Area (km²)	Total Marine Area (km²)	Main Biodiversity Features *(UNEP-Nairobi Convention and WIOMSA, 2021; Governo de Moçambique, 2021b)*	Threats and Risks *(UNEP-Nairobi Convention and WIOMSA, 2021)*
Quirimbas National Park	(V)	Management is undertaken by ANAC. There is currently no co-management partner for the QNP. Due to the rise of violent extremism, WWF left this area.	Decree 14/2002 of 6 June	14,550	2,380	**Habitats:** sandy beaches, mangroves, seagrass beds, coral and biogenic reefs, rocky shores, deep sea and offshore pelagic, estuaries, seamounts and ridges. **Most iconic species:** dolphins, whales, dugongs, turtles, coconut crabs and seabirds.	Overfishing and use of illegal and/or destructive fishing gear, poaching, and climate change (sea-level rise).
Primeiras and Segundas Islands Environmental Protection Area	(V)	Co-Management undertaken by ANAC and WWF	Decree 42/2012 of 12 December	8,075	5,861	**Habitats:** sandy beaches and coastal dunes; mangroves; seagrass beds; coral and biogenic reefs; deep sea and offshore pelagic; estuaries; seamounts and ridges; coast- al forests; islands and atolls (12 islands). **Most iconic species:** dolphins, whales, dugong, marine turtles and seabirds.	Overfishing, deforestation and unsustainable use of coastal forest and mangrove resources, and poaching of protected species.
Bazaruto Archipelago National Park	(IV)	Co-Management undertaken by ANAC and African Parks	(Legislative Decree 46/71 of 25 May), (Decree 39/2001 of 25 May)	1,359	1,242	**Habitats:** sandy beaches, coastal dunes and coastal lakes, mangroves, seagrass beds, coral and biogenic reefs, deep sea and offshore pelagic (including deep-sea canyons), and five islands. **Most iconic species:** dugongs (the only viable population in the WIO), turtles, whales, dolphins, billfish, and sand oysters (*Pinctada spp.*).	Overfishing, illegal/ unregulated/ unreported fishing, poaching of protected species and climate change.
Cabo de São Sebastião Santuary	(VI)	Solely managed by a private entity (Sanctuário Bravio de Vilanculos Limited) which has a concession valid for 25 years	Decree 18/2003 of 18 April	438	219	**Habitats:** sandy beaches and coastal dunes, mangroves, seagrass beds, coral and biogenic reefs, deep sea and offshore pelagic (including deep-sea canyons), coastal forests, and three islands. **Most iconic Species:** dugongs, turtles, whales, dolphins, and billfish.	Increased fishing pressure from migrant fishers from the mainland; conflicts between local fishers and those from the mainland; night fishing and use of destructive gear; and climate change (erosion, sea-level rise).
Maputo National Park (Formerly Ponta do Ouro Partial Marine Reserve and Maputo Special Reserve).	(V)	Co-Management undertaken by ANAC and Peace Parks Foundation		1747	698	**Habitats:** sandy beaches, coastal dunes, mangroves, seagrass beds, rocky reefs and estuaries. **Most iconic Species:** whales, dolphins, dugongs, turtles, sharks, Potato groupers (*Epinephelus tukula*) and Brindle groupers (*E. lanceolatus*), as well as the largest aggregation of the Giant trevally (*Caranx ignobilis*) ever reported.	Dramatic increase of coastal development, often within the primary dunes, impacting turtle nesting and the integrity of the dune system. Proposed deepwater port development at Ponta Techobanine, illegal commercial fishing, uncontrolled recreational activities, unsustainable extractive use by the local communities, and climate change (erosion, sea-level rise).

Marine and Coastal protected Areas	IUCN level	Management regime and entities	Legal framework	Total Area (km²)	Total Marine Area (km²)	Main Biodiversity Features *(UNEP-Nairobi Convention and WIOMSA, 2021; Governo de Moçambique, 2021b)*	Threats and Risks *(UNEP-Nairobi Convention and WIOMSA, 2021)*
Maputo Environmental Protection Area (includes the Maputo National Park)	(V)	Management is undertaken by ANAC		5,732	2,565	**Habitats:** sandy beaches, coastal dunes, mangroves, seagrass beds, rocky reefs and estuaries. **Most iconic species:** whales, dolphins, dugongs, turtles, sharks, Potato groupers (*Epinephelus tukula*) and Brindle groupers (*E. lanceolatus*), as well as the largest aggregation of the Giant trevally (*Caranx ignobilis*) ever reported.	Dramatic increase of coastal development, often within the primary dunes, impacting turtle nesting and the integrity of the dune system. Proposed deepwater port development at Ponta Techobanine, illegal commercial fishing, uncontrolled recreational activities, unsustainable extractive use by the local communities, and climate change (erosion, sea-level rise).
Marromeu National Reserve	(II)	Solely managed by ANAC, with no partners apart from local government agencies or local communities identified.	Portaria 13:186 of 20 June Legislative Decree 2070 of 4 March	1,559		**Habitats:** mangroves, seagrass beds, estuaries and coastal forests. **Most iconic Species:** African buffalo (*Syncerus caffer*). No iconic marine species have been identified.	Coastal environment are degraded hydrology and inundation cycle, and climate change (droughts, sea-level rise, floods).
Pomene National Reserve	(V)	Solely managed by ANAC, with no partners apart from local government agencies or local communities identified.	Legislative Decree 109/72 of 16 November	51		**Habitats:** coastal forests, sandy beaches, dunes, estuaries and mangroves. **Most iconic species**: No iconic marine species have been identified.	Human settlement and unregulated subsistence activities; disregard for the value of critical habitats; and arbitrary attribution of land.

4.1 Mozambique's conservation goals & objectives

In the past decade, Mozambique has committed to various global policy frameworks with the aim of expanding coverage of MPAs. As a member of the CBD, Mozambique committed to efficiently and equitably protecting at least 10% of coastal and marine areas (under Aichi Target 11), especially areas of particular importance for biodiversity and ecosystem services. Similar to Aichi target 11, goal 14.5 of the Sustainable Development Goals (SDGs) committed Mozambique to conserving at least 10% of coastal and marine areas by 2020, consistent with national and international law and based on best available scientific information. These targets also highlight the need for protected areas to be ecologically representative, meaning they capture a representative sample of all species/ecosystems in Mozambique.

Within the scope of the CBD, in 2015 Mozambique developed its Strategy and Action Plan for the Conservation of Biological Diversity (NBSAP 2015-2035), a guiding policy with long-term objectives aimed at halting biodiversity loss. Among the various goals established, in the context of the marine environment, goal 11A stands out: "By 2025, formally include at least 5% of marine ecosystems in the national network of conservation areas".

In 2019, during the Oceans Conference, Mozambique committed to protect at least 7% of marine ecosystems by 2020. In the same year, Mozambique also joined the High Ambition Coalition (HAC) for Nature and People – an intergovernmental group of 60 countries co-chaired by Costa Rica, France and the United Kingdom – that is pushing for a global agreement to protect 30% of the marine and terrestrial environment by 2030 (the 30x30 target).

Despite committing to numerous goals of protecting 5-10% of its EEZ by 2020, it is important to note that only around 2.2% of Mozambique's EEZ is currently protected. As such, we used Mozambique's existing commitments around EEZ protection to develop a series of scenarios for the strategic expansion of MPAs.

These scenarios are divided into three sets:
- Scenario A (7-8% of the EEZ)
- Scenario B (10-12% of the EEZ)
- Scenario C (30% of the EEZ)

This will allow the Government to make an informed decision about where to designate MPAs in line with the country's international conservation commitments.

Figure 13. Bazaruto Archipelago, Inhambane Province

SECTION 5. **DATA CHARACTERIZING THE REGION**

5.1 Biodiversity

MSP analyses are used to try to balance human uses of the ocean against conservation of marine biodiversity. As such, one of the most important steps is to obtain data of the elements of biodiversity that will be included in the final MPA network. In this analysis, biodiversity features were categorized into three broad groups: ecosystems, species, and other important areas. This section describes the data sources and processing steps used to generate maps of each feature.

5.1.1 Ecosystem Map

A map of marine ecosystems is a crucial input for spatial prioritization analysis, as a representative MPA network should preserve a portion of all ecosystems. Ecosystem maps are especially valuable in areas where data on species are limited, because ecosystems can act as species surrogates, such that by representing each ecosystem an MPA network will also represent the diversity of species within each ecosystem.

To develop a marine ecosystem map for Mozambique, the approach used to generate South Africa's marine ecosystem map was followed and adapted (Sink et al., 2019a). A nested hierarchical approach was used, in order to enhance the utility of the map of ecosystem types, making it more appropriate as a basis for assessment and prioritisation at a range of spatial scales (Figure 14). This approach uses datasets with the largest spatial scale at the top of the classification (Marine Ecoregions), and then spatially divides these areas using successively more refined datasets (Figure 14). The final map of ecosystem types thus represents the unique combination of all datasets in the hierarchy.

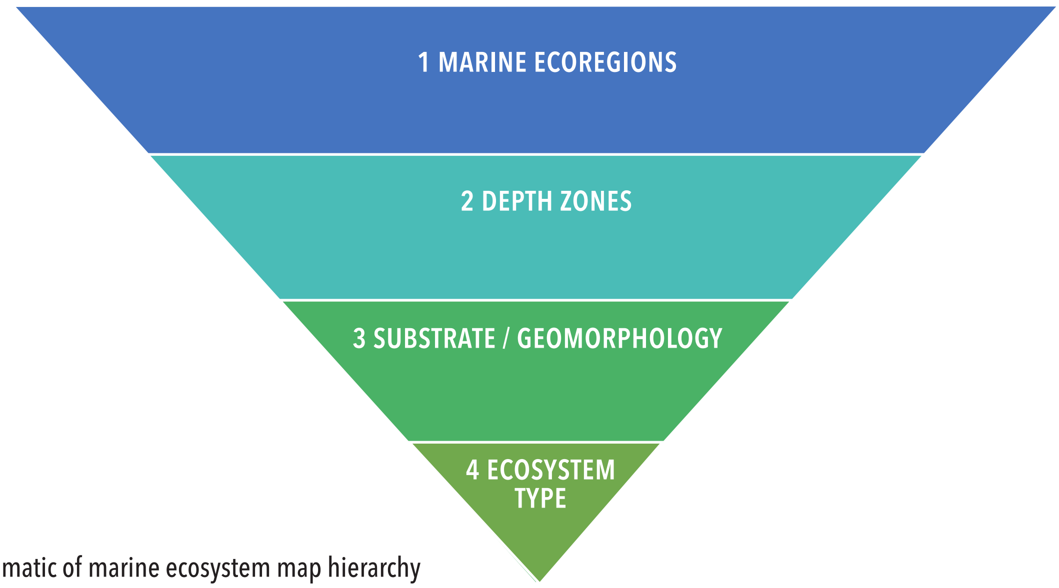


Figure 14. Schematic of marine ecosystem map hierarchy

Marine Ecoregions

Marine ecoregions were defined using the Marine Ecoregions and Pelagic Provinces of the World dataset (The Nature Conservancy, 2012). These data represent a biogeographic classification of the world's oceans, and aim to capture generic patterns of biodiversity across habitats and taxa. In Mozambique, there are three coastal shelf ecoregions (Delagoa, East African and Sofala Bight), and one deep-ocean ecoregion (Mozambique Channel, Figure 15). Because the original marine ecoregions dataset used coarse bathymetry data to separate the shelf and deep-ocean ecoregions, the shelf edge boundary was updated using SWIOBC Bathymetry data (Dorschel *et al.* 2018), explained below.

Depth classes

Water depth is known to have a considerable influence on marine biodiversity patterns, so high-resolution bathymetry data were combined with shoreline and rivermouth maps to delineate 10 depth classes (Table 2). To delineate estuaries and their outflows, river mouths were first manually identified by examining recent satellite imagery using Google Earth, and a point was placed at the approximate centre of each river mouth (Figure 16). Next, the outflow area was approximated by making a 2.5 km circular buffer from this point, and erasing the land area from the terrestrial ecosystems map (Lotter *et al.* 2021) within this buffer. This left a circular outflow area at each river, extending roughly 2.5 km into the ocean, with the landward boundary of each estuary defined using Mozambique's terrestrial vegetation map. While this 2.5km outflow size is an approximate, and thus likely over/underestimates actual outflow areas depending on river size, there are no readily available data with which to map river outflow plumes more accurately. As such, this method represents a simple way to capture the important influences that rivers and their outflows have on marine biodiversity that can be refined using fine-scale analyses for applications where such detail is required.

To delineate the shore class – including the supralittoral area below the permanent vegetation line, the intertidal area, and the surf zone – a 300 m seaward buffer from the edge of Mozambique's recently developed terrestrial ecosystem map was used (Lötter *et al.*, 2021). This terrestrial ecosystem map extends to only vegetated areas, and does not cover sandy, muddy or rocky shorelines. As such, using this

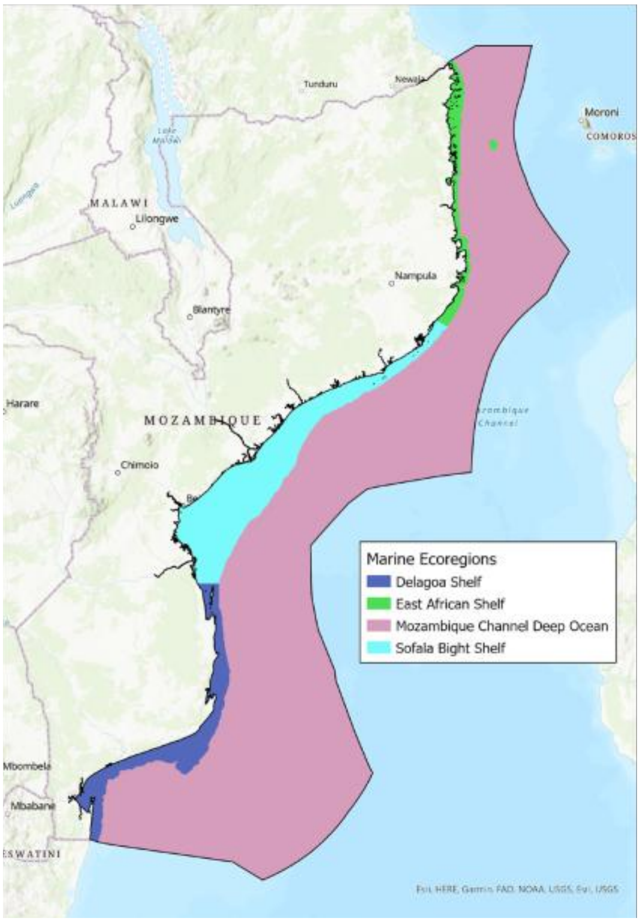


Figure 15. Marine Ecoregions in Mozambique

line as the beginning of the marine ecosystem map ensures a seamless transition between ecosystem maps, which is extremely useful for cross realm planning (e.g., connectivity between mangroves and coral reefs; Harris *et al.*, 2019). The 300 m distance was chosen based on visual examination of satellite imagery, and was chosen to be large enough to extend beyond the surf zone in most areas.

Finally, SWIOBC bathymetry data (Dorschel *et al.*, 2018) were used to divide the EEZ into eight depth classes: four continental shelf classes (upper shelf, mid shelf, lower shelf, shelf edge), and four slope classes (upper slope, mid slope, lower slope, abyss). The depths of each class are shown in Table 2. The shelf edge was manually delineated by examining where depth increases rapidly – this represents the edge of the continental shelf, and was the same approach used in development of South Africa's marine ecosystem map (Sink *et al.*, 2019a).

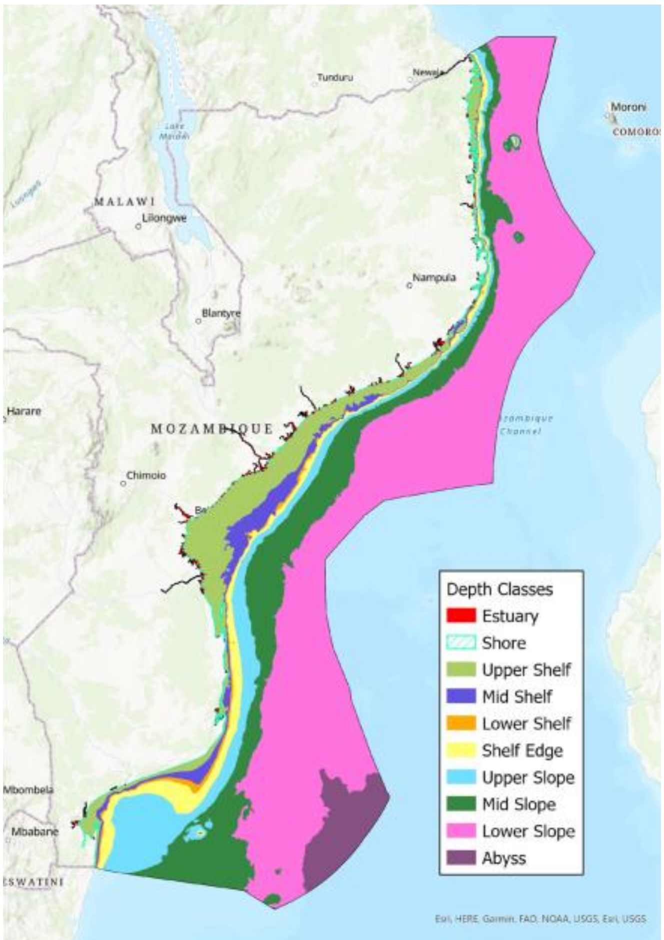


Figure 16. Depth classes used to develop marine ecosystem map

Figure 17. Espirito Santo Estuary, Maputo Province

Table 2. Depth classes and datasets used to map them

Depth Class	Description	Dataset
Estuary	Estuaries and their outflows (2.5-km buffer from river mouths)	River mouths manually delineated from satellite imagery
Shore	Shore, intertidal zone and surf zone (300m seaward buffer from shoreline)	Shoreline taken from Mozambique terrestrial ecosystem map
Upper Shelf	Waters 0-40m deep (that are not part of estuary/shore zone)	SWIOBC Bathymetry.
Mid Shelf	Waters 40-100m deep	SWIOBC Bathymetry.
Lower Shelf	Waters 100-150m deep	SWIOBC Bathymetry.
Shelf Edge	Waters 150-500m deep (manually identified through identification of rapid depth change)	SWIOBC Bathymetry.
Upper Slope	Waters 500-1000m deep	SWIOBC Bathymetry.
Mid Slope	Waters 1000-1800m deep	SWIOBC Bathymetry.
Lower Slope	Waters 1800-3500m deep	SWIOBC Bathymetry.
Abyss	Waters >3500m deep	SWIOBC Bathymetry.

Substrate/Geomorphology

At the third level of the ecosystem hierarchy, important substratum types are recognized (e.g., coral reefs, rocky reefs), along with major geomorphological features (seamounts, canyons). Both can have important influences on the biodiversity found in an area.

Substrate

Because there are no data currently available that can be used to map benthic substrate across Mozambique's entire EEZ, only datasets of coastal substrate were used. Primarily, this data was taken from the Allen Coral Atlas (Allen Coral Atlas, 2020), which uses satellite imagery to map coral reefs and associated habitats (seagrass, microalgae, etc.) at a very high resolution. This dataset delineates five different categories of benthic substrate (Figure 18), although it is limited by deep or turbid water, both of which prevent satellite sensors from accurately determining the benthic substrate.

Figure 18. Benthic substrate mapped by the Allen Coral Atlas (Allen Coral Atlas 2020). Data cover most coral reef regions along Mozambique's coastline, but a zoomed inset is shown here for clarity.

Because the Allen Coral Atlas data excludes turbid and deep waters, it was combined with an additional dataset mapping the distribution of coral reefs (UNEP-WCMC *et al*., 2021) Figure 20). Because these data are older and coarser than the Allen Coral Atlas data, Allen Coral Atlas was preferentially used where both datasets overlapped.

Figure 19. Coral reef, Vamizi Island

Figure 20. Coral reefs mapped by UNEP-WCMC et al. (2021).

Geomorphology

Submarine canyons and seamounts are associated with unique biodiversity and large biomasses and abundances of ocean predators, cetaceans, pinnipeds, sea turtles, seabirds and many other species (Harris *et al.*, 2014; Yesson *et al.*, 2011). As such, they were included addition to the benthic substrate data described above (Figure 21). Most canyons and seamounts occur in deep water, helping delineate areas of interest in a large area of the EEZ that would otherwise be homogenous. Canyons were mapped using data from Yesson et al. (2011), and seamounts were extracted from the global seafloor morphology map from Harris *et al.* (2014).

Final Ecosystem Types

To generate a final map of marine ecosystem types, unique combinations of datasets from the first three levels of the hierarchy were generated (ecoregions, depth classes, and substrate/geomorphology). The four ecoregions were first used to divide each depth class, giving a map with all unique combinations of ecoregion and depth. Next, the substrate and geomorphology dataset were added. A limitation to this hierarchical approach is that some data do not nest neatly within the hierarchy. For example, canyons stretch over multiple depth classes. Similarly, most

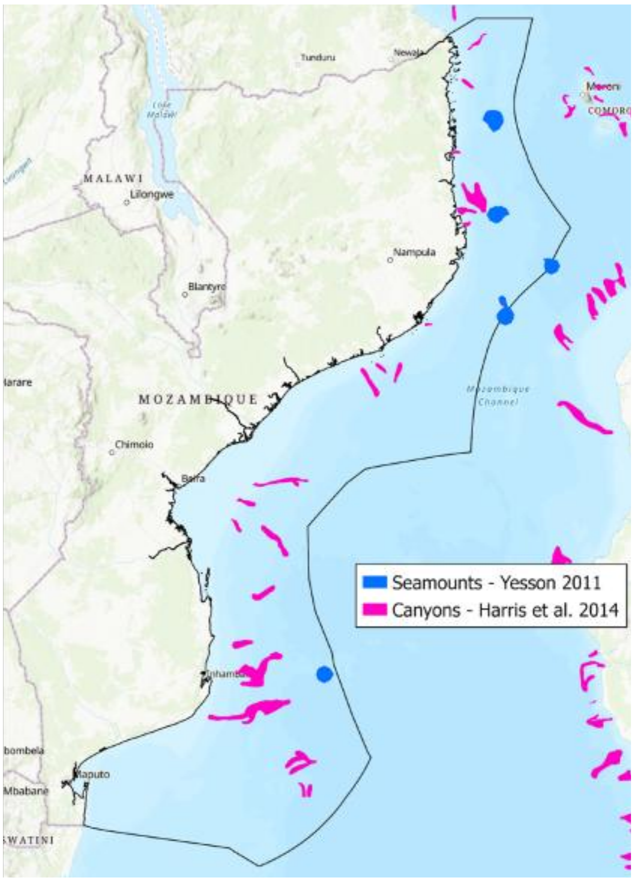


Figure 21. Seamounts mapped by Yesson (2011), and submarine canyons mapped by Harris *et al.* (2014).

Table 3. Example combination of layers to generate final ecosystem type classification.

1. Ecoregion	2. Depth Class	3. Substrate /Geomorphology	4. Final Ecosystem Type
Delagoa	Mid Shelf	Coral Reefs	Delagoa Coral Reefs
Mozambique Channel	Mid Slope	Seamount	Mozambique Channel Seamount
Sofala Bight	Estuary	N/A	Sofala Estuary

coral reef and seagrass area is found in the shore and upper shelf depth classes, but some extends into the mid-shelf. Because the Allen Coral Atlas data are based on centimetre-accurate bathymetry data, corals and seagrass found outside the shore and upper shelf zone are likely to be due to errors in the coarser national scale bathymetry we used to map depth zones. To allow these data to nest neatly into the hierarchy, all substrate/geomorphology datasets were split by ecoregion, but not by depth class. As such, for the map of ecosystem types, data on benthic substrate and geomorphology take precedence over depth classes. Table 3 shows an example of how the layers were combined to generate a final ecosystem type classification, and Figure 23 shows the final ecosystem map, containing 47 unique ecosystem types. See Appendix 1 for a full description of the ecosystem types.

5.1.2 Species Data

Although an ecosystem map is a useful tool to capture broad patterns of biodiversity across Mozambique's EEZ, it is also important to include data on important species directly where possible. This is particularly relevant for species that are not well represented by ecosystem types, e.g., sea turtles. Therefore, a comprehensive search of the published and grey literature was undertaken to find spatial data on species ranges/distributions, nesting sites or sightings.

IUCN species range maps

Species range maps were obtained from the IUCN Red List of Threatened Species website for marine mammals, holothuridea, marine fishes and chondrichthyes (https://www.iucnredlist.org/). Because there was a very large number of marine fishes, the dataset was filtered to only include threatened species, in order to reduce processing time in the prioritizR analysis to a manageable level. For all species groups, species with a range that covered Mozambique's entire EEZ were excluded, as these range maps offer no utility for spatial prioritisation because everywhere in the EEZ is ranked as equally important for those species. After these processing steps, 85 species were included as conservation features in PrioritizR (Appendix 2).

Figure 22. *Mobula birostris* (Endangered species - EN)

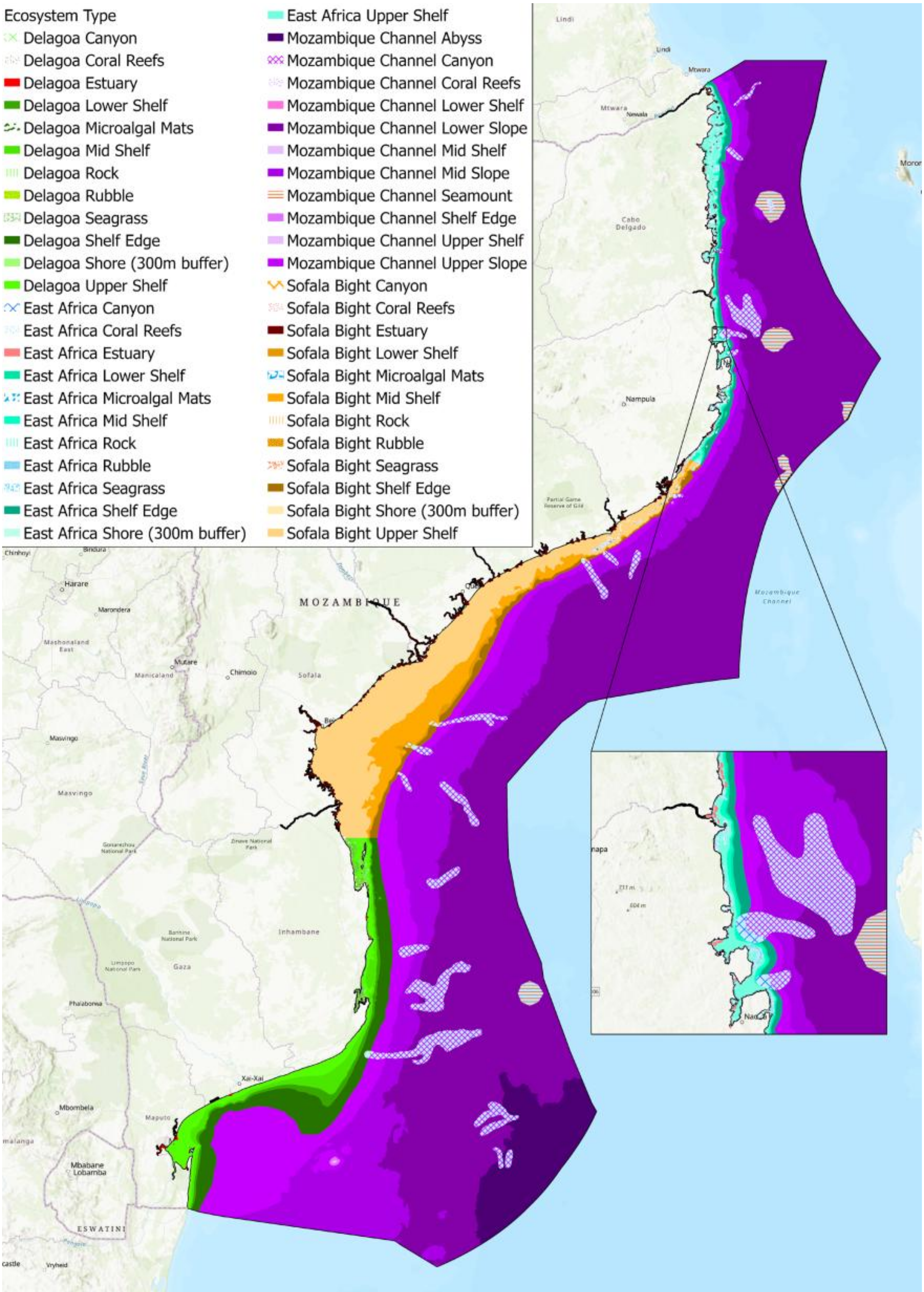


Figure 23. Marine Ecosystem Type map for Mozambique.

Turtle nesting sites

Turtle nesting sites were obtained from The State of the World's Turtles (https://seamap.env.duke.edu/swot), which compiles confirmed point locations of sea turtle nesting beaches from a number of sources (Figure 26). Nesting beaches were included for Green Turtles (*Chelonia mydas*), Hawksbill Turtles (*Eretmochelys imbricata*), Leatherback Turtles (*Dermochelys coriacea*), Loggerhead Turtles (*Caretta caretta*), and Olive Ridley Turtles (*Lepidochelys olivacea*).

Turtle Distributions

Distribution data for loggerhead and leatherback sea turtles was obtained from Harris *et al.* (2018). These maps were developed using satellite tracks from 34 turtles (Figure 25).

Figure 24. Leatherback turtle with tracking equipment

Figure 26. Nesting sites for five sea turtle species in Mozambique.

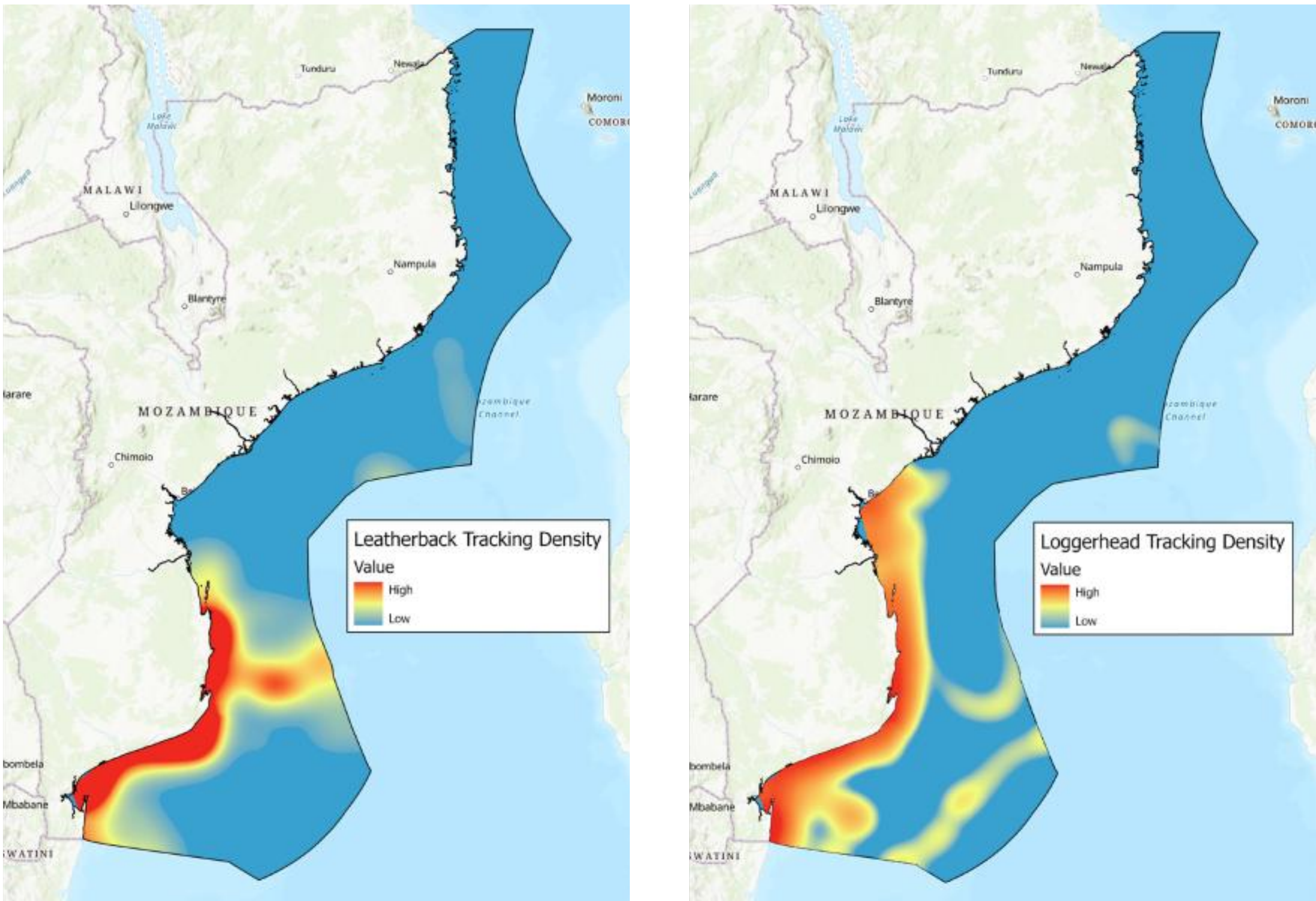


Figure 25. A. Leatherback turtle distribution and B. loggerhead turtle distribution, taken from Harris *et al.* (2018)

Dugong Sighting Data

Dugong sighting data in the Bazaruto region were obtained from the environmental pre-feasibility and scope definition study (EPDA) for implementation of SASOL's project for natural gas extraction (Figure 27; Golder, 2019).

Figure 27. Dugong sightings in the Bazaruto region, taken from Golder (2019).

5.1.3 Other Important Areas

Beyond considering the distributions of ecosystems and species, datasets that capture important areas and key ecological processes were also included. These data identify areas of especially high productivity, locations of significant species aggregations (e.g., breeding sites), hotspots of species larvae distribution, and mangrove habitats.

High Productivity Areas

Areas of high primary productivity are important for biodiversity, as these are nutrient rich areas with high levels of phytoplankton and algae, which form the base of the ecosystem food chain for many higher trophic organisms (Schaeffer et al., 2008). Average primary productivity between 2010-2020 was mapped using MODIS chlorophyll-a concentration data in Google Earth Engine, and high productivity areas were defined as the top 5% of values across Mozambique's EEZ (Figure 28).

Aggregation Sites

Species aggregation sites were mapped through a combination of literature review and consultation with several local, regional and international experts that took place mainly during the course of Mozambique's recent Key Biodiversity Area (KBA) identification process (WCS *et al.*, 2021).

From this work it was possible to identify significant aggregations of marine species occurring in Vamizi Island, Sofala Bank, Tofo and Ponta do Ouro (Figure 29). In the Tofo region, aggregations of manta ray (*Mobula birostris*), reef manta (*Mobula alfredi*) and whale shark (*Rhincodon typus*) were reported by Marshall, (2009), Marshall *et al.* (2011) and Bradley *et al.* (2017) respectively. The Sofala Bank holds significant aggregations of leatherback turtles (*Dermochelys coriacea*), reported by Robinson *et al.* (2016), and Ponta do Ouro and Vamizi Island have a significant aggregation of giant trevally (*Caranx ignobilis*; Daly *et al.*, 2018; Da Silva, 2014).

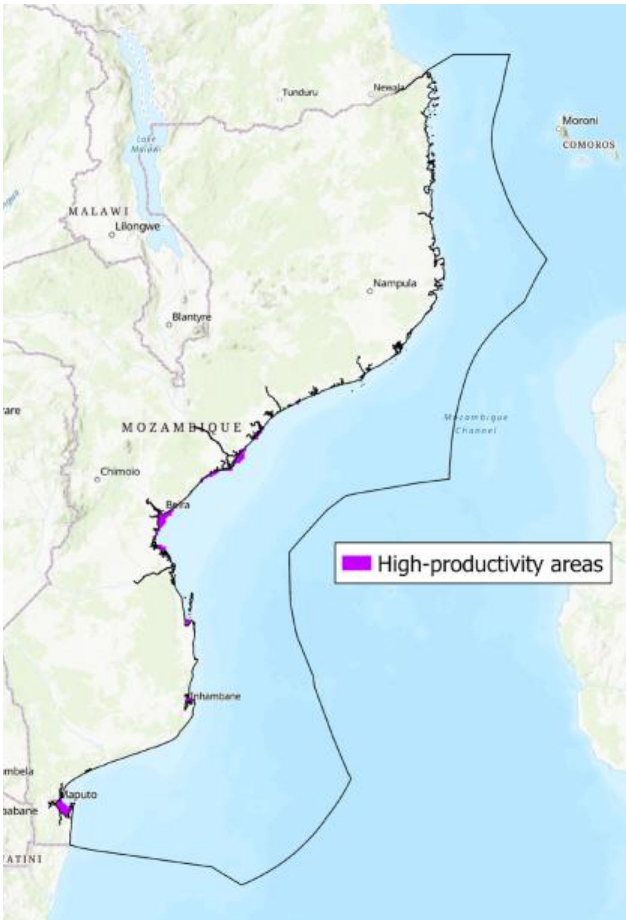


Figure 28. Areas of high primary productivity, mapped by MODIS chlorophyll-a concentration data

Figure 29. Species Aggregation sites

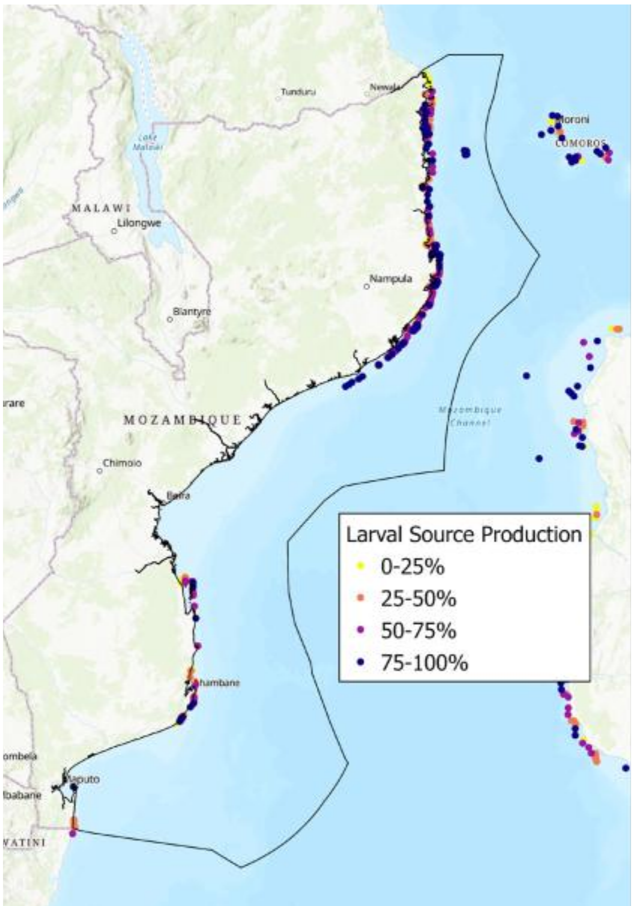


Figure 30. Larval production for Emperor fish species

Larval Connectivity Model

Larval dispersal is a crucial form of movement and distribution for many marine species, whereby planktonic larvae travel away from the area where they were released, and seed species populations elsewhere. In a seascape with a mosaic of areas under varying levels of human pressure and ecological condition, places that produce a large number of larvae that are then dispersed elsewhere (larval sources), are important for the maintenance of species populations in less productive sites (Christie *et al.*, 2010). As such, it is important to ensure the protection of these larval sources.

Data on larval connectivity for five species (Emperor, Fusilier, Grouper, Parrotfish and Mud Crab) was obtained from Treml *et al.*, (2020). Key larval sources were mapped by identifying sites within the top quartile of larvae production for each species (Figure 30).

Mangroves

Mangroves are crucially important as nursery habitat for the juvenile stage of many fish and crustacean species, and are important to consider in MPA planning (Olds *et al.*, 2013). Because mangroves were considered as a terrestrial ecosystem in Mozambique's terrestrial ecosystem map (Lotter *et al.*, 2021) they were not included in the marine ecosystem map (section 5.1.1). However, they were included in our MPA planning analysis, by creating a 1-km buffer into the ocean around mangrove areas mapped by Mozambique's terrestrial ecosystem map (Figure 30). Because mangroves are intertidal forests, these 1-km buffers allow for connectivity between mangroves and nearby coral reefs. The 1-km distance was chosen based on the results of Olds *et al.* (2013), who showed a threshold for mangrove-reef connectivity between 100-1000 m.

Figure 31. Mangrove forest in Marromeu National Reserve-Zambezi Delta

Figure 32. Mangrove ecosystems, as mapped in Mozambique's terrestrial ecosystem map

5.2 Human Pressures

A crucial part of spatial prioritization analyses is gathering data on human uses of the ocean. This helps to facilitate informed and coordinated decisions about how to use marine space and marine resources sustainably, and to recognise the importance of many areas for providing food and livelihoods to local people. Because most of the activities that people undertake in the ocean have negative impacts on biodiversity, they are often referred to as human pressures. In Mozambique, the primary pressure on marine biodiversity is fishing, both from industrial fishing fleets and artisanal fishing communities.

5.2.1 Industrial Fishing

Industrial fishing in Mozambique is a key industry, accounting for 57% of total monetary catch value across all fisheries (UNCTAD, 2017). The primary gears used are long-line fishing, trawling for prawns/shrimp, and tuna fishing. To map industrial fishing pressures in Mozambique, IIP vessel tracking data from 2017 (prawn trawling, shrimp trawling and long-line) and 2020 (tuna fishing) was used. Because vessel tracking data consist of a series of points where fishing occurs, data was interpolated using the kernel density function in ArcGIS 10.5 to generate continuous maps of fishing intensity for each fishing type. The resulting maps of each fishing type were summed to generate an overall map of industrial fishing intensity (Figure 33).

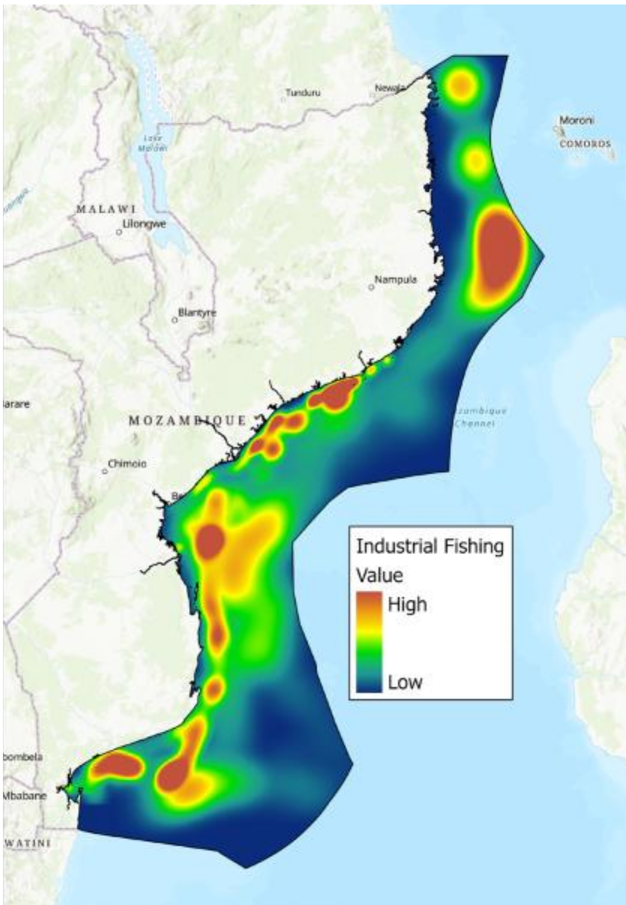


Figure 33. Industrial fishing intensity in Mozambique.

5.2.2 Artisanal Fishing

To generate a map of artisanal fishing effort, district level fishing effort data from 2017, measured in fishing days was used (Figure 34A). To spatially distribute district level fishing effort into the ocean, points were set at 1-km intervals along the entire coastline. For each district, total fishing effort was divided by the number of coastal points within the district, so that each point along the coast had a fishing effort assigned to it. This assumes fishing is equally distributed along the entire coastline, which is unlikely to be accurate, and proxies such as human population do not correlate well with artisanal fishing effort in Mozambique.

Next, the kernel density tool in ArcGIS 10.5 was used to create a search radius to distribute this fishing effort into the ocean from each coastal point. Based on information provided by the IIP experts, the average maximum distance travelled by artisanal fishers is 15 km. While this distance is unlikely to be consistent across all fishing communities in Mozambique, it provided a useful starting point to generate maps of artisanal fishing effort. The output of the kernel density function was set to have a 1-km cell size, and so for each 1-km cell in the output, the kernel density function searched a surrounding 15-km radius and took the values of any coastal district points therein. In the kernel density function, the influence of the coastal district fishing points decreases as distance to a cell becomes greater. Beyond 15 km to the shoreline, the fishing effort is zero (Figure 34B).

After assigning an artisanal fishing estimate to each cell using the kernel density analysis, the artisanal fishing layer was cut to certain depths. Artisanal fishers rarely fish past 50-m depth in most regions of the country. There are a few districts in central Mozambique where the bathymetry is shallower because of the presence of the Sofala Bank. In these areas, artisanal fishers rarely fish past 30-m depth. Those depths were used as the outer range of the artisanal fishing layer, with cells beyond the 30- to 50-m bathymetry cut-off set to a fishing pressure of zero (Figure 34B).

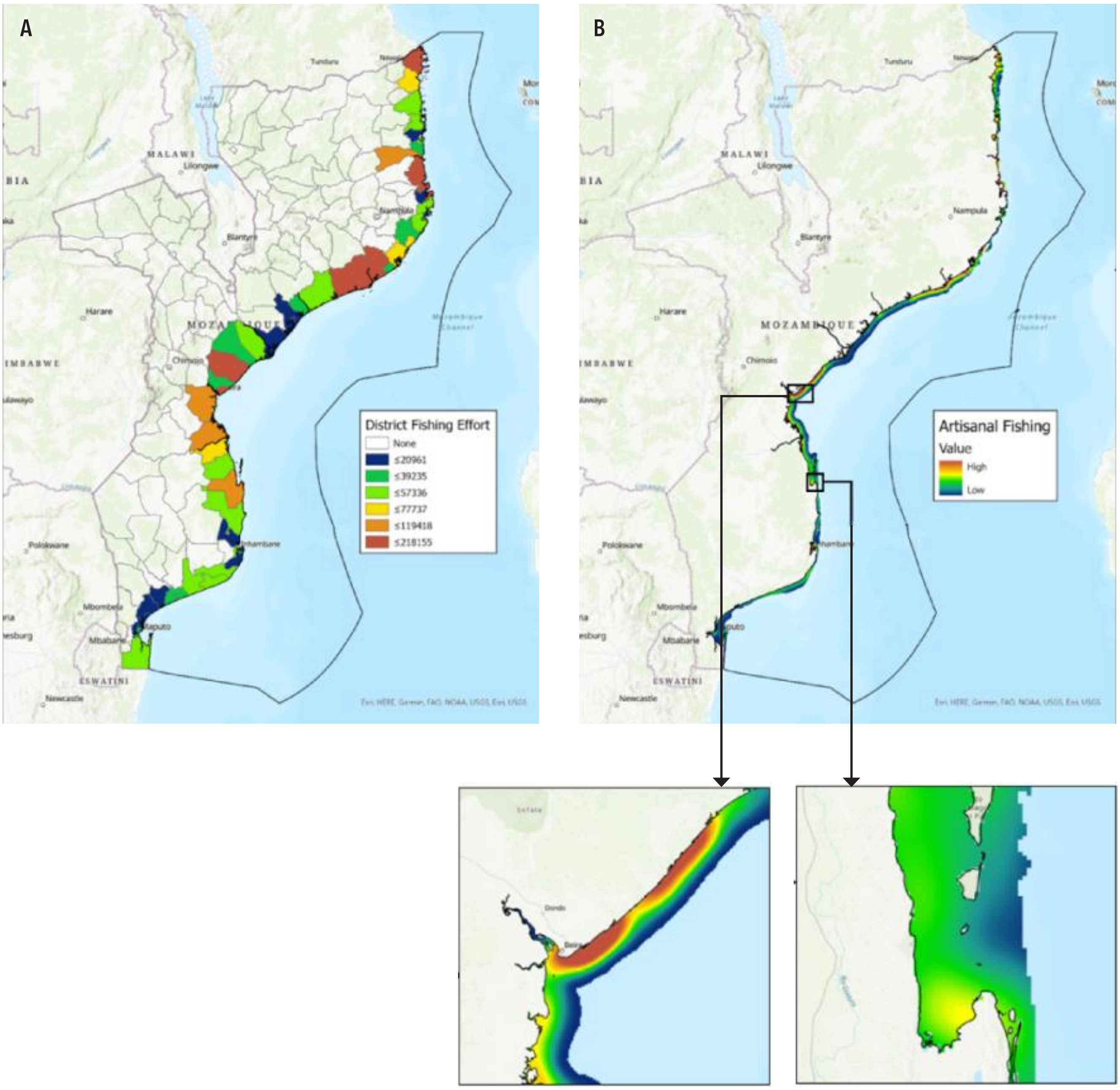


Figure 34. A. District level artisanal fishing effort data, and B. modelled artisanal fishing effort in coastal areas up to 50-m depth/15-km distance from shore, whichever offshore extent is less

5.2.3 Other Human Pressures

Although fishing is the primary human pressure on marine biodiversity in Mozambique, there are a number of other activities that may impact biodiversity. Data was collated for six additional pressures: commercial shipping, ocean-based pollution, coastal mining, coastal development, fertiliser runoff, and pesticide runoff (Table 4 summarises data sources and processing steps). To generate an overall map of non-fishing human pressure (Figure 35), each pressure layer was rescaled between 0-1 and then all layers were summed, following the cumulative impact mapping approach of Halpern et al. (2015).

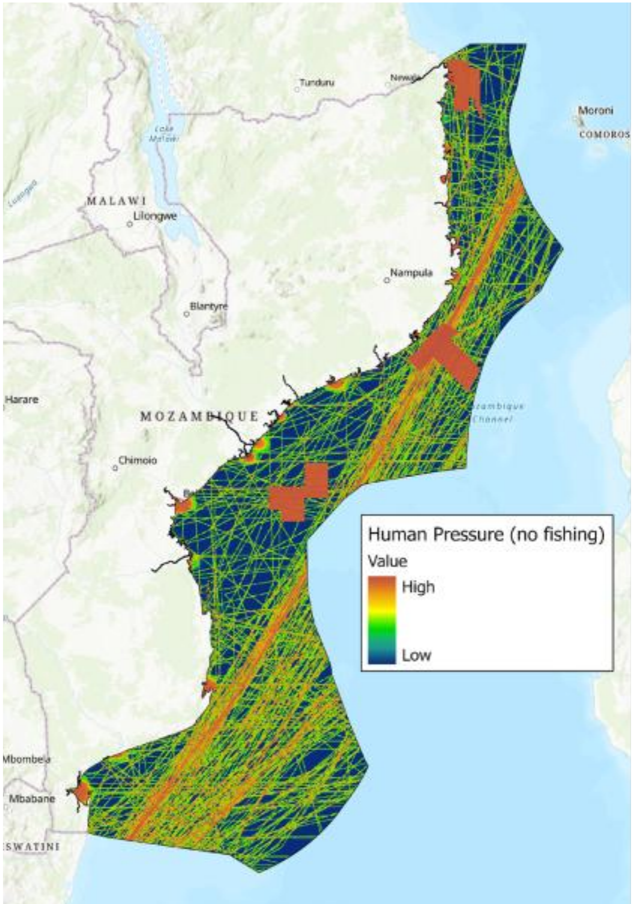


Figure 35. Non-fishing human pressure map

Table 4. Datasets used to develop non-fishing human pressure map.

Human Pressure	Description	Data Processing
Commercial Shipping	Commercial shipping activity can lead to ship strikes of large animals, noise pollution, and a risk of ship groundings or sinkings.	Commercial ship traffic data from World Meteorological Organization Voluntary Observing Ships Scheme, provided by Halpern et al. (2015)
Ocean-based pollution	Intensity of pollution is based on shipping traffic and port location, as ocean-based pollution is assumed to derive from commercial and recreational ship activity, via fuel leaks, oil discharge, waste disposal, etc.	Data on port-based pollution taken from Halpern et al. (2015), with missing port locations updated using data from POEM webGIS portal. Missing ports were assigned average impact score of Mozambique ports with data. Ship-based pollution taken from Halpern et al. (2015). Port-based and ship-based pollution layers are summed to generate overall ocean-based pollution layer.
Coastal Mining	Areas of active coastal mining concessions, which lead to direct conversion of habitat.	Data on mining concessions provided by Ministry of Mineral Resources and Energy (MIREME). Concessions were assigned a score of 1.
Offshore Oil & Gas Activities	Areas of offshore mining concessions, where exploration activities (seismic surveys, drilling, etc.) and production activities (drill platforms, etc.) impact biodiversity.	Data on Oil and Gas concessions provided by National Petroleum Institute (INP). Concessions were assigned a score of 1.
Coastal Development	A general score of for the direct impact of humans, such as coastal engineering, intertidal trampling and noise pollution from land, which likely scale with population size.	Modelled as a sum of coastal population, defined as the number of people within a moving circular window around an arbitrary focal coastal cell of radius 25 km on the basis of the worldpop unconstrained population density data for 2020 (https://www.worldpop.org/). This value was then assigned to the adjacent ocean cell since this driver primarily affects intertidal and very nearshore ecosytems.
Fertiliser Runoff	Agricultural fertiliser runoff has widespread negative impacts on marine biodiversity (Halpern et al. 2015).	Taken from Halpern et al. (2015). Modeled based on rivermouth locations and FAO national-scale fertiliser-use statistics.
Pesticide Runoff	Runoff of pesticides used in agriculture has widespread negative impacts on marine biodiversity (Halpern et al. 2015)	Taken from Halpern et al. (2015). Modeled based on rivermouth locations and FAO national-scale pesticide-use statistics.

5.3 Important community areas

Along with mapping human pressures to understand where humans impact the ocean, in spatial prioritization it is also important to recognize areas that are important to people for cultural or community reasons. Many of these places provide food or livelihoods to local people, for example through tourism revenue, and so these important benefits should be included in the MSP process.

5.3.1 Community Managed Fishing Areas

Data on community managed fishing areas was obtained from IIP, based on projects where the institution has participated (Figure 36). This is not an exhaustive mapping of all the community managed fishing areas that exist in Mozambique and should be improved over time.

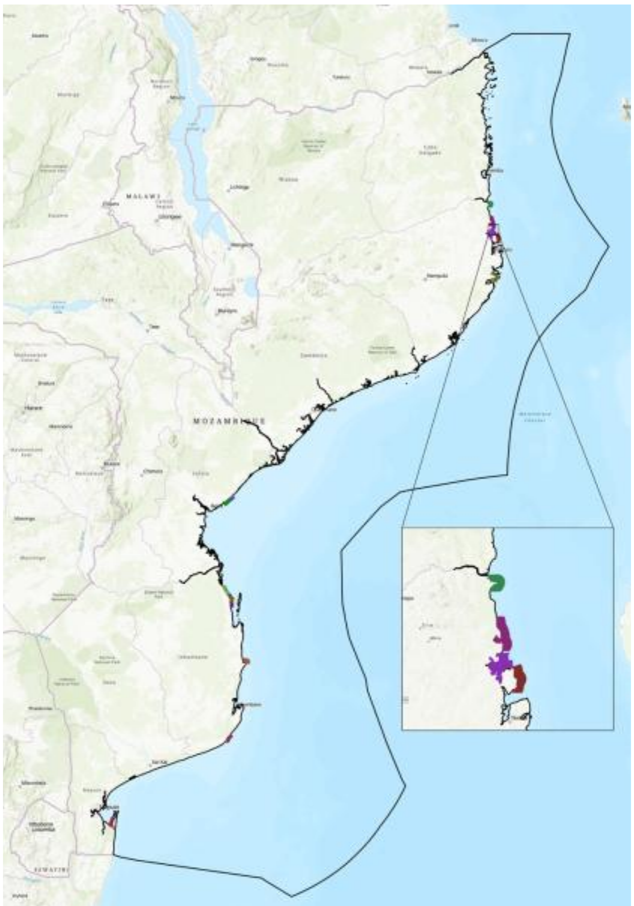


Figure 36. Community managed fishing areas, with different colours representing different community fishing areas.

5.3.2 Zones of Touristic Importance

Tourism is an important and growing industry in Mozambique, so to include important tourism areas, we combined two datasets from the Mozambican MSP webGIS (https://poem.gov.mz/POEMwebgis/). Using ArcGIS 10.5, boundaries of the *Zonas de Interesse Turístico*, and *Pólos Turísticos* datasets were manually digitised. Because both datasets map important tourism areas along Mozambique's coast, they were combined into a single feature showing Zones of Touristic Importance (Figure 37)

5.3.3 Shipwrecks

Shipwrecks have cultural and historical importance, and are also often utilized as tourism sites by dive operators. We obtained data on shipwreck locations from the Mozambican government's webGIS (https://poem.gov.mz/POEMwebgis/). Shipwreck locations were manually digitized by tracing the boundaries of the *Naufrágios* dataset in ArcGIS 10.5 (Figure 37).

5.3.4 Historical Ports

Ports of historical interest have cultural importance, so we obtained data on their locations from the Mozambican MSP webGIS (https://poem.gov.mz/POEMwebgis/). Historical ports were manually digitized by tracing the boundaries of the Portos com interesse histórico dataset in ArcGIS 10.5 (Figure 37).

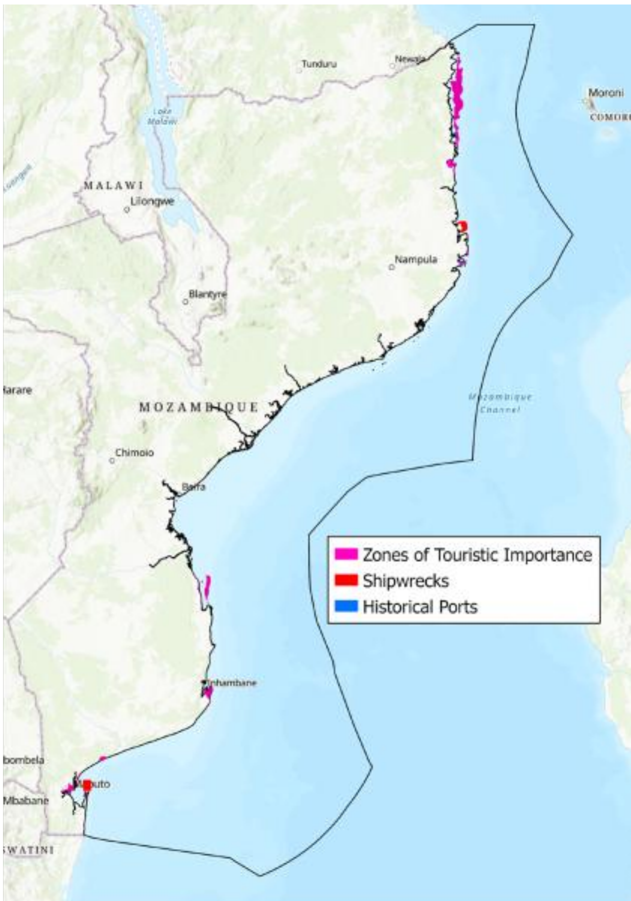


Figure 37. Zones of Touristic Importance, shipwrecks and historical ports

SECTION 6. **SPATIAL PRIORITIZATION METHODS**

After collating and mapping data on biodiversity, human activities and pressures across Mozambique's EEZ, a spatial prioritization analysis was conducted to identify a set of MPA expansion areas that best meets conservation objectives, while balancing trade-offs with human uses of the ocean. The systematic conservation planning tool prioritizr was used. Prioritzr uses integer linear programming (ILP) to determine optimal locations of protected areas that meet conservation objectives in an efficient manner (Hanson et al., 2021). It is similar to Marxan (Ball et al., 2009), the most widely used conservation planning tool, however instead of using simulated annealing to solve the optimization problem, the ILP algorithm finds the exact optimal solution (Beyer et al., 2016).

Regardless of the planning software used, there are a few key elements that are used in a spatial prioritization analysis, namely: 1) planning units, 2) conservation features and 3) targets, and 4) avoidance layers (Figure 38).

6.1 Planning Units

Planning units are used as the basis of a spatial prioritization analysis, as potential locations to be selected by prioritizr as important for achieving objectives. For this analysis, 1 km2 grid cells that covered Mozambique's EEZ were created, using the terrestrial boundary from Mozambique's terrestrial ecosystem map (see Figure 39). This resulted in a total of 566,128 planning units in the planning domain.

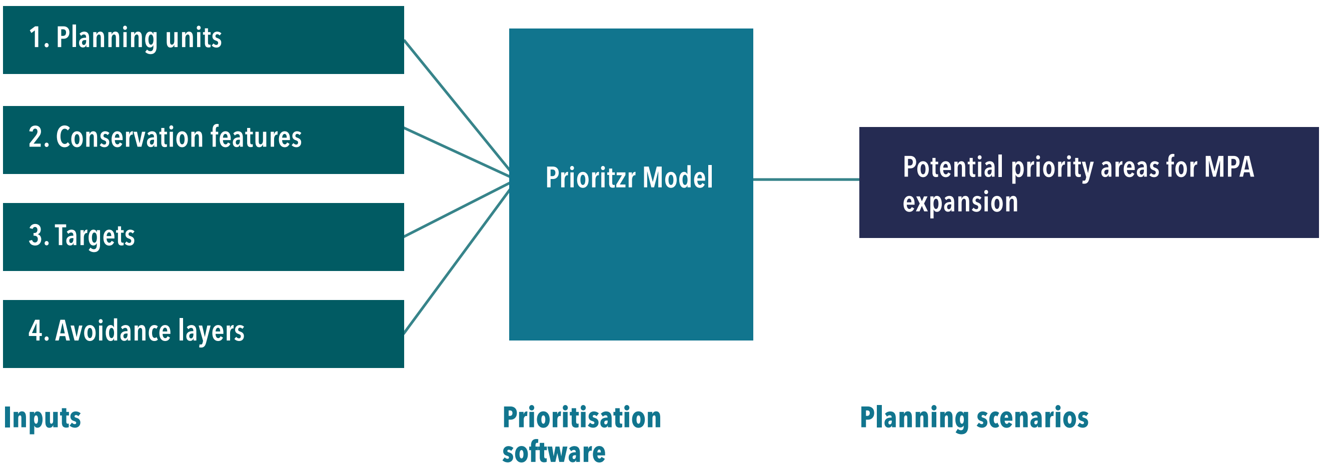


Figure 38. Schematic of prioritizr model

6.2 Conservation Features and targets

In a spatial prioritization analysis, conservation features are the elements of biodiversity that will be represented within the areas selected as potential conservation zones (Ball et al., 2009). Maps of conservation features are used as inputs to conservation planning software, which aims to select a set of areas that capture a portion of each conservation feature. To tell the software how much of each conservation feature should be included, a "target" was set for each feature, which is a quantification of how much of that feature should be captured in the final MPA network. This is typically a proportion of each conservation feature's distribution or abundance.

This analysis included 186 different conservation features, separated into 3 categories: ecosystem types, species, and other important areas (Table 5). Existing and already proposed MPAs and KBAs cover around 6% of Mozambique's EEZ, and three different MPA expansion scenarios – aiming to capture 7-8%, 10-12% and 30% of Mozambique's EEZ – were considered. These scenarios correspond roughly to Mozambique's conservation commitments under a range of international conservation conventions and agreements (see Section 4). While Mozambique has committed to conserving set amounts of its EEZ (e.g. 10%, 30%), targets were not simply set to be equal for each conservation feature. Instead, consultations with experts and local stakeholders were used to set variable targets for each conservation feature based on their importance to Mozambique's marine environment, while also aiming to achieve broad protection goals of 7%, 10% and 30% of the EEZ. Targets ranged from 2.5% - 100% depending on the conservation feature and target scenarios (Table 5, summarises all conservation features and targets used in each scenario).

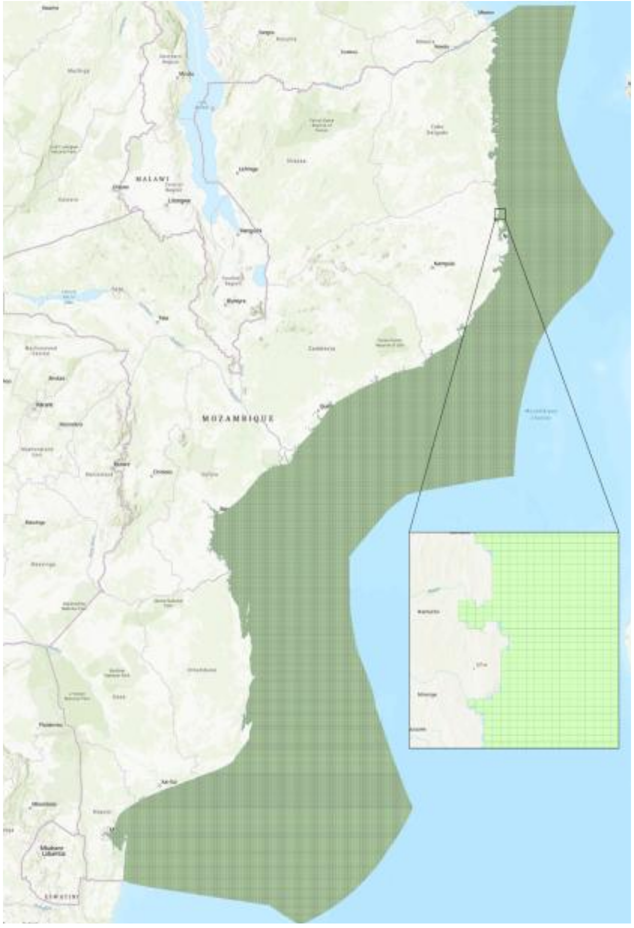


Figure 39. Planning units used in prioritizr analysis

Table 5. Targets used in planning scenarios

	Conservation Features	Scenario A (7-8% of EEZ)	Scenario B (10-12% of EEZ)	Scenario C (30% of EEZ)
Marine Ecosystem Types	Biodiverse Coastal Ecosystem Types (Coral, Seagrass, Microalgae, Rocky Reef)	10	30	50
	Shore zone (sand & nearshore water)	5	15	40
	Estuaries/rivermouths	10	30	50
	Other Shelf Ecosystem Types	5	15	40
	Other Deep-water Ecosystem Types	2	5	30
	Canyons	5	30	40
	Seamounts	5	30	40
Species	Turtle Nesting Beaches (point data)	50	70	90
	Turtle Tracking Density Maps	5	7.5	12.5
	IUCN Species Ranges	5	5	15
	Dugong sighting areas	30	50	80
Important Biodiversity Areas	Important Larval Sources	10	40	70
	High-productivity areas	5	30	50
	Aggregation Sites	5	30	50
	Mangroves	15	30	50
Important Community Areas	Community fisheries management areas	15	50	80
	Zones of Touristic Importance	15	30	50
	Shipwrecks	80	80	80
	Historical Ports	80	80	80

6.3 Avoidance layers

In MSP analyses, avoidance layers are an essential part of identifying new conservation priorities, as they allow for consideration of various human uses of the ocean. By incorporating data on different human activities, spatial prioritization software will aim to meet pre-defined targets for each conservation feature (described in Section 6.2), while avoiding parts of the EEZ based on the other human uses occurring there. These are often referred to as "cost" layers, and indeed in some cases they do represent the financial cost of conserving a particular area. For example, spatial prioritization analyses often use fishing data as a cost layer, and attempt to meet conservation feature targets while minimizing the cost of lost fishing activity by avoiding selection of important fishing grounds. Since this analysis combines many different datasets on human pressures, not all of which have a financial element, the term avoidance layer is used instead.

To simultaneously incorporate multiple human pressures (artisanal fishing, industrial fishing, and other activities), these data were combined into a composite human pressure layer. The human pressure data described in section 5.2 was processed and rescaled, following the processing steps and rationale described in Table 6. The overall rationale behind this layer is that Mozambique's MPA network should meet the conservation feature targets in Table 5 while: 1) targeting sustainable-use MPAs towards areas where artisanal fishing is highest; 2) minimizing impact of no-take MPAs on the industrial fishing sector; and 3) aiming to select areas under low pressure from other human activities (e.g. shipping, mining, etc.). To generate the final avoidance layer, the rescaled layers were summed, such that the final layer has high values in areas that should be avoided (Figure 40). The PrioritzR software will then select a set of areas that meets all the targets outlined in Table 5, while avoiding high value areas from the avoidance layer as much as possible (Figure 40). Some areas may always be selected, even if they have high value in the avoidance layer, if a certain conservation feature is only found in that small region.

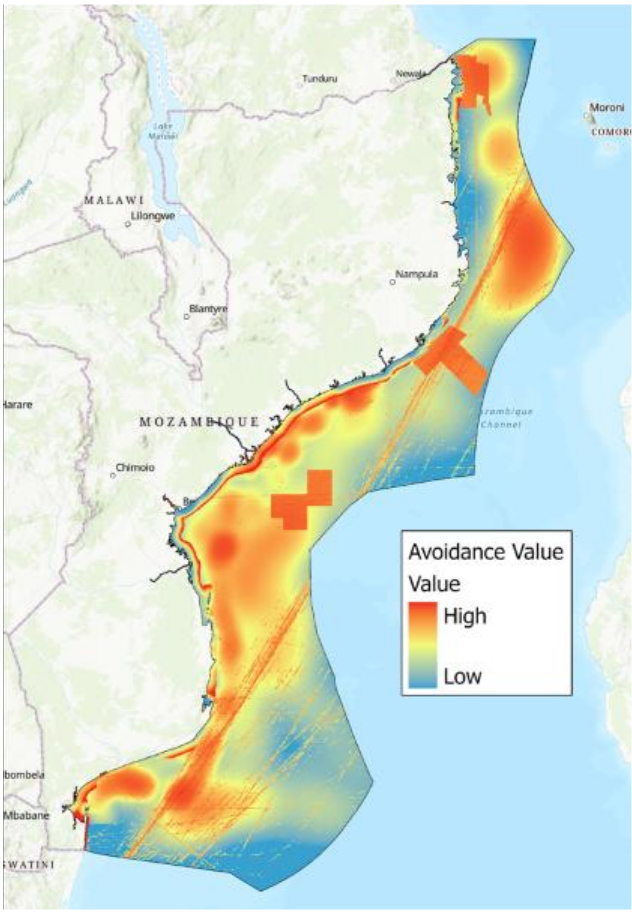


Figure 40. Integrated avoidance layer, created by summing artisanal fishing, industrial fishing and other human pressure layers. Areas with high values (red colours) are less likely to be selected as MPA priorities.

Table 6. Layers and processing steps used to create final avoidance layer

Layer	Rationale	Description	Area applied
Artisanal Fishing	Target sustainable fisheries management towards areas with the highest artisanal fisheries	Rescale artisanal fishing layer between 0-1, where 0 is the highest fishing	Waters <30 m depth
Industrial Fishing	Avoid conflict between industrial fishing areas and MPAs	Rescale industrial fishing layer between 0-1, where 1 is the highest fishing	Waters >30 m depth
Other Human Pressures	While meeting above objectives, prioritize less impacted areas	Rescale human pressure layer between 0-1, where 1 is the highest pressure.	Whole EEZ

6.4 Other inputs

Beyond the primary inputs described above, there are other parameters required for the PrioritizR analysis.

MPAs and KBAs

In each scenario, existing MPAs, Key Biodiversity Areas and proposed MPAs were locked in, so they were always selected by PrioritzR (Figure 41).

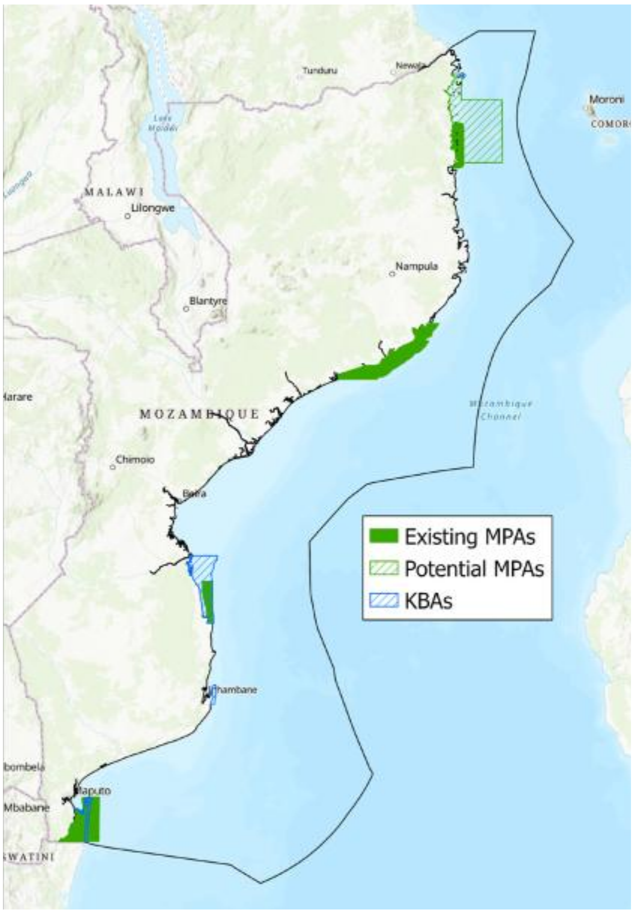


Figure 41. Existing MPAs, Existing KBAs and proposed MPAs

6.4.1 Avoiding fragmented solutions

To avoid developing extremely fragmented MPA expansion priorities, 'boundary penalty function' in prioritizR was applied. Fragmented MPA networks are undesirable, as large MPAs generally provide greater benefits to biodiversity, and the cost of managing many small MPAs can be prohibitive. However, we also want to avoid excessively large reserves that are unrealistic to implement and manage. To do this, Prioritizr uses a numeric penalty that scales the importance of selecting planning units that are clumped together or connected.

To calibrate the boundary length penalty to use for our analysis, a common method adapted from Stewart and Possingham (2003) was used. A series of prioritizR analyses were run, using 8 different boundary penalty values starting with 0, then exponentially increasing from 1x10-7 to 1. For all runs, a processing time of 11 hours was set, with a gap limit of 0.1%. The gap limit tells PrioritizR how close a solution must be to the optimal solution before we consider it acceptably close. Runs with boundary penalties set higher than 0.00001 did not reach the gap limit within 11 hours of processing time, and so a boundary penalty of 0.00001 was chosen to balance efficient clumping of reserves against processing time.

6.5 Participatory approach

The process was planned to include participation of relevant national stakeholders. Therefore, as mentioned before, a coordination group chaired by IIP was established, composed of institutions from MIMAIP, MTA, other Ministries and civil society organizations (Appendix 3). This group met (Figure 42) on 17th September 2020, 20th January and 24th May 2021. These webinars included one or two technical presentations, followed by discussions to clarify any doubts, comment the approach and provide suggestions. To support the development of the marine ecosystem map, members of this group and other marine specialists were invited for a webinar which happened in 05th May 2021. The webinar's methodology was the same as described above.

In addition to the above, meetings with the team that was developing the national Marine Spatial Plan occurred in 6th November 2020 and 28th May and 1th June 2021. IIP's and WCS's team designated to this project met several times during the period of the project.

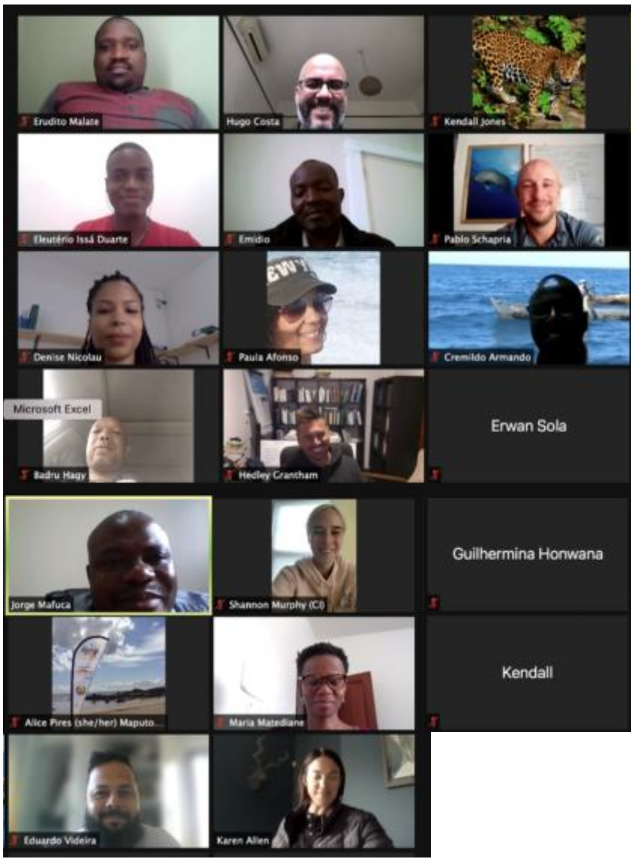


Figure 42. MPA coordination group

SECTION 7. **RESULTS**

Existing MPAs, Key Biodiversity Areas, and proposed MPAs cover 5.8% of Mozambique's EEZ (32,174.7 km2), and are primarily located along the coastline and continental shelf (Figure 43). The three MPA expansion scenarios identified an additional 13,384 km^2, 23,551 km^2, and 151,987 km^2 of MPA priorities, bringing MPA coverage to 8.2%, 9.9% and 32.6% of the EEZ, respectively (Table 7). Targets for all conservation features are met in each scenario (Appendix 4).

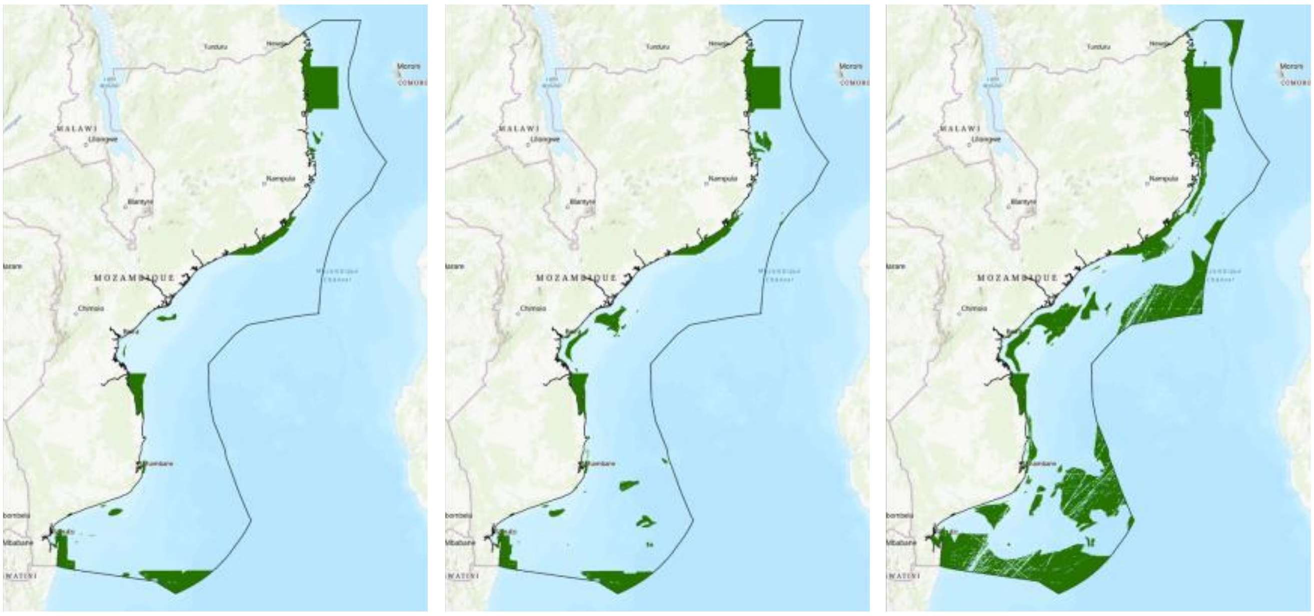
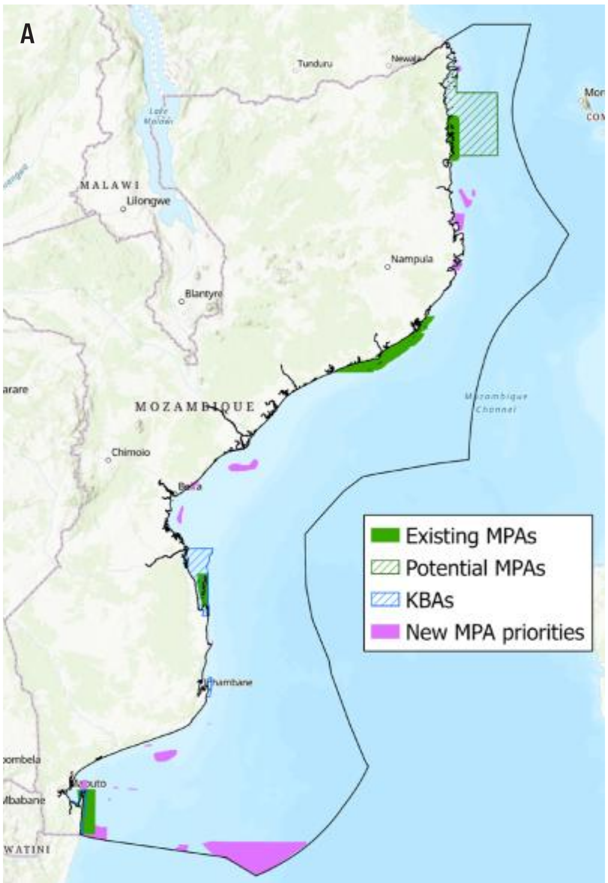


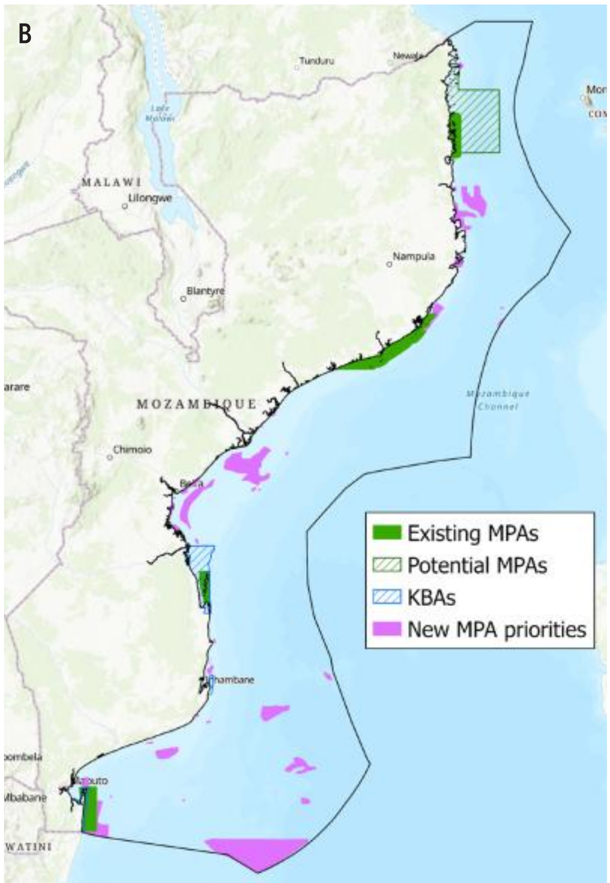
Figure 43. PrioritizR output, where green areas are selected for conservation priority. (A) Scenario A aims to conserve 7-8% of the EEZ in MPAs to meet the objectives in the NBSAP; (B) Scenario B aims to conserve 10-12% of the EEZ in MPAs to meet the objectives of Aichi Target 11 and the SDGs; and (C) Scenario C aims to conserve 30% of the EEZ in MPAs to meet the objectives of the HAC (see Section 4.3 for details).

In Scenario A (7-8%), additional conservation priorities are primarily concentrated in coastal areas and along the continental shelf, with one potential offshore area located at the southernmost point of Mozambique's EEZ (Figure 44A). Scenario B (10% of EEZ) shows many more small areas along the coastline, and some larger priorities on the Sofala Bank and around the Memba/Nacala region (Figure 44B). Scenario C (30% of EEZ) adds a considerable amount of very large offshore areas in the South-West and the Mozambique Channel, and some large continental shelf areas stretching from Quirimbas National Park to Primeiras and Segundas Environmental Protection Area (Figure 44C).

Table 7. Area (km^2) of new MPA priorities identified through PrioritizR, as well as the area (km^2) and proportion (%) of the EEZ that they comprise.

MPA Expansion Scenario	New MPA Priority Area (km^2)	Total Area (km^2)	% of EEZ
Existing/Proposed MPAs and KBAs	-	32174	5.8
Scenario A (NBSAP, 7-8%)	13384	45558	8.1
Scenario B (Aichi/SDGs, 10-12%)	23551	55725	9.9
Scenario C (HAC, 30%)	151987	184161	32.6





To identify broad regions for MPA expansion, areas of interest were manually delineated by creating polygons around large blocks of new MPA priorities identified by PrioritizR. These areas represent a more realistic potential MPA design than the raw prioritizR output (Figure 44). In scenario A, there are 21 new MPA priorities with an average size of 753 km^2. In scenarios B and C, the number of new priorities increases to 41 and 53 respectively, with the average size of new MPAs being 688 km2 and 3138 km^2, respectively. The large average size of new priorities in scenario C is due to the selection of very large offshore areas required to meet 30% coverage of the EEZ. .

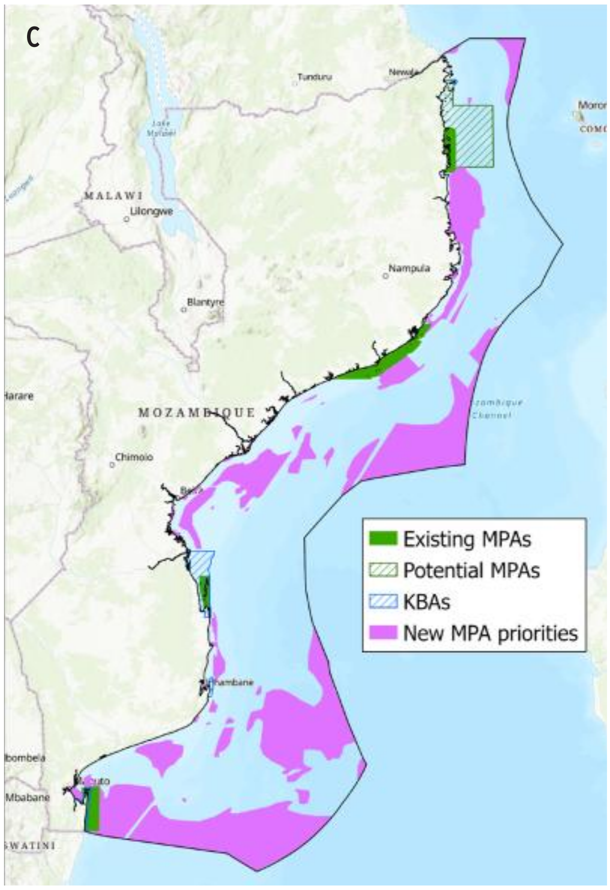


Figure 44. Existing MPAs, proposed MPAs, Key Biodiversity Areas, and New MPA Priorities as identified by PrioritizR analysis. New MPA priorities were manually delineated from raw PrioritizR output

SECTION 8. DISCUSSION

8.1 Proposed Priorities for MPA Expansion in Mozambique

This study identified priorities areas for potential MPA expansion for Mozambique, by: i) mapping ecosystems, species and other important areas; ii) understanding human uses of Mozambique's EEZ, and iii) combining these data to identify new MPA priorities. When viewing the results, it is important to remember that spatial prioritization provides an evidence-based approach to identify areas of conservation priority, but it does not make a decision on where to place MPAs. These maps highlight areas for consideration as MPAs, but final MPA design requires a more comprehensive process including more intensive stakeholder feedback, expert review, feasibility assessments, and more.

In scenario A (7-8% of EEZ), priority areas are primarily concentrated in coastal areas and along the continental shelf, likely because most of the conservation features that were included are found close to shore. In scenario's B and C, increased targets for offshore ecosystems led to selection of many remote areas in the southern and central areas of Mozambique's EEZ. These offshore zones are likely to hold different biodiversity features to coastal areas, face very different kinds of human pressures, and pose different challenges for MPA management and enforcement of marine regulations.

While this study identified priorities for future MPA expansion, it does not attempt to categorise these priorities into different specific management types. The dynamic nature of management and enforcement of MPAs in Mozambique meant it was not feasible to systematically incorporate types of enforcement and the associated costs or budget into our analysis. However, there is a range of different MPA types in Mozambique (see Section 4.3), and the most appropriate management type for each priority area will depend on many factors, including size, major human uses and stakeholders affected, and the biodiversity features within. Many of the priority areas are adjacent to existing MPAs (e.g., Maputo APA, Primeiras and Segundas), or proposed MPAs (Quirimbas APA), and so the management of new priority areas should be coherent with the existing/proposed MPAs.

MPAs in Mozambique are mostly managed and enforced by the Government, in some cases under a co-management regime with conservation partners. There is only one protected area that is managed by the private sector (Cabo S. Sebastião). Despite being provided for in the national legislation, and the presence of several initiatives to try to implement such an approach (e.g., Vamizi), there are still no official community managed conservation areas.

The two existing National Parks are, in theory, total conservation areas, meaning that these should be no-take MPAs. However, "de facto" use of resources is happening, as is the case in Quirimbas National Park. The current trend is to gazette MPAs as sustainable-use conservation areas, like the Primeiras and Segundas Environmental Protection Area and Maputo Environmental Protection Area. In these cases, sustainable use of resources is allowed if compatible with the conservation objectives of the area and if it is done according to the management plan. Currently, there are at least five initiatives to expand the MPA network in the following locations:

- **Vamizi:** With the support of the Faculty of Natural Sciences of the University of Lúrio (FCN-UniLúrio), an application for a Community Conservation Area was developed for Vamizi. This area is also a KBA and it was locked in in the current analysis for all the scenarios that were developed.
- **Quirimbas:** as part of the project "Rethinking Quirimbas" (Cabo Delgado) by the World Wide Fund for Nature (WWF) and ANAC, a plan is in place to resize the National Park, reducing it onshore and increasing it offshore, and part of the area will be re-gazetted as an Environmental Protection Area. This process is at its final stage, a report was developed, and it was presented at the Provincial level. Due to this reason, this area was already locked in the current analysis for all the scenarios that were developed.
- **Great Bazaruto:** Conservation International and ANAC are developing a process to create an Environmental Protection Area (or two) between Save River's mouth and Závora (Inhambane Province). A workshop with many stakeholders, including the current project's team, was held in Vilankulus and a final report was developed. The coordination group established under the current project was involved in the process, which is currently under discussion.

- **Marromeu / Sofala Bank:** There is a project in place to assess the feasibility of creating a MPA in the region of Marromeu/Sofala Bank. This project is being led by the Gregg Carr Foundation.
- **Memba-Mossuril:** This project is being led by WCS in partnership with IIP, ProAzul Trust Fund, Ajuda de Desenvolvimento de Povo para Provo (ADPP), Associação do Meio Ambiente (AMA), the University Eduardo Mondlane (UEM) and the Foundation for Biodiversity Conservation (BIOFUND). The objective is to establish a sustainable-use MPA that that includes a network of well-operated community-managed fishing areas.

The new REPMAR includes the new figure of community-managed fishing areas, in this case by Community Fishing Councils (CCPs). These areas should include no-take zones and temporary closures managed by the fishers.

For offshore MPAs where industrial fishing is likely to be the main human pressure, government-enforced no-take zones are likely to be the most feasible management option, despite concerns around feasibility of monitoring areas far from shore. For most coastal priorities, MPAs managed and enforced by local fishers, such as Community Conservation Areas or Community Sanctuaries (both of which are recognised in the Conservation Law) may be the most appropriate and feasible form of management as the MPA network expands. Given limited government capacity for MPA enforcement, working with local communities and establishing Community Managed Fishing Areas that can work as OECMs may be a way to help ensure regulations are followed. However, the size, organizational and institutional capacity, and level of governance varies greatly among CCPs, and additional support is likely to be required to ensure effective management in these areas (Benkenstein, 2013; Samoilys *et al.*, 2017).

Stakeholder engagement has been vital in identifying the new MPA priorities mapped here, and further engagement with a broad range of stakeholders will be important when deciding on the final locations for new MPAs. A review conducted in 2011 noted that establishment of MPAs in Mozambique has followed a top-down approach, with limited community involvement, and many communities feel excluded or suspicious of the ultimate goals of the MPAs (Benkenstein, 2013). The current analysis attempted to take other stakeholders into account, by avoiding areas where industrial fishing or other human activities occur, and by targeting sustainable-use MPAs towards areas where artisanal fishing is likely to be most intense. However, when moving towards MPA designation and implementation, it is crucial to facilitate direct engagement with different stakeholders, such as industrial fishers, artisanal fisheries groups, and government institutions. Stakeholders can play a significant role in the implementation of any conservation plan, especially when livelihoods of large populations are at stake, as is the case with MPAs in Mozambique. As such, a comprehensive stakeholder engagement plan will be important when moving towards MPA establishment.

8.2 Limitations and Research Priorities

Although the analysis attempted to incorporate the most up to date data on biodiversity and human pressures in Mozambique, there are a number of limitations that should be recognised when interpreting the results.

8.1.1 Ecosystems

There are a number of improvements that could be made to the marine ecosystem map if appropriate data become available. Allen Coral Atlas data was used to map benthic substrate, but these data are available only for shallow areas, and it is not clear how much validation has been completed in Mozambique. Data on benthic substrate over the entire EEZ would allow for more refined delineation of ecosystems in deep water areas, as was done in South Africa's marine ecosystem map (Sink et al., 2019a). It would also be useful to separate muddy, sandy, rocky, and mixed shores, which could potentially be accomplished by refining the analysis of Luijendijk et al., (2018). To further improve delineation of shore areas, contemporary remote sensing approaches could be used to map the back of the surf zone (e.g., Harris et al., 2019), as opposed to using a standard distance from shore. Similarly, GIS models of river plumes could potentially be used to more accurately map estuaries and their outflows, as demonstrated for the Zambezi River by Nehama and Reason (2015). There is an ongoing project called WIO-BENTH (Identification, Characterization and

Vulnerability Assessment of Benthic Ecosystems in the Western Indian Ocean) led by the Oceanographic Research Institute of South Africa, which includes Mozambique's EEZ and could produce, in the short term, useful information to improve the ecosystem map, as it will be concluded in 2022.

8.1.2 Species

The majority of the species data used in the analysis was in the form of IUCN species range maps, which are generally coarse Extent of Occurrence polygons. These polygons do not reflect the specific spatial variability of species distributions within their boundaries. As such, additional data on detailed species distributions, species tracking data, or species' habitat preferences (e.g., coral reef, sandy bottom) would greatly improve the analysis by highlighting especially important areas for particular species. However, by aiming to capture a portion of every marine ecosystem, the MPA priorities that were identified should capture the diversity of marine habitats in Mozambique, and also the diversity of associated species.

8.1.3 Human uses/pressures

The primary focus for improvement of the human pressure data that were used should focus on the maps of artisanal and industrial fishing effort. Industrial fishing effort maps could be improved by 1) obtaining more recent fisheries data, 2) obtaining data from other fishing gears, or 3) weighting the impact of fishing gears on different marine ecosystems, for example by making the impact of trawling over coral reefs higher than the impact of trawling over a sandy bottom. In South Africa, two kinds og human activity maps are used. Human pressure maps show only the intensity of various human activities, whereas human impact maps incorporate additional estimates of the impact of activities on different marine ecosystem types. Such an approach would provide useful information for marine conservation in Mozambique, although it would require estimates on the sensitivity and resilience of marine ecosystems to various human activities (Halpern et al., 2015).

The map of artisanal fishing effort used here relies on some broad assumptions, and could thus be improved if new data could be used to refine these assumptions. The primary assumption revolves around average fisher travel distance, which was assumed to be 15 km based on discussions with IIP. This value is unlikely to be accurate for all fishers, especially given that fishers have boats of different sizes, use different gears, and some embark on multi-day trips while others make day trips only. If more accurate data on average travel distance could be collected, for example through district-level surveys or questionnaires, then the spatial estimates of artisanal fishing could be improved. Fishing effort was also assumed to be equal along the entire coastline of each district, which is unlikely to be accurate, so ancillary data could be used to map hotspots of fishing activity more accurately. Consultation with IIP revealed that population density is not an accurate predictor of artisanal fishing effort, but other datasets that might be useful include fishing infrastructure (e.g., ports, piers) or number of boats, which can potentially be determined from satellite imagery (Johnson *et al.*, 2017).

In terms of non-fishing human pressures, a major improvement could be made by investing in up-to-date shipping traffic maps. The data used were from Halpern *et al.*, (2008), which were the best freely available data, but there are much better data available from commercial organizations such as Marine Traffic (www.marinetraffic.com).

8.3 Next steps

The scenarios that have been developed are a result of a systematic process based on a scientific approach using the best available information. Each of the scenarios informs priority areas for establishing a network of representative MPAs, based on the input data. However, these are intended to be tools to support the decision-making process, which is comprised of several steps before gazetting a site as an MPA. The national step-by-step process includes:

- Developing a proposal for a specific site, which can be submitted by government agencies, academic institutions, the private sector, non-governmental organizations, local communities and even municipalities.
- Submitting the proposal to the relevant authorities.
- Receiving proposal approval.
- Developing the management and zoning plan.
- Establishing the Management Authority and the Management Board.
- Operationalizing and monitoring the MPA.

However, given that the current situation (2.2% of the EEZ in MPAs) is far below Mozambique's desired scenarios and international commitments (see Section 4.3), efforts must be made to ensure that the expansion and creation of new MPAs is done in an integrated way, taking advantage of the Marine Spatial Plan process currently underway. Considering that Mozambique should now have at least 7% of its EEZ under formal protection, whereas the actual figure is only 2.2%, an approach where several MPAs are proposed simultaneously is preferential. Furthermore, it is imperative that the expanded MPA network is representative of the marine biodiversity in Mozambique, and is not purely an area-based expansion. Protection must be spread across ecosystem types, species and other important areas for biodiversity. Representation across features can be more easily considered when proposing and implementing a coherent network that has been identified based on a systematic assessment (such as in this report) rather than on a case-by-case basis. Further advantages of proposing an MPA network rather than individual sites is that additional design elements, such as the sizing, spacing and connectivity among MPAs, can also be part of the negotiations and design planning.

Therefore, we propose an approach similar to the one that unfolded in South Africa. In that case, there was an initial proposal of focus areas for protection based on a systematic conservation plan, developed with stakeholder engagement (Sink *et al.*, 2011). This ultimately led to the declaration of 20 new MPAs in 2019, in a representative design that affords at least some protection for 87% of the 150 marine ecosystem types in South Africa (Sink *et al.*, 2019b) because of the underlying systematic prioritisation (Sink *et al.*, 2011).

From this successful example in South Africa, the following steps are proposed for Mozambique:

1. Integrate the three scenarios of the current analysis in the Marine Spatial Plan underway
2. Discuss the proposed focus areas under each scenario with all relevant stakeholders under the MSP process and discuss their concerns and priorities, promoting alignment between sectors
3. Make any necessary adjustments before the final MSP is published
4. Develop the proposed boundaries for each focus area
5. Start the national step-by-step process described above, developing the proposal for each site, as simultaneous as possible, and submit the proposal to the relevant authorities
6. Create awareness and public engagement regarding the value of MPAs, especially socio-economic
7. Proclamation of the areas
8. Develop the final management and zoning plan for each area
9. Establish the Management Authority and the Management Board for each area
10. Operationalize and monitor each of the new MPAs

The implementation of these 10 steps should start immediately, considering that the Marine Spatial Plan is currently at its final stage.

Figure 45. Tofinho Beach, Inhambane province

SECTION 9. **CONCLUSIONS**

Through the steps described here, the initially defined objectives of this MPA planning process were achieved.

- A coordination group was established to discuss aspects of MPA expansion in Mozambique, not only for supporting the development of the current scenarios, but also to support other initiatives to expand existing MPAs or create new ones. The group is composed of institutions from MIMAIP, MTA, other ministries and civil society organizations.
- Three different scenarios that identify appropriate areas for MPA proclamation or expansion were developed. One allows the country to protect 7-8% of the Mozambican EEZ (and thereby meet the target in the NBSAP); another covers 10-12% (and thereby meet the Aichi and SDG targets); and a final scenario aims to protect 30% (and thereby meet the HAC target).
- The results (data layers) of this process were provided to the team that has developed the National Marine Spatial Planning (POEM) process, and scenario C relative to the protection of 30% of the EEZ was incorporated into the POEM, allowing proper consideration for biodiversity.

Although the outputs of this analysis can be improved when more data become available, the government now has appropriate information to make informed decisions on how to expand the MPA network to achieve the protection targets the country has committed to under international conventions and initiatives. This is also an important step towards achieving future targets that will be established in the new Global Biodiversity Framework for 2030. Finally, any MPA network must be representative Mozambique's marine biodiversity, and must not be based purely on area. The new map of ecosystem types presented here, along with the systematic analysis and resulting priority maps provide a robust, scientific foundation on which such a representative MPA network can be based. Mozambique is now poised to make progress towards meeting its international commitments for protecting marine biodiversity by expanding its current MPA estate, strengthening the sustainability of human uses – especially fishing, and securing the benefits and opportunities associated with marine biodiversity for generations to come.

It should also be highlighted that now that the new national Marine Spatial Plan is ready to be implemented with the inclusion of the 30% protection scenario, Mozambique has the adequate set of tools to start a process to meet the marine protection targets it has committed.

Figure 46. Presenting the results during the second edition of the growing blue international conference, Vilankulos, Inhambane Province

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APPENDIX 1. **TABLE OF ECOSYSTEM TYPES**

Ecoregion	Bathome	Substrate/ Geomorphology	Ecosystem Type	Description
Delagoa	-	Canyon	Delagoa Canyon	Canyon in the Delagoa Ecoregion (steep-walled underwater valleys with V-shaped cross sections)
Delagoa	-	Coral Reefs	Delagoa Coral Reefs	Coral Reefs in the Delagoa Ecoregion (live reefs or algae)
Delagoa	-	Estuary	Delagoa Estuary	Estuaries and outflows in the Delagoa Ecoregion (areas within 2.5km buffer from rivermouth)
Delagoa	-	Microalgal Mats	Delagoa Microalgal Mats	Microalgal Mats in the Delagoa Ecoregion (visible accumulations of microscopic algae in sandy sediments)
Delagoa	-	Rock	Delagoa Rock	Rock in the Delagoa Ecoregion (exposed hardbottom area with few corals)
Delagoa	-	Rubble	Delagoa Rubble	Rubble in the Delagoa Ecoregion (loose, rough fragments of broken coral)
Delagoa	-	Seagrass	Delagoa Seagrass	Seagrass in the Delagoa Ecoregion
Delagoa	Lower Shelf	-	Delagoa Lower Shelf	Lower Shelf waters in the Delagoa Ecoregion (100-150 m depth)
Delagoa	Mid Shelf	-	Delagoa Mid Shelf	Mid Shelf waters in the Delagoa Ecoregion (40-100 m depth)
Delagoa	Shelf Edge	-	Delagoa Shelf Edge	Shelf Edge waters in the Delagoa Ecoregion (150 – 500 m depth)
Delagoa	Shore	-	Delagoa Shore (300m buffer)	Shore waters in the Delagoa Ecoregion (300 m buffer from shore)
Delagoa	Upper Shelf	-	Delagoa Upper Shelf	Upper Shelf waters in the Delagoa Ecoregion (0-40 m depth)
East Africa	-	Canyon	East Africa Canyon	Canyon in the East Africa Ecoregion (steep-walled underwater valleys with V-shaped cross sections)
East Africa	-	Coral Reefs	East Africa Coral Reefs	Coral Reefs in the East Africa Ecoregion (live reefs or algae)
East Africa	-	Estuary	East Africa Estuary	Estuaries and outflows in the East Africa Ecoregion (areas within a 2.5 km buffer from rivermouth)
East Africa	-	Microalgal Mats	East Africa Microalgal Mats	Microalgal Mats in the East Africa Ecoregion (visible accumulations of microscopic algae in sandy sediments)
East Africa	-	Rock	East Africa Rock	Rock in the East Africa Ecoregion (exposed hardbottom area with few corals)
East Africa	-	Rubble	East Africa Rubble	Rubble in the East Africa Ecoregion (loose, rough fragments of broken coral)
East Africa	-	Seagrass	East Africa Seagrass	Seagrass in East Africa Ecoregion
East Africa	Lower Shelf	-	East Africa Lower Shelf	Lower Shelf waters in the East Africa Ecoregion (100-150 m depth)
East Africa	Mid Shelf	-	East Africa Mid Shelf	Mid Shelf waters in the East Africa Ecoregion (40-100 m depth)
East Africa	Shelf Edge	-	East Africa Shelf Edge	Shelf Edge waters in the East Africa Ecoregion (150-500 m depth)
East Africa	Shore	-	East Africa Shore (300m buffer)	Shore waters in the East Africa Ecoregion (300 m buffer from shore)
East Africa	Upper Shelf	-	East Africa Upper Shelf	Upper Shelf waters in the East Africa Ecoregion (0-40 m depth)
Moz Channel	-	Canyon	Mozambique Channel Canyon	Canyon in the Mozambique Channel Ecoregion (steep-walled underwater valleys with V-shaped cross sections)
Moz Channel	-	Coral Reefs	Mozambique Channel Coral Reefs	Coral Reefs in the Mozambique Channel Ecoregion (live reefs or algae)
Moz Channel	-	Seamount	Mozambique Channel Seamount	Seamount in the Mozambique Channel Ecoregion (conical areas rising >1000 m from seafloor)
Moz Channel	Abyss	-	Mozambique Channel Abyss	Abyssal waters in the Mozambique Channel (>3500 m depth)
Moz Channel	Lower Shelf	-	Mozambique Channel Lower Shelf	Lower Shelf waters in the Mozambique Channel Ecoregion (100-150 m depth)
Moz Channel	Lower Slope	-	Mozambique Channel Lower Slope	Lower Slope waters in the Mozambique Channel Ecoregion (1800-3500 m depth)
Moz Channel	Mid Shelf	-	Mozambique Channel Mid Shelf	Mid Shelf waters in the Mozambique Channel Ecoregion (40-100 m depth)
Moz Channel	Mid Slope	-	Mozambique Channel Mid Slope	Mid Slope waters in the Mozambique Channel Ecoregion (1000-1800 m depth)
Moz Channel	Shelf Edge	-	Mozambique Channel Shelf Edge	Shelf Edge waters in the Mozambique Channel Ecoregion (150 - 500m depth)
Moz Channel	Upper Shelf	-	Mozambique Channel Upper Shelf	Upper Shelf waters in the Mozambique Channel Ecoregion (0-40m depth)

Ecoregion	Bathome	Substrate/ Geomorphology	Ecosystem Type	Description
Moz Channel Sofala Bight	Upper Slope	-	Mozambique Channel Upper Slope	Upper Slope waters in the Mozambique Channel Ecoregion (500-1000m depth)
Sofala Bight Sofala Bight	-	Canyon	Sofala Bight Canyon	Canyon in the Sofala Bight Ecoregion (steep-walled underwater valleys with V-shaped cross sections)
Sofala Bight	-	Coral Reefs	Sofala Bight Coral Reefs	Coral Reefs in the Sofala Bight Ecoregion (live reefs or algae)
Sofala Bight Sofala Bight	-	Estuary	Sofala Bight Estuary	Estuaries and outflows in the Sofala Bight Ecoregion (areas within 2.5 km buffer from rivermouth)
Sofala Bight	-	Microalgal Mats	Sofala Bight Microalgal Mats	Microalgal Mats in the Sofala Bight Ecoregion (visible accumulations of microscopic algae in sandy sediments)
Sofala Bight Sofala Bight	-	Rock	Sofala Bight Rock	Rock in the Sofala Bight Ecoregion (exposed hardbottom area with few corals)
Sofala Bight Sofala Bight	-	Rubble	Sofala Bight Rubble	Rubble in the Sofala Bight Ecoregion (loose, rough fragments of broken coral)
Sofala Bight	-	Seagrass	Sofala Bight Seagrass	Seagrass in the Sofala Bight Ecoregion
	Lower Shelf	-	Sofala Bight Lower Shelf	Lower Shelf waters in the Sofala Bight Ecoregion (100-150 m depth)
	Mid Shelf	-	Sofala Bight Mid Shelf	Mid Shelf waters in the Sofala Bight Ecoregion (40-100 m depth)
	Shelf Edge	-	Sofala Bight Shelf Edge	Shelf Edge waters in the Sofala Bight Ecoregion (150-500 m depth)
	Shore	-	Sofala Bight Shore (300m buffer)	Shore waters in the Sofala Bight Ecoregion (300 m buffer from shore)
	Upper Shelf	-	Sofala Bight Upper Shelf	Upper Shelf waters in the Sofala Bight Ecoregion (0-40 m depth)

APPENDIX 2. **IUCN SPECIES USED IN ANALYSIS**

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern.

Fish Species (threat category)

Acanthopagrus vagus (VU)
Acroteriobatus leucospilus (EN)
Aetobatus ocellatus (DD)
Aetomylaeus bovinus (CR)
Aetomylaeus nichofii (VU)
Aetomylaeus vespertilio (EN)
Alopias superciliosus (VU)
Alopias vulpinus (VU)
Bolbometopon muricatum (VU)
Carcharhinus albimarginatus (VU)
Carcharhinus amblyrhynchos (EN)
Carcharhinus brevipinna (VU)
Carcharhinus melanopterus (VU)
Carcharhinus obscurus (EN)
Carcharhinus plumbeus (VU)
Carcharias taurus (VU)
Carcharodon carcharias (VU)
Centrophorus granulosus (EN)
Centrophorus moluccensis (VU)
Centrophorus squamosus (EN)
Centrophorus uyato (EN)
Dalatias licha (VU)
Deania quadrispinosa (VU)
Echinorhinus brucus (EN)
Epinephelus albomarginatus (VU)
Epinephelus fuscoguttatus (VU)
Epinephelus polyphekadion (VU)
Halaelurus natalensis (VU)
Haploblepharus kistnasamyi (VU)
Hemipristis elongata (VU)
Himantura uarnak (VU)
Hippocampus histrix (VU)
Holohalaelurus favus (EN)
Holohalaelurus punctatus (EN)
Lamna nasus (VU)
Leucoraja wallacei (VU)
Makaira nigricans (VU)
Mobula alfredi (VU)
Mobula birostris (EN)
Mobula kuhlii (EN)
Mobula mobular (EN)
Mobula thurstoni (EN)
Myliobatis aquila (CR)
Nebrius ferrugineus (VU)
Negaprion acutidens (VU)
Odontaspis ferox (VU)
Parablennius lodosus (VU)
Paragaleus leucolomatus (VU)
Pastinachus ater (VU)
Pateobatis jenkinsii (VU)
Polysteganus praeorbitalis (VU)
Polysteganus undulosus (CR)
Pristis pristis (CR)
Pristis zijsron (CR)
Pseudoginglymostoma brevicaudatum (CR)
Rhina ancylostoma (CR)
Rhinoptera javanica (VU)
Rhizoprionodon acutus (VU)
Rhynchobatus australiae (CR)
Rhynchobatus djiddensis (CR)
Rostroraja alba (EN)
Sphyrna lewini (CR)
Sphyrna mokarran (CR)
Sphyrna zygaena (VU)
Stegostoma tigrinum (EN)
Taeniurops meyeni (VU)
Thunnus maccoyii (CR)
Thunnus obesus (VU)
Triaenodon obesus (VU)
Urogymnus asperrimus (VU)

Mammal Species (threat category)

Balaenoptera musculus (EN)
Caperea marginata (LC)
Dugong dugon (VU)
Eubalaena australis (LC)
Feresa attenuata (LC)
Lissodelphis peronii (LC)
Sousa plumbea (EN)
Tursiops aduncus (NT)

Holothuridae (threat category)

Actinopyga echinites (VU)
Holothuria fuscogilva (VU)
Holothuria lessoni (EN)
Holothuria nobilis (EN)
Holothuria scabra (EN)
Stichopus herrmanni (VU)
Thelenota ananas (EN)

APPENDIX 3. LIST OF THE MEMBERS OF THE COORDINATION GROUP THAT WAS ESTABLISHED TO SUPPORT THIS PROCESS

#	Names	Institutions
1	Alexandre Bartolomeu	DINAB- Nairobi Convetion
2	Alima Taju	WWF
3	Ana Paula Francisco	DINAB_CBD
4	Anselmo Gaspar	DINAB-CMS
5	Armindo Araman	ANAC
6	Badru Hagy	IIP
7	Bartolomeu Soto	PPF
8	Celso Montanha	IIP
9	Denise Nicolau	BIOFUND
10	Edson Jose	Rare
11	Eduardo Videira	WWF
12	Eleutério Duarte	WCS
13	Emídio Andre	IIP
14	Guilhermina Honwana	INP
15	Hadija Mussagy	ADNAP
16	Hugo Costa	WCS
17	Ivan Suege	IIP
18	Jorge Mafuca	IIP
19	Karen Allen	Conservation International
20	Manuel Mutimucuio	MTA-HAC
21	Maria Matediane	IUCN
22	Mohamed Harun	ANAC- HAC
23	Moniz Munguambe	DIPOL
24	Naseeba Sidat	WCS
25	Nazario Bangalane	INP
26	Pablo Shapira	African Parks
27	Paula Santana Afonso	IIP
28	Sidonia Muhorro	DINAB- RAMSAR
29	Shannon Murphy	Conservation International

APPENDIX 4. **VERIFICATION OF TARGET ACHIEVEMENT**

		Scenario A (7-8% of EEZ)		Scenario B (10-12% of EEZ)		Scenario C (30% of EEZ)	
Conservation Feature	Extent (km^2)	Target (km^2)	Amount selected (km^2)	Target (km^2)	Amount selected (km^2)	Target (km^2)	Amount selected (km^2)
Delagoa Canyon	91	4.55	5	8	43946	8	43946
Delagoa Coral Reefs	260	26	138	6.5	43946	6.5	43946
Delagoa Lower Shelf	3182	159.1	547	1386959.25	4645	1386959.25	4645
Delagoa Microalgal Mats	88	8.8	74	3153427.75	2604	3153427.75	2604
Delagoa Mid Shelf	5448	272.4	668	3.5	7140	3.5	7140
Delagoa Rock	82	8.2	61	2.8	7648	2.8	7648
Delagoa Rubble	119	11.9	87	8.4	18924	8.4	18924
Delagoa Seagrass	891	89.1	767	11.9	12221	11.9	12221
Delagoa Shelf Edge	15937	796.85	2012	0.7	4	0.7	4
Delagoa Shore	261	13.05	83	5972.1	23161	5972.1	23161
Delagoa Upper Shelf	7436	371.8	2203	3483.2	23161	3483.2	23161
East Africa Canyon	254	12.7	173	12055.75	28	12055.75	28
East Africa Coral Reefs	1298	129.8	703	3628.5	21176	3628.5	21176
East Africa Lower Shelf	684	34.2	207	883	13051	883	13051
East Africa Microalgal Mats	39	3.9	21	885.25	22964	885.25	22964
East Africa Mid Shelf	1062	53.1	357	28245.25	8656	28245.25	8656
East Africa Rock	379	37.9	210	154.25	19405	154.25	19405
East Africa Rubble	73	7.3	37	8824.7	12887	8824.7	12887
East Africa Seagrass	778	77.8	365	16012.05	44264	16012.05	44264
East Africa Shelf Edge	3613	180.65	958	3785.95	44752	3785.95	44752
East Africa Shore	137	6.85	61	3589.45	17493	3589.45	17493
East Africa Upper Shelf	3360	168	2024	3350.55	43917	3350.55	43917
Mozambique Channel Abyss	22794	455.88	1415	15124.5	40541	15124.5	40541
Mozambique Channel Canyon	16429	821.45	822	16034.35	10050	16034.35	10050
Mozambique Channel Coral Reefs	153	15.3	153	12272.45	16629	12272.45	16629
Mozambique Channel Lower Shelf	16	0.8	1	28245.5	25983	28245.5	25983
Mozambique Channel Lower Slope	277893	5557.86	14301	4772.6	43926	4772.6	43926
Mozambique Channel Mid Shelf	18	0.9	1	1925.6	54767	1925.6	54767
Mozambique Channel Mid Slope	90607	1812.14	4750	4357.6	13590	4357.6	13590
Mozambique Channel Seamount	5197	259.85	1267	2025.95	34258	2025.95	34258
Mozambique Channel Shelf Edge	136	6.8	15	17723.55	44872	17723.55	44872
Mozambique Channel Upper Shelf	5	0.25	1	15.8	55584	15.8	55584
Mozambique Channel Upper Slope	49435	988.7	2547	1994.45	6698	1994.45	6698
Sofala Bight Canyon	345	17.25	18	2936.3	15134	2936.3	15134
Sofala Bight Coral Reefs	514	51.4	410	7000.65	55825	7000.65	55825
Sofala Bight Lower Shelf	1684	84.2	116	7034.95	42498	7034.95	42498
Sofala Bight Microalgal Mats	1	0.1	1	1073.5	23103	1073.5	23103
Sofala Bight Mid Shelf	12303	615.15	617	0.45	25963	0.45	25963
Sofala Bight Rock	17	1.7	14	12053.8	43933	12053.8	43933
Sofala Bight Rubble	27	2.7	23	12055.75	20623	12055.75	20623
Sofala Bight Seagrass	180	18	152	12053.8	43844	12053.8	43844
Sofala Bight Shelf Edge	4703	235.15	444	1872.95	43933	1872.95	43933
Sofala Bight Shore	770	38.5	214	807.1	728	807.1	728
Sofala Bight Upper Shelf	36899	1844.95	7149	4.25	39	4.25	39
Delagao Estuary	135	13.5	18	1023.3	45	1023.3	45
East Africa Estuary	403	40.3	121	10050.8	39	10050.8	39
Sofala Bight Estuary	1361	136.1	367	28245.5	16	28245.5	16

		Scenario A (7-8% of EEZ)		Scenario B (10-12% of EEZ)		Scenario C (30% of EEZ)	
Conservation Feature	Extent (km²)	Target (km²)	Amount selected (km²)	Target (km²)	Amount selected (km²)	Target (km²)	Amount selected (km²)
Aggregation Site Tofo	19	0.95	19	5.7	19	9.5	19
Aggregation Site Inhambane	74	3.7	70	22.2	70	37	70
Aggregation Site Sofala	19360	968	968	5808	5808	9680	9680
Community Fishing Area Baixo Pinda	141	21.15	98	70.5	99	112.8	113
Community Fishing Area Farol	97	14.55	15	48.5	49	77.6	78
Community Fishing Area Fequete	21	3.15	20	10.5	20	16.8	20
Community Fishing Area Machangulo	69	10.35	60	34.5	60	55.2	69
Community Fishing Area Memba Sede	181	27.15	28	90.5	91	144.8	145
Community Fishing Area Mucocuene	29	4.35	27	14.5	27	23.2	27
Community Fishing Area Nhagondzo	45	6.75	45	22.5	45	36	45
Community Fishing Area Petane	10	1.5	10	5	10	8	10
Community Fishing Area Pomene	103	15.45	16	51.5	52	82.4	83
Community Fishing Area Sengo	72	10.8	11	36	36	57.6	58
Community Fishing Area Serrissa	108	16.2	17	54	54	86.4	87
Community Fishing Area Simuco	190	28.5	29	95	95	152	152
Community Fishing Area Tsondzo	111	16.65	110	55.5	110	88.8	111
Community Fishing Area Vuca	82	12.3	82	41	82	65.6	82
Community Fishing Area Zavora	108	16.2	17	54	54	86.4	87
Community Fishing Area Seongo and Farol	169	25.35	26	84.5	85	135.2	136
Community Fishing Area Ihla de Mocambique	167	25.05	26	83.5	84	133.6	134
Community Reserve Serissa	19	2.85	3	9.5	10	15.2	17
Community Reserve Baixo Pinda	31	4.65	14	15.5	16	24.8	25
Community Reserve Fequete	6	0.9	6	3	6	4.8	6
Community Reserve Machangulo	19	2.85	19	9.5	19	15.2	19
Community Reserve Memba sede	4	0.6	1	2	2	3.2	4
Community Reserve Muco Tsindzo	9	1.35	9	4.5	9	7.2	9
Community Reserve Pomene	5	0.75	1	2.5	3	4	4
Community Reserve Sengo Farol	34	5.1	6	17	27	27.2	34
Community Reserve Simuco	36	5.4	6	18	18	28.8	29
Community Reserve Vuca Petane	19	2.85	19	9.5	19	15.2	19
Community Reserve Zavora	16	2.4	3	8	8	12.8	13
Community Reserve Ihla de Mocambique	13	1.95	2	6.5	7	10.4	11
Leatherback Turtle Distribution	27739185	1386959.25	2182872	1386959.25	3821546	3467398.125	9103133
Loggerhead Turtle Distribution	63068555	3153427.75	10734108	3153427.75	13285499	7883569.375	26133685
Green Turtle Nesting Sites	5	2.5	4	3.5	4	4.5	5
Hawksbill Turtle Nesting Sites	4	2	3	2.8	3	3.6	4
Leatherback Turtle Nesting Sites	12	6	7	8.4	9	10.8	12
Loggerhead Turtle Nesting Sites	17	8.5	10	11.9	12	15.3	16
Olive Ridley Turtle Nesting Sites	1	0.5	1	0.7	1	0.9	1
Acanthopagrus vagus range map (IUCN)	119442	5972.1	11415	5972.1	17451	17916.3	39404
Acroteriobatus leucospilus range map (IUCN)	69664	3483.2	16950	3483.2	22257	10449.6	31409
Aetobatus ocellatus range map (IUCN)	241115	12055.75	35684	12055.75	43926	36167.25	81905
Aetomylaeus bovinus range map (IUCN)	72570	3628.5	16073	3628.5	21324	10885.5	31508
Aetomylaeus nichofii range map (IUCN)	17660	883	883	883	1048	2649	5689
Aetomylaeus vespertilio range map (IUCN)	17705	885.25	886	885.25	953	2655.75	4953
Alopias superciliosus range map (IUCN)	564905	28245.25	46026	28245.25	56139	84735.75	184403
Alopias vulpinus range map (IUCN)	3085	154.25	1680	154.25	1688	462.75	2470
Bolbometopon muricatum range map (IUCN)	176494	8824.7	30006	8824.7	37721	26474.1	61328
Carcharhinus albimarginatus range map (IUCN)	320241	16012.05	35979	16012.05	44264	48036.15	88635

		Scenario A (7-8% of EEZ)		Scenario B (10-12% of EEZ)		Scenario C (30% of EEZ)	
Conservation Feature	**Extent (km²)**	**Target (km²)**	**Amount selected (km²)**	**Target (km²)**	**Amount selected (km²)**	**Target (km²)**	**Amount selected (km²)**
Carcharhinus amblyrhynchos range map (IUCN)	75719	3785.95	17839	3785.95	23182	11357.85	33353
Carcharhinus brevipinna range map (IUCN)	71789	3589.45	13232	3589.45	18671	10768.35	29269
Carcharhinus melanopterus range map (IUCN)	67011	3350.55	16178	3350.55	21367	10051.65	30095
Carcharhinus obscurus range map (IUCN)	302490	15124.5	17201	15124.5	23700	45373.5	84282
Carcharhinus plumbeus range map (IUCN)	320687	16034.35	35979	16034.35	44264	48103.05	88736
Carcharias taurus range map (IUCN)	245449	12272.45	35675	12272.45	43946	36817.35	82664
Carcharodon carcharias range map (IUCN)	564910	28245.5	46028	28245.5	56141	84736.5	184407
Centrophorus granulosus range map (IUCN)	95452	4772.6	4868	4772.6	4842	14317.8	28784
Centrophorus moluccensis range map (IUCN)	38512	1925.6	2023	1925.6	2319	5776.8	12601
Centrophorus squamosus range map (IUCN)	87152	4357.6	11485	4357.6	11046	13072.8	40600
Centrophorus uyato range map (IUCN)	40519	2025.95	3384	2025.95	3875	6077.85	15063
Dalatias licha range map (IUCN)	354471	17723.55	19692	17723.55	27592	53170.65	110816
Deania quadrispinosa range map (IUCN)	316	15.8	16	15.8	16	47.4	265
Echinorhinus brucus range map (IUCN)	39889	1994.45	4879	1994.45	5194	5983.35	17830
Epinephelus albomarginatus range map (IUCN)	58726	2936.3	5640	2936.3	6151	8808.9	20623
Epinephelus fuscoguttatus range map (IUCN)	140013	7000.65	25070	7000.65	30667	21001.95	51840
Epinephelus polyphekadion range map (IUCN)	140699	7034.95	25081	7034.95	30834	21104.85	52085
Halaelurus natalensis range map (IUCN)	21470	1073.5	4397	1073.5	4702	3220.5	9097
Haploblepharus kistnasamyi range map (IUCN)	9	0.45	9	0.45	9	1.35	9
Hemipristis elongata range map (IUCN)	241076	12053.8	35675	12053.8	43917	36161.4	81892
Himantura uarnak range map (IUCN)	241115	12055.75	35684	12055.75	43926	36167.25	81905
Hippocampus histrix range map (IUCN)	241076	12053.8	35675	12053.8	43917	36161.4	81892
Holohalaelurus favus range map (IUCN)	37459	1872.95	2096	1872.95	2308	5618.85	13072
Holohalaelurus punctatus range map (IUCN)	16142	807.1	1074	807.1	1433	2421.3	4160
Lamna nasus range map (IUCN)	85	4.25	84	4.25	84	12.75	85
Leucoraja wallacei range map (IUCN)	20466	1023.3	2897	1023.3	3122	3069.9	7078
Makaira nigricans range map (IUCN)	201016	10050.8	10051	10050.8	11011	30152.4	88267
Mobula alfredi range map (IUCN)	564910	28245.5	46028	28245.5	56141	84736.5	184407
Mobula birostris range map (IUCN)	564910	28245.5	46028	28245.5	56141	84736.5	184407
Mobula kuhlii range map (IUCN)	212466	10623.3	14228	10623.3	17457	31869.9	64911
Mobula mobular range map (IUCN)	564910	28245.5	46028	28245.5	56141	84736.5	184407
Mobula thurstoni range map (IUCN)	564910	28245.5	46028	28245.5	56141	84736.5	184407
Myliobatis aquila range map (IUCN)	114983	5749.15	20382	5749.15	26722	17247.45	45652
Nebrius ferrugineus range map (IUCN)	246057	12302.85	35675	12302.85	43946	36908.55	82664
Negaprion acutidens range map (IUCN)	246057	12302.85	35675	12302.85	43946	36908.55	82664
Odontaspis ferox range map (IUCN)	24026	1201.3	4450	1201.3	4645	3603.9	12467
Parablennius lodosus range map (IUCN)	16396	819.8	2412	819.8	2604	2459.4	7739
Paragaleus leucolomatus range map (IUCN)	19004	950.2	4017	950.2	7140	2850.6	10016
Pastinachus ater range map (IUCN)	11510	575.5	7375	575.5	7648	1726.5	8033
Pateobatis jenkinsii range map (IUCN)	142820	7141	12874	7141	18924	21423	42377
Polysteganus praeorbitalis range map (IUCN)	93707	4685.35	10580	4685.35	12221	14056.05	28097
Polysteganus undulosus range map (IUCN)	4	0.2	4	0.2	4	0.6	4
Pristis pristis range map (IUCN)	72761	3638.05	17599	3638.05	23161	10914.15	32348
Pristis zijsron range map (IUCN)	72761	3638.05	17599	3638.05	23161	10914.15	32348
P. brevicaudatum range map (IUCN)	560	28	28	28	28	84	84
Rhina ancylostoma range map (IUCN)	63726	3186.3	16008	3186.3	21176	9558.9	28720
Rhinoptera javanica range map (IUCN)	47869	2393.45	9504	2393.45	13051	7180.35	21467
Rhizoprionodon acutus range map (IUCN)	80457	4022.85	17395	4022.85	22964	12068.55	34935
Rhynchobatus australiae range map (IUCN)	12477	623.85	8382	623.85	8656	1871.55	9008

		Scenario A (7-8% of EEZ)		Scenario B (10-12% of EEZ)		Scenario C (30% of EEZ)	
Conservation Feature	Extent (km^2)	Target (km^2)	Amount selected (km^2)	Target (km^2)	Amount selected (km^2)	Target (km^2)	Amount selected (km^2)
Rhynchobatus djiddensis range map (IUCN)	60560	3028	14362	3028	19405	9084	26829
Rostroraja alba range map (IUCN)	96746	4837.3	10595	4837.3	12887	14511.9	29132
Sphyrna lewini range map (IUCN)	320687	16034.35	35979	16034.35	44264	48103.05	88736
Sphyrna mokarran range map (IUCN)	453354	22667.7	36249	22667.7	44752	68003.1	127000
Sphyrna zygaena range map (IUCN)	132261	6613.05	11415	6613.05	17493	19839.15	41533
Stegostoma tigrinum range map (IUCN)	241076	12053.8	35675	12053.8	43917	36161.4	81892
Taeniurops meyeni range map (IUCN)	190067	9503.35	32565	9503.35	40541	28510.05	71388
Thunnus maccoyii range map (IUCN)	72563	3628.15	10758	3628.15	10050	10884.45	35919
Thunnus obesus range map (IUCN)	242733	12136.65	14503	12136.65	16629	36409.95	89212
Triaenodon obesus range map (IUCN)	96789	4839.45	20017	4839.45	25983	14518.35	41302
Urogymnus asperrimus range map (IUCN)	241115	12055.75	35684	12055.75	43926	36167.25	81905
Balaenoptera musculus range map (IUCN)	561539	28076.95	44796	28076.95	54767	84230.85	182682
Caperea marginata range map (IUCN)	62564	3128.2	14308	3128.2	13590	9384.6	38593
Dugong dugon range map (IUCN)	133096	6654.8	27848	6654.8	34258	19964.4	56596
Eubalaena australis range map (IUCN)	526273	26313.65	34760	26313.65	44872	78940.95	168642
Feresa attenuata range map (IUCN)	562326	28116.3	45876	28116.3	55584	84348.9	183738
Lissodelphis peronii range map (IUCN)	23724	1186.2	6736	1186.2	6698	3558.6	16861
Sousa plumbea range map (IUCN)	37368	1868.4	12709	1868.4	15134	5605.2	17738
Tursiops aduncus range map (IUCN)	556616	27830.8	45587	27830.8	55825	83492.4	181470
Actinopyga echinites range map (IUCN)	242569	12128.45	34230	12128.45	42498	36385.35	79527
Holothuria fuscogilva range map (IUCN)	87445	4372.25	20912	4372.25	23103	13116.75	35554
Holothuria lessoni range map (IUCN)	102047	5102.35	23771	5102.35	25963	15307.05	40482
Holothuria nobilis range map (IUCN)	245975	12298.75	35662	12298.75	43933	36896.25	82643
Holothuria scabra range map (IUCN)	74598	3729.9	18510	3729.9	20623	11189.7	31802
Stichopus herrmanni range map (IUCN)	244981	12249.05	35573	12249.05	43844	36747.15	81802
Thelenota ananas range map (IUCN)	245975	12298.75	35662	12298.75	43933	36896.25	82643
chlorophyll_top5pct range map (IUCN)	2425	121.25	211	727.5	728	1212.5	1213
Larval sources - Emperor	85	8.5	37	34	39	59.5	60
Larval sources - Fusilier	87	8.7	43	34.8	45	60.9	63
Larval sources - Grouper	85	8.5	37	34	39	59.5	60
Larval sources - Mud Crab	33	3.3	14	13.2	16	23.1	24
Larval sources - Parrotfish	91	9.1	46	36.4	48	63.7	66
Mangroves	20477.28	3071.59	4219.14	6143.18	6144.12	10238.64	10238.91
Polos Turisticos	19910	2986.5	15415	5973	15429	9955	15720
Zones of Touristic Interest	592	88.8	108	177.6	204	296	296
Shipwreck Ihla de Mocambique (West)	1	0.8	1	0.8	1	0.8	1
Shipwreck Nacala	336	268.8	269	268.8	269	268.8	308
Shipwreck Ihla de Mocambique (South-East)	1	0.8	1	0.8	1	0.8	1
Shipwreck Ihla de Mocambique (North)	4	3.2	4	3.2	4	3.2	4
Shipwreck Memba	219	175.2	176	175.2	176	175.2	176
Historical Ports	3	2.4	3	2.4	3	2.4	3

WCS Mozambique
A Wildlife Conservation Society Program

Saving wildlife and wild places

By discovering how to save nature, we can inspire everyone to work with us to protect wildlife in the last wild places on Earth.