MONACO EXPLORATIONS

*Reconnecting Humanity and the Sea*

BASELINE STUDY · SEPT. 2022

# INDIAN OCEAN EXPEDITION

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*Reconnecting Humanity and the Sea*

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# INTRODUCTION

Monaco Explorations is a platform supporting H.S.H. Prince Albert II of Monaco's commitment to knowledge, sustainable management, and protection of the Ocean. It brings together under the aegis of the Government, the Prince Albert II of Monaco Foundation, the Oceanographic Institute, the Scientific Centre of Monaco, and the Yacht Club of Monaco.

The objective of the Monaco Explorations initiative is to conduct international collaborative missions linking scientific research, outreach towards the public, and governmental cooperation. The four main themes that guide its action concern the protection of megafauna, the protection of corals, new exploration technologies, and the development of marine protected areas. Monaco Explorations has already visited many regions from Macaronesia to Colombia, with a passage in the Pacific. The new study areas include, in particular, the Mediterranean, Melanesia, and the Indian Ocean.

The "Indian Ocean Expedition" is the first phase of the "Monaco Explorations" project endorsed as a contribution to the United Nations Decade of Ocean Science for Sustainable Development 2021-2030.

The Expedition will cover the area between Reunion Island, Mauritius, and Seychelles (Figure 1) with a strong focus on the Saya de Malha Bank and have the following objectives:

- Improving the understanding of the ecosystem status and functioning of the area explored through a multidisciplinary scientific approach and advising stakeholders through a holistic scientific approach (sustainability science).
- Sharing the issues and knowledge with the greatest possible number of people through an ambitious outreach programme.
- Through diplomatic action, mobilizing governments and informing policies by making available information and analyses to support the sustainable management of maritime areas.

The Expedition is expected to benefit from extensive media coverage and should result in the production of a documentary film for international distribution and the writing of a book by a renowned author.

It is planned that the Expedition will be coordinated with an official visit to the region by HSH the Sovereign Prince. Other official activities of the Sovereign Prince related to the objectives of the Expedition, in particular, His interventions in various forums dealing with the protection of the Ocean, may enhance the policy dimension of the Expedition.

The science programme, guided by the four main themes of Monaco Explorations, focuses on meeting the needs of the Governments of Seychelles and Mauritius while also relating closely with relevant international and regional organizations and initiatives, notably the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), and the Nippon Foundation GEBCO project Seabed 2030 and the continuation of the Second International Indian Ocean Expedition (IIOE-2 – 2015-2025).

Outreach activities will be based mainly on the scientific dissemination programme "Dialogue Science-Decision Makers for Integrated Management of Coastal and Marine Environments" (DiDEM) in the Western Indian Ocean (WIO) basin (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, United Republic of Tanzania) coordinated by the French Research Institute for Development (IRD). In addition, the active collaboration will be requested from all the participating entities in order to optimize the use of the preparation, progress, contents, and results of this Expedition for pedagogic and educational purposes and, more generally, for public outreach and communication.

Initially planned for April and May 2021, the Expedition is scheduled for October and November 2022 through a charter, currently under negotiation, of the South African oceanographic vessel *S.A. Agulhas II* which would be made available from Cape Town from 1 October to 30 November 2022.

The overall coordination of the Expedition is led by the Directing Board of Monaco Explorations chaired by the Minister of State of the Principality of Monaco. The Expedition will be managed by an Executive Board composed of representatives of the main partners and chaired by the Chief Operation Officer of Monaco Explorations.

The preparation of the Expedition is guided by an International Advisory Committee which warrants that the Expedition implements a holistic approach based on a multidisciplinary programme including natural and social sciences.

In that regard, the Advisory Committee ensures that the scientific projects contributing to the Expedition are relevant, prioritised and adequately integrated. To this end, it draws not only on the elements collected during the Expedition but also on all the information available from the area, ranging from oceanographic data to historical, cultural, sociological, and economic aspects, so that the Expedition outcomes provide relevant advice for the sustainable management of the area, per the maxim of Monaco Explorations: "Reconnecting Humanity and the Sea".

The Baseline Document is a result of the above objectives. It has been drafted from existing data and information and from communications provided by the Advisory Committee members. It aims at gathering the knowledge of the Expedition area from diverse perspectives: geography, oceanography, ecology, and policy and governance. It also includes a chapter about threats to biodiversity and associated measures.

By gathering this existing knowledge, the Baseline Document provides guidance to support and prioritise the development of the research programmes to be implemented during the Expedition. It allows all parties and partners to take stock of existing knowledge and to use it as a framework for developing research as well as outreach activities.

# 1. GEOGRAPHY, GEOLOGY, OCEANOGRAPHY

## 1.1. GEOGRAPHY

### 1.1.1. INDIAN OCEAN

The Indian Ocean is the third largest of the world's oceanic divisions, covering 70,560,000 km$^2$ or 19.8% of the water on the Earth's surface[1] [2]. It is bounded by Asia to the north, Africa and the meridian of Cape Agulhas to the west, and Australia and the meridian of South East Cape (Tasmania) to the east. To the south it is bounded by the Southern Ocean or Antarctica, depending on the definition in use[3]. Along its core, the Indian Ocean has some large marginal or regional seas such as the Arabian Sea, the Laccadive Sea, the Gulf of Aden and the Red Sea, the Bay of Bengal, and the Andaman Sea.

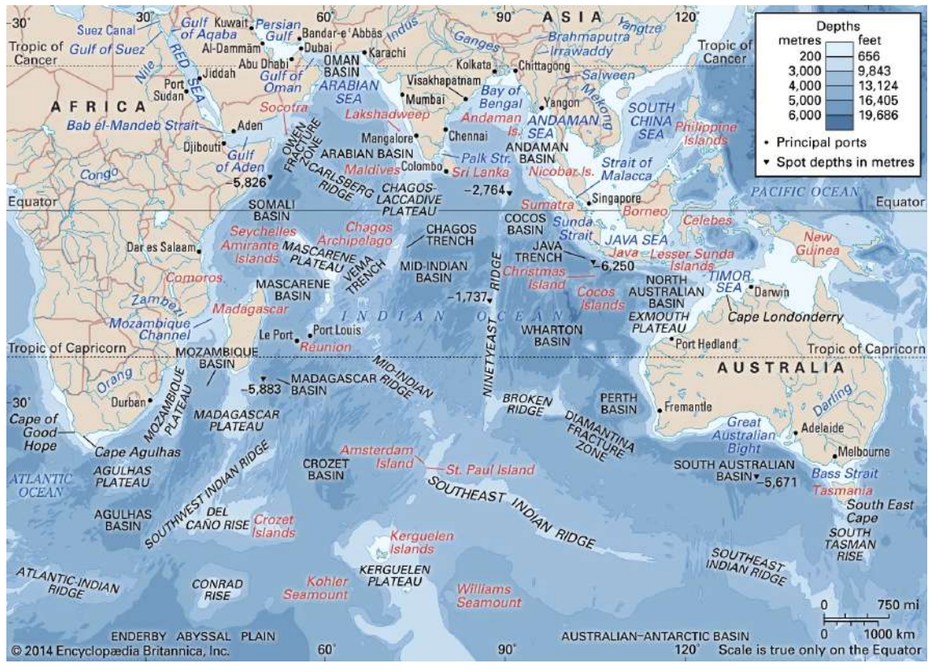


Figure 1: Map of the Indian Ocean (https://www.britannica.com/place/Indian-Ocean)

### 1.1.2. MASCARENE PLATEAU

The **Mascarene Plateau**, also known as the **Mascarene Ridge**, is a submarine plateau in the Indian Ocean, north and east of Madagascar. The plateau extends approximately 2,000 km from the North Seychelles Bank and the Ritchie Bank in the north[4], to Réunion in the south. The plateau covers an area of over 115,000 km$^2$ of shallow water, with depths ranging from 8–150 m (30–490 ft), plunging to 4,000 m to the abyssal plain at its edges[5].

The northern part of the Mascarene Plateau includes Seychelles and the Agaléga Islands. The southern part of the Mascarene Plateau includes the Mascarene Islands, Hawkins Bank, Nazareth Bank, the Saya de Malha Bank, and the Soudan Banks. The Mascarene Islands are the mountainous islands of Mauritius, Réunion, Rodrigues, and the Cargados Carajos Shoals, also known as the Cargados Carajos Bank, or Saint Brandon.

It is the most prominent bathymetric feature of the Indian Ocean and extends as a complex submerged seafloor elevation[6]. It is larger than the Great Barrier Reef, longer than the Red Sea and is one of the few submerged features clearly visible from space.

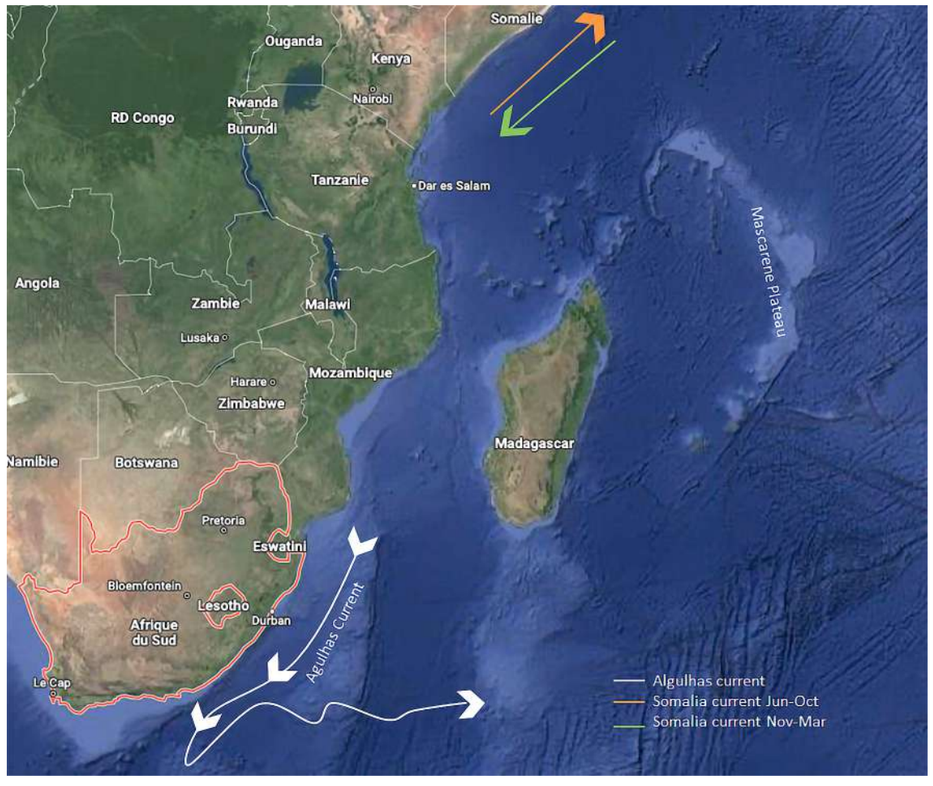


Figure 2: Map of the Western Indian Ocean region: The region covers approximately 22.3 million km$^2$ and includes three Large Marine Ecosystems – The Agulhas Current, the Somali Current and the Mascarene Plateau[6].

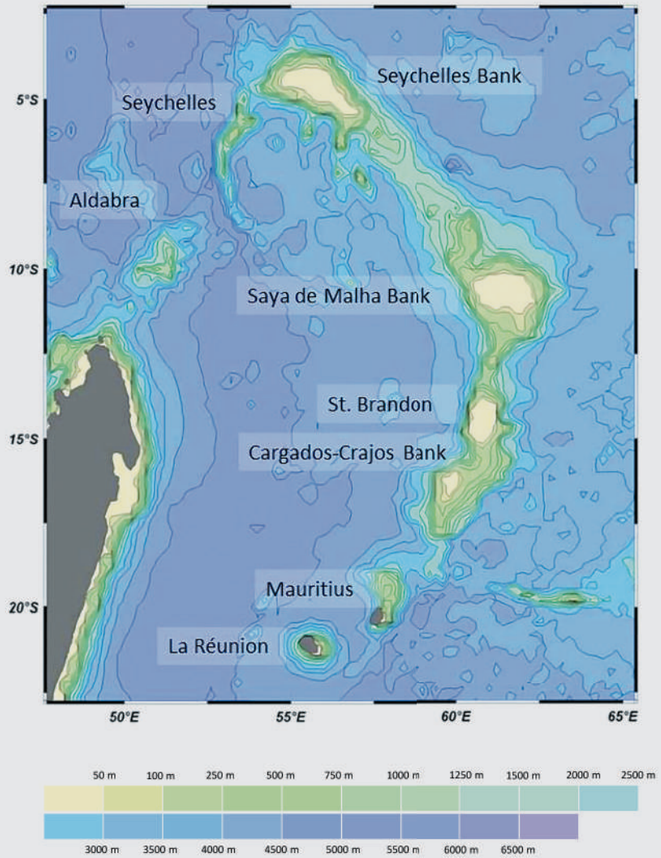


Figure 3: Map showing the location of the Mascarene Plateau. A color bar highlights isobath readings[7].
A color bar highlights isobath readings. (after: 51 ASCLME cruise report 2008 MASCARENE PLATEAUall-acc)

### 1.1.3. SAYA DE MALHA BANK

The **Saya de Malha Bank**, located between 8°30' ***- 12° S and 59°30'*** - 62°30' E, is the largest of the banks of the Mascarene Plateau[8 9 10] with an area of approximately 40,000 km$^2$.

It lies northeast of Madagascar, southeast of Seychelles, and north of Nazareth Bank, the Cargados Carajos Shoals (Saint Brandon), and the island of Mauritius. The closest land is the tiny island of Agaléga (one of the Outer Islands of Mauritius), some 300 km (190 mi) further west, followed by the southern Seychellois island of Coëtivy, some 400 km (250 mi) to the northwest[11].

The bank covers an area of 40,808 km$^2$ (15,756 sq mi) and is composed of two separate structures, the smaller **North Bank** (also called Ritchie Bank), and the huge **South Bank**.

It consists of a series of narrow shoals, with depths from 17 to 29 m (56 to 95 ft) on the rim. They are arranged in a semi-circular manner, around the former lagoon, about 73 m (240 ft) deep, which slopes on the southeast. Some areas of the bank are shallow, less than 10 m (33 ft) below the surface. The shallowest sites known are Poydenot Shoal[12], at a depth of 8 m (26 ft), and an unnamed site 145 km (90 mi) further northwest, with a depth of 7 m (23 ft).

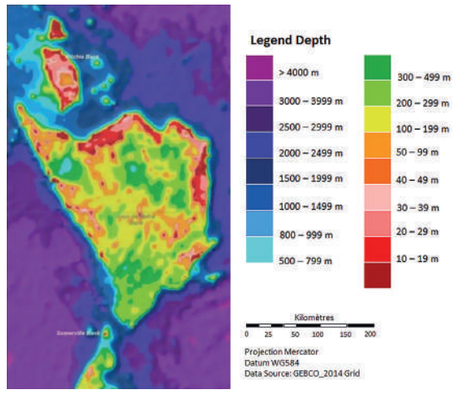


Figure 4a: Map of Saya de Malha Bank with bathymetry (from MSP R oad Map-GEBCO)

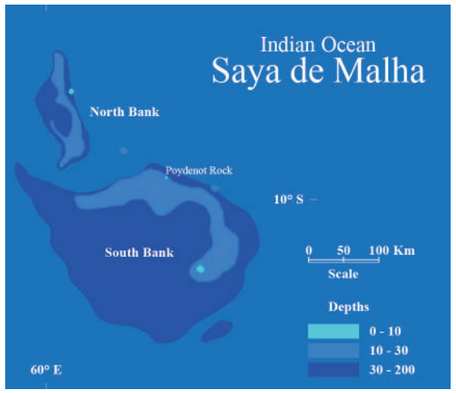


Figure 4b: Map of the Saya de Malha Bank (Vorsepneva)

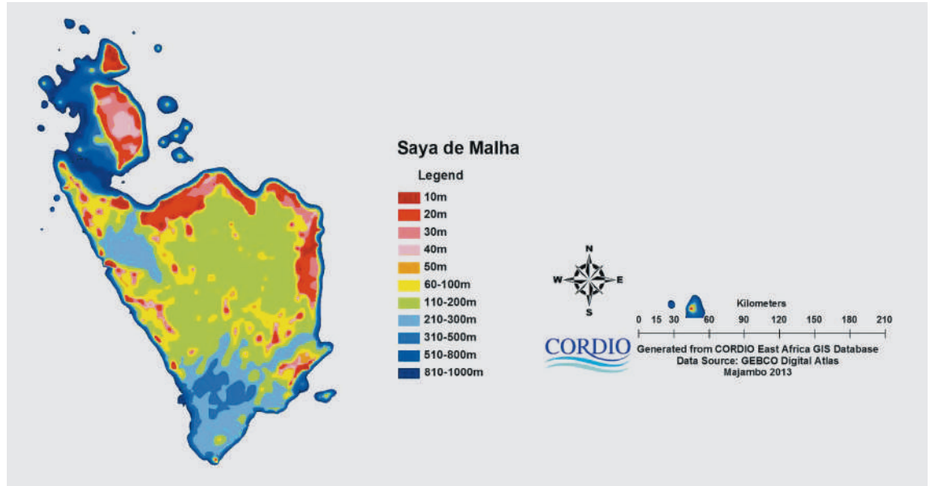


Figure 4c: Map of the Saya de Malha Bank (CORDIO)

### 1.1.4. AMIRANTE ISLANDS

The **Amirante Islands** (*Les Amirantes*) are a group of coral islands and atolls that belong to the Outer Islands of Seychelles.

They stretch about 155 km from the African Banks (African Islands) in the north to Desnœufs (Isle des Noeufs) in the south, all on the shallow Amirante

Bank (Amirante Plateau, with depths of mostly 25 to 70 m), except the main island Île Desroches in the east, and submerged Lady Denison-Pender Shoal at the northern end. Ninety kilometres south of the Amirante Islands is the Alphonse Group, the closest group of islands, which are sometimes considered part of the Amirantes.

There are 13 coral islands in the Farquhar Group, south-southwest of the Amirante Islands: Farquhar Atoll (comprising ten islands–Bancs de Sable, Déposés, Île aux Goëlettes, Lapins, Île du Milieu, North Manaha, South Manaha, Middle Manaha, North Island and South Island), Providence Atoll (comprising two islands–Providence and Bancs Providence) and St Pierre[13].

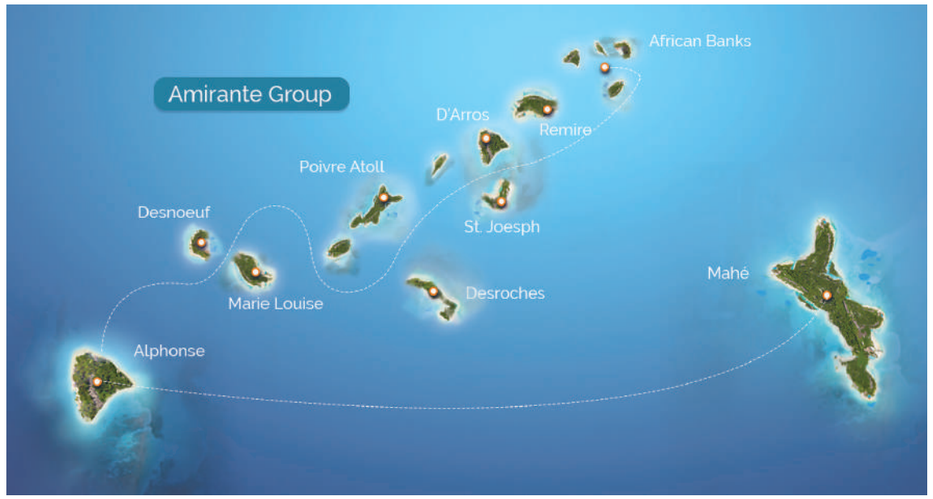


Figure 5: Map of the Amirante Islands

## 1.1.5. ALDABRA

The **Aldabra Group** is part of the Outer Islands of Seychelles, lying in the southwest of the island nation, 1,000 km (620 mi) from the capital, Victoria, on Mahé Island[14].

- **Aldabra Atoll** (a raised atoll with four main islands and some 40 small islets).
- Assumption Island (a single island on a raised reef).
- Cosmoledo Atoll (a raised atoll with two main and about 18 smaller islets).
- Astove Island (a raised atoll with just one island).

**Aldabra** is the world's second-largest coral atoll[15].


Figure 6: Map of the Outer Islands of Seychelles (Wikipedia)



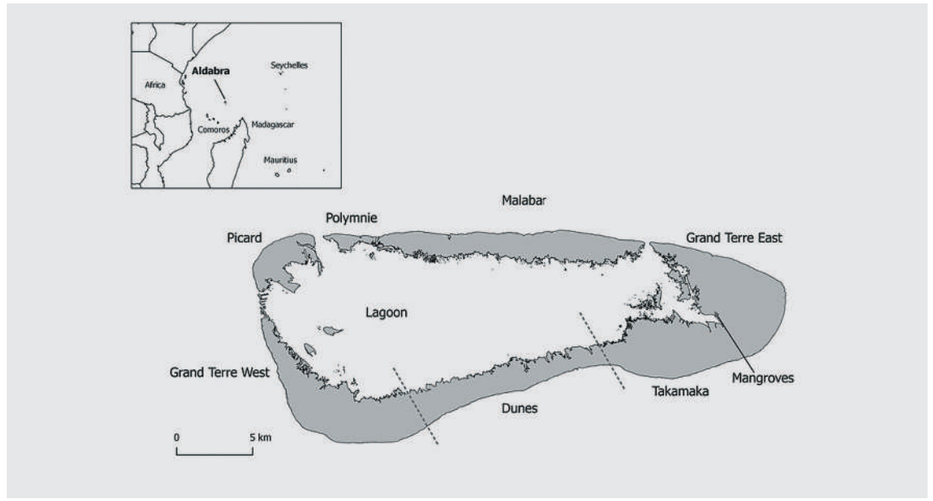


Figure 7: Map of Aldabra

## 1.1.6. SAINT BRANDON

Saint Brandon, also known as the **Cargados Carajos Shoals**, is an Indian Ocean archipelago about 430 km (270 mi) northeast of Mauritius, consisting of a number of sand banks, shoals, and islets. Saint Brandon consists of five island groups, with about 28-40 islands and islets in total, depending on seasonal storms and related sand movements. There are 22 named islands and shoals. It has an aggregate land area estimated variously at 1.3 km$^2$ (0.50 mi2) and 500 acres (2.0 km$^2$). The very extensive shallow bank covers approximately 900 mi2 (2,300 km$^2$) around the islands[16].

The reef measures more than 50 km (31 mi) from north to south, and is 5 km (3.1 mi) wide, cut by three passes. The reef area is 190 km$^2$ (73 mi2).

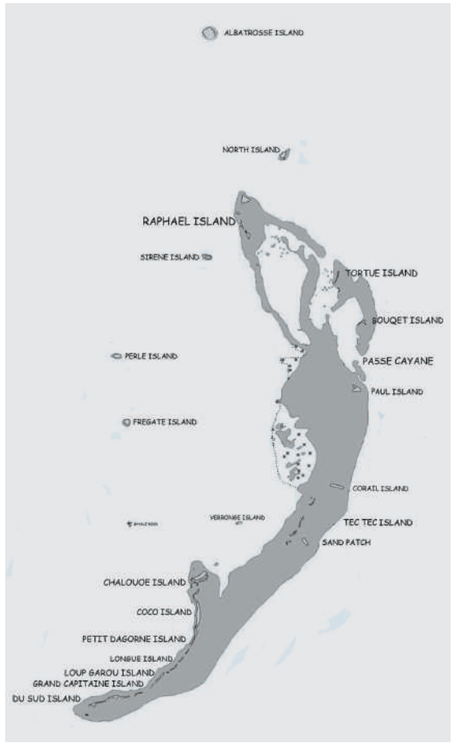


Figure 8: Map of Saint Brandon

# 1.2. GEOLOGY

## 1.2.1. INDIAN OCEAN

The WIO is one of the most geologically diverse ocean basins and contains every type of tectonic plate boundary, both active and fossil, some of the deepest fracture zones, the most complex mid-ocean ridge configurations, and some of the thickest sedimentary sequences. The continental land mass of Africa, the micro-continent Madagascar, and the North Seychelles Bank, are remnants of the supercontinent Gondwana, dating from pre-Cambrian times, over 650 million years ago (mya), which started to break up 180 mya[4],when the land mass containing future Madagascar, Australia, India and Antarctica split from the African coast. From 120 mya Australia started to separate from Madagascar-India, and from 80 mya, India began to separate from Madagascar and move northwards. From about 70-50 mya the Indian Plate exhibited among the highest recorded speeds, up to 16 cm/year, potentially as a result of superplume activity of the Réunion hotspot[4].

The ocean floor is currently composed of three major plates, the African, Indian and Australian plates, as well as the Arabian plate in the north. Currently the Indian and Australian plates are rifting away from the African plate, but with apparently little motion relative to one another. The Arabian plate is rifting from the African plate, forming the Red Sea, which started in the Eocene and accelerated during the Oligocene[4]. These spreading ridges meet at the Rodrigues Triple Point with the Central Indian Ocean Ridge, including the Carlsberg Ridge, separating the African Plate from the Indian Plate; the Southwest Indian Ridge separating the African Plate from the Antarctic Plate; and the Southeast Indian Ridge separating the Australian Plate from the Antarctic Plate.

There are only two trenches in the Indian Ocean: the 6,000 km (3,700 mi) - long Java Trench between Java and the Sunda Islands and the 900 km (560 mi) - long Makran Trench south of Iran and Pakistan[17].

A series of ridges and seamount chains produced by hotspots pass over the Indian Ocean. The Réunion hotspot (active 70–40 mya) connects Réunion and the Mascarene Plateau to the Chagos-Laccadive Ridge and the Deccan Traps in North-western India; the Kerguelen hotspot (100–35 mya) connects the Kerguelen Islands and Kerguelen Plateau to the Ninety East Ridge and the Rajmahal Traps in North-eastern India; the Marion hotspot (100–70 mya) possibly connects the Prince Edward Islands to the Eighty-Five East Ridge[18]. These hotspot tracks have been broken by the still active spreading ridges mentioned above[21].

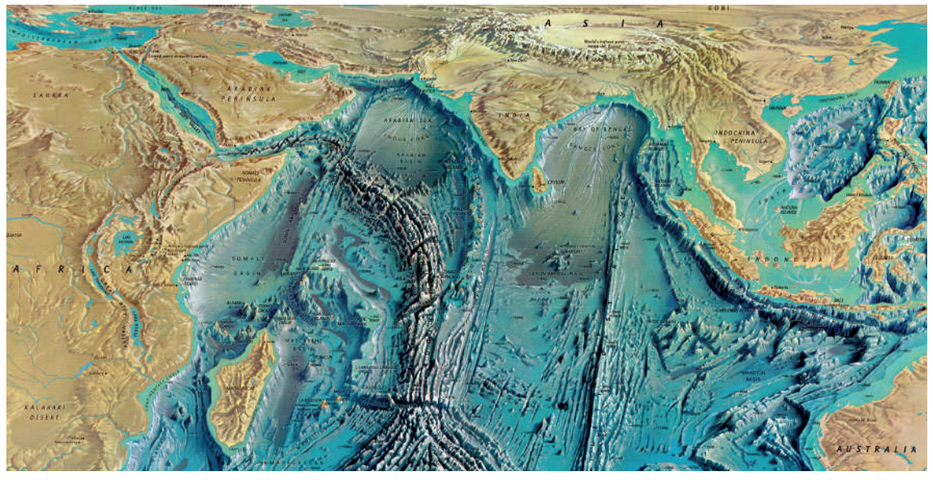


Figure 9: Indian Ocean Seafloor (see also Figure 1 Map of the Indian Ocean)

There are fewer seamounts in the Indian Ocean than in the Atlantic and Pacific Oceans. These are typically deeper than 3,000 m (9,800 ft) and located north of 55°S and west of 80°E. Most originated at spreading ridges but some are now located in basins far away from these ridges. The ridges of the Indian Ocean form ranges of seamounts, sometimes very long. The Agulhas Plateau and **Mascarene Plateau** are the two major shallow areas[19].

**Hotspots and magmatic provinces** – the WIO contains a number of these, including the Mascarene-Réunion hotspot, the Comoros hotspot and the remnants of massive magmatic extrusions including features in India (Deccan Traps), Madagascar and the underwater plateau extending southwards (Cretaceous activity) and others[4].

**Mascarene-Réunion hotspot** – at the Cretaceous-Tertiary (K-T) boundary, about 67-64 mya, a massive eruption of magma that formed the Deccan Traps in India (classified as a Large Igneous Province, or LIP) occurred as India was already moving away from Madagascar and is implicated in the stranding of part of the Indian continent as part of the northern Seychelles bank in the middle of the ocean. The 'superplume event' that produced the Deccan Traps may have played a role in the last of five mass extinctions that have occurred in the Earth's history, at the K-T boundary, in which all the dinosaurs and up to 30 % of genera of many marine taxa (including corals), went extinct.

Following this, the Mascarene-Réunion hotspot remained active, and combined with the rapid tectonic movements of India, has produced a unique mid-ocean feature – the volcanic islands and carbonate-topped banks of the western and central Indian Ocean, the Mascarene Plateau.

Starting with the Lakshadweep – Maldives chains (57-60 mya), the series of banks and islands strung southwards down the Indian Ocean include: the Chagos archipelago (48 mya), Saya de Malha (45 mya), Nazareth and Cargados Carajos Banks (34 mya), Mauritius (7-8 mya) and finally, Réunion (0-2 mya), which is still volcanically active today. Two complications add further interest to this system: the North Seychelles Bank and its granitic islands are remnants of continental rock, stranded in mid-ocean as India passed over the spreading ridge 65 mya. Second, the spreading ridge itself moved over the hotspot about 45 mya, splitting the Chagos and Saya de Malha Banks, and forming a kink in the otherwise continuous chain from India to Réunion. These islands and banks form a classic example of the progression from volcanic high islands to sunken coralline banks, from Réunion to India, charting the span of the entire Cenozoic era[4].

**Seychelles-Mascarene activity** – A complex geological history is also suggested by the multiple islands and groups in Seychelles, such as the Aldabra group, Farquhar/ Providence and the Amirantes. The island of Rodrigues is associated with the Soudan Bank that stretches between it and Mauritius, and is a result of the complex fractures extending at right angles from the Central Indian Ocean ridge. Capping these diverse geological island/bank features, are a diverse array of shallow-water carbonate producing systems, from classic island-arc subduction series of fringing – barrier – atoll – submerged reefs (Mascarene Plateau and Comoros-Glorieuses islands) to isolated carbonate islands (Farquhar, Amirantes).

**Ocean basins** – the Indian Ocean spreading ridge rises to just under 2,000 m depth, isolating the WIO from deep waters to the east. The four deep basins in the WIO include the Madagascar (5,500 m, southeast of Madagascar), Mascarene (4,900 m, west of the Mascarene Plateau), Mozambique (5,000 m, south of the Mozambique Channel) and Somali basins (5,100 m, between Somalia and Seychelles). Little has been done on the abyssal plains and soft sediments of these basins, though drilling on and near the Mascarene Plateau shows thick accumulations of marine sediments, and of terrestrial sediments in the Mozambique Channel[4].

## 1.2.2. MASCARENE PLATEAU

Although it superficially appears as a single structure the Mascarene Plateau comprises elements of very different geological origins and ages[10]. The Seychelles Plateau comprises pre-Cambrian granite about 650 ***mya*** old and Seychelles islands, one of only two sets of granitic islands in the world which are a continental fragment left over from the break-up and drift of Gondwana[10]. The Saya de Malha Bank lies at an inflexion in the Mascarene Ridge where it is crossed by a transform fault extending to the Central Indian Ridge. This means that the geological origin of the northern and southern elements of the Saya de Malha Bank may be different. The Ocean Drilling Programme has drilled three boreholes around the Saya de Malha Bank (Sites 705, 706 and 707). It concluded that the basalts that form the basement layer of the bank are of the same origin as the Deccan Traps in India which formed during the rupture of India and Africa about 64-69 mya. Back tracking suggests that the Chagos Archipelago and the Saya de Malha Bank were originally a single feature but were divided and drifted apart because of the formation of the Central Indian Ridge[8 20].

The bank was formed 35 mya by the Réunion hotspot and is composed of basaltic basal rock overlain with limestone. The limestone banks found on the plateau are the remnants of coral reefs. Millions of years ago, the bank was one or more mountainous volcanic islands, like present-day Mauritius and Réunion, which subsequently sank below the waves. Some of the banks may have been low islands as recently as 18,000-6,000 years ago, when sea levels were up to 130 m (430 ft) lower during the most recent ice age[21].

Many of the other islands in the Indian Ocean, such as the Maldives, Lakshadweep and Chagos archipelagos are atolls. These form as coral reefs grow around the edges of subsiding submarine volcanoes typically forming a bowl-like morphology. However, the Saya de Malha Bank forms a large area of flat horizontal terrain. This is found on some seamounts (e.g., Atlantis Bank, Southwest Indian Ridge) where features were once islands and as they subsided became wave cut. In such cases, erosional features and fossilised beaches etc. are generally found, consistent with geological history. Such features are not evident (so far?) on the Saya de Malha Bank and topographic rings associated with coral reef formation have also not been seen to date. Instead, the carbonate accumulation which lies atop the basalt that forms the feature appears to have been built up mainly by calcareous red algae, not coral as suggested in older literature[22], which tends to grow in waters too deep, too cold or too nutrient rich for corals. Rhodoliths, spherical concretions formed by calcareous red algae, are a common feature of Saya de Malha Bank and other locations globally which are tropical or sub-tropical but less favourable for coral growth (e.g., deeper reef areas off Bermuda; Tuvalu in the SW Pacific; seamounts off Brazil)[10].



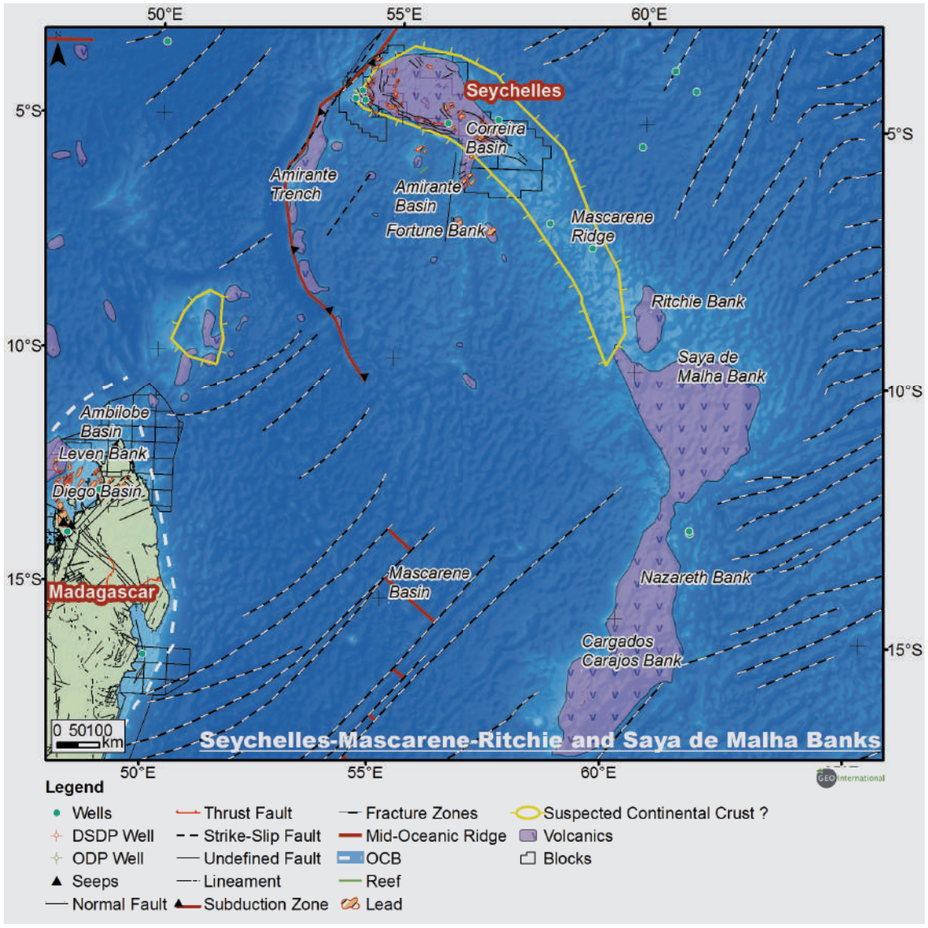


Figure 10: Geology of the Mascarene Plateau

The smaller northern bank, the Ritchie Bank, is separated from the main bank by a transform fault and is part of the granitic continental rocks of the Seychelles bank and the ridge extending between them in a northwest - southeast direction. South of the Saya de Malha Bank, the Nazareth and Cargados Carajos Banks are of similar construction, but younger, and only Saint Brandon, at the southern end of the Cargados Carajos Bank, has any aerially exposed landmass[4 9].

Rhodoliths are also often associated with areas subject to strong currents that prevent the accumulation of sand or fine sediments. Hilbertz et al. (2002)[10] drilled a shallow borehole in the surface of the bank using scuba divers and found it to be composed of layers of calcium carbonate formed by calcareous algae. These findings[10], however, are at odds with the description of the Saya de Malha Bank from Russian observations which describe it as an atoll, with the rims hosting corals and the lagoon dropping to a maximum depth of 70 m in the north and 140 m in the south. Two depressions on the bank are reported, one in the south at 980 m depth and the other in the north at 455 m depth. The slope to the east is reported as very steep

with cavernous reef limestone from 20-120 m and rhythmically foliated limestone from 200-400 m depth. The south slope of the bank is reported to be formed of several narrow shoals and then a steep drop to 300 m depth. Thickly foliated limestone gives way to thinly foliated limestone at 800-1,650 m depth although it is unclear what this means. The west slope of the bank is described as steep and concave with an angle of 16o in the upper part. The Nazareth Bank lies 20 km to the south with a depth of 1,100 m between it and the Saya de Malha Bank. This is covered in silt up to 700 m thick and formed by lime silt in the upper layers and chalk with silica intrusions at greater depths below the sea floor[9 10 23].

### 1.2.3. ALDABRA[24]

© Martin van Rooyen

The atoll reflects both fossil and geomorphological features; the former is the source of the biodiversity seen today[25]. The atoll is made of reef limestone of Pleistocene age (with irregular coral formations called "champignon", made up of two layers of varying stages of crystallization[26] and this extends over an average width of 2 km (1.2 mi) rising to a height of 8 m (26 ft) above sea level, and forming the rim line (low cliffs with "deep notches, preceded by jagged pinnacles") of the shallow central lagoon. Geologically the limestone beds have been subjected to striation, sink holes and pits with a prominent and continuous limestone bed on the eastern side above the sediment deposits. The coastline has undercut limestone cliffs above a perched beach; it is in two clear terraces of 8 m (26 ft) and 6 m (20 ft) height above sea level. Sand dunes dominate the windward south coast. While the terrestrial topography (spread over an elevation range of 0-8 m (0-26 ft)) is rugged and dictated by the geomorphic conditions, the land surface comprises limestone of about 125,000-year age, which has uplifted many times above the sea level. The surface conditions are criss-crossed and riddled with potholes and pits. In the eastern zone of the lagoon, though the surface is continuous, sediment beds are also seen. The windward southern coast is made up of sand dunes[16].



## 1.3. OCEANOGRAPHY AND CURRENTS

### 1.3.1. PALEO-OCEANOGRAPHY HISTORY AND CURRENTS OF THE INDIAN OCEAN

Little is known about the oceanographic history that influences the WIO, but emerging research is highlighting some key features that may have contributed to today's unique features in the WIO. Until the closure of the Tethys Sea (30- 15 mya), it is likely that ocean currents linked the Tethys and the WIO. Equatorial currents crossing the Indian Ocean from east to west were first blocked by India as it migrated northwards (65-40 mya), and then likely by the string of islands and banks produced by the Mascarene-Réunion hotspot (45-20 mya) that now form the Mascarene Plateau. Further, before the Miocene, there was very little development of the shallow marine communities that are dominant today (e.g., coral reefs) in what is now Southeast Asia. These communities began forming only at the start of the Miocene, 24 mya, when the Australian and Asian plates collided and formed the Indonesian island arc. As a result, up to 24 mya it appears that shallow marine habitats in the WIO had a primary connection with the Tethys Sea as it closed, and only after that, a primary connection with the emerging centre of diversity in the Southeast Asian region[4].

The Indian Ocean's currents are mainly controlled by the monsoon. Two large gyres, one in the northern hemisphere flowing clockwise and one south of the equator moving anticlockwise (including the Agulhas Current and Agulhas Return Current), constitute the dominant flow pattern. However, during the winter monsoon (November-February), the circulation is reversed north of 30°S and winds are weakened during winter and the transitional periods between the monsoons[27].

Deep water inflow into the Indian Ocean is 11 Sv (1 Sv=106 m3/s), most of which comes from the Circumpolar Deep Water (CDW). The CDW enters the Indian Ocean through the Crozet and Madagascar basins and crosses the Southwest Indian Ridge at 30°S. In the Mascarene Basin the CDW becomes a deep western boundary current before it is met by a re-circulated branch of itself, the North Indian Deep Water. This mixed water partly flows north into the Somali Basin whilst most of it flows clockwise in the Mascarene Basin where Rossby waves produce an oscillating flow[28].

Water circulation in the Indian Ocean is dominated by the Subtropical Anticyclonic Gyre, the eastern extension of which is blocked by the Southeast Indian Ridge and the 90°E Ridge. Madagascar and the Southwest Indian Ridge separate three cells south of Madagascar and off South Africa. North Atlantic Deep Water (NADW) reaches into the Indian Ocean south of Africa at a depth of 2,000-3,000 m (6,600-9,800 ft) and flows north along the eastern continental slope of Africa. Deeper than NADW, Antarctic Bottom Water flows from Enderby Basin to Agulhas Basin across deep channels (<4,000 m (13,000 ft)) in the Southwest Indian Ridge, from where it continues into the Mozambique Channel and Prince Edward Fracture Zone[24].

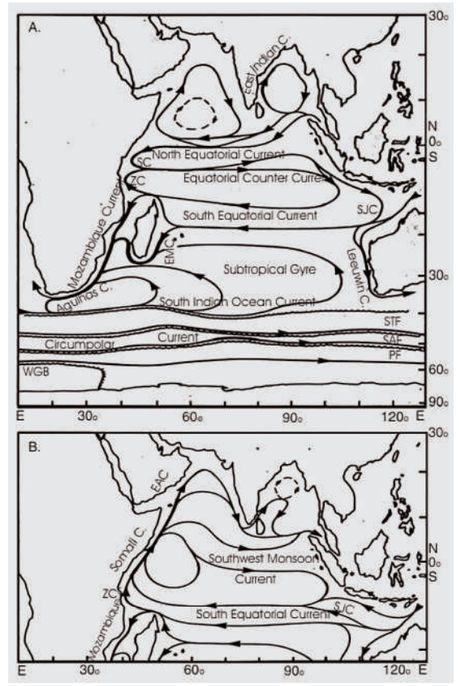


Figure 11a: Map of the Indian Ocean currents (in *The deep Indian Ocean floor* p. 22, fig 7.2, modified from Tomczak and Godfrey, 1994)

A: During the Northeast Monsoon season (March-April)
B: During the Southwest Monsoon season (September-October)

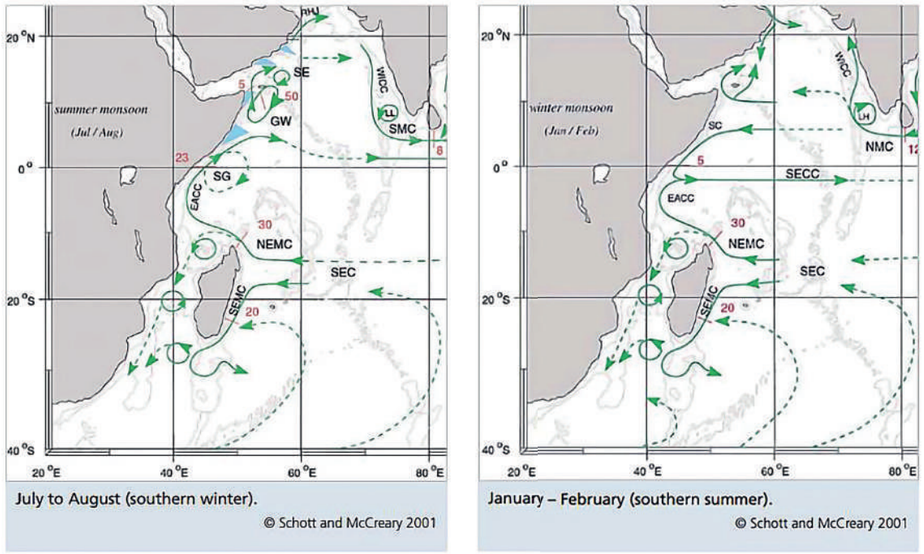


Figure 11b: Map of the Indian Ocean currents (in Obura, D.O. et al.[4] p. 38)

## 1.3.2. MASCARENE PLATEAU

The South Equatorial Current (SEC) is the major westward current in the South Indian Ocean. It crosses the Mascarene Plateau, an extensive range of banks and islands, near 60°E[29]. Upstream from the Plateau the SEC carries 50–55 Sv westwards between 10 and 16°S. As it approaches the Plateau, 25 Sv of this is constricted to pass over a narrow sill (about which we provide new information) between the Saya de Malha and Nazareth Banks at 12–13° S. This then forms a northern core to the SEC between 10 and 14°S downstream from the Plateau (25 Sv). The remainder of the inflow passes either around the northern edge of the Saya de Malha Bank (8–9°S) or between Mauritius and the Cargados Carajos Bank (18–20°S). The former may retroflect to flow eastwards near 8°S, joining the South Equatorial Counter Current (SECC), whereas the latter, strengthened near Mauritius by further flows from the south, forms a southern core to the SEC downstream from the Plateau (20–25 Sv between 17 and 20°S).

The overall effect of the Plateau is to split the SEC into two cores. On reaching Madagascar, these cores may then form the Northeast and Southeast Madagascar Currents.

The SEC also forms a sharp boundary between upper and intermediate level water masses. At deeper levels, North Indian Deep Water (NIDW) passes southwards below the SEC on the western side of the Plateau. While there is no indication of North Atlantic Deep Water, Antarctic Bottom Water (AABW) is present west of the Plateau. Finally, there is evidence of significant mixing in the upper and intermediate waters as they pass across the sill at 12–13°S, and in the deeper waters on the eastern side of the Plateau above the rough bottom topography of the Central Indian Ridge.

The propagation of the open ocean SEC over the shallow Saya de Malha and adjacent banks, and through the relatively constricted channels between the banks, is accompanied by a strong intensification of currents manifesting in all three dimensions. The approaching unidirectional SEC undergoes significant lateral and vertical disturbances associated with vertical and lateral mixing. These disturbances include lateral vortex production shed from topographic features within the SEC's pathway through the system, vertical Ekman-induced upwelling (i.e., intense eddies that lift deeper waters towards the surface), associated transport of nutrients from depth to the euphotic zone and concentration of biological matter in recirculating flows. These are classic features of topographically induced oceanic biodiversity hotspots (canyons, seamounts, ridges, etc.)[30].

Furthermore, the SEC and the biotic mass that it entrains and carries en route westward out of the Mascarene Plateau system is an important ecological delivery 'highway' for receiving environments downstream. This includes the east coast of Madagascar, and to north and south Madagascar stemming from the bifurcation latitude where the SEC splits into coastal currents known as the northward-flowing Northeast Madagascar Current and southward-flowing Southeast Madagascar Current, respectively[51].

The Southeast Madagascar Current also spawns large eddies feeding into the Agulhas Current, some of which enter the Atlantic Ocean after rounding the Cape of Good Hope and some of which retroflect towards the Southeast Indian Ocean. Recent studies suggest surface jets deriving from the retroflection are important in the East Indian Ocean in contributing inputs to the Leeuwin Current off Western Australia, which then rounds Southwest Australia as a continuing Southern Ocean boundary current towards Southeast Australia. Hence, the SEC's passage and adoption of new ecological traits over the Mascarene Plateau has not only local relevancy to the Mascarene Plateau *per se* and the Saya de Malha Bank, but also to the wider Earth system domains (e.g., Atlantic and Southern oceans)[51].

The northern portion of the Plateau is also part of the region where another specific important oceanographic phenomenon manifests, commonly referred to by oceanographers as the thermocline ridge (which is centred at around ***7°S***). Complex equatorial dynamics and winds result in this being an area where the thermocline is forced up towards the surface, resulting in relatively high sea surface temperatures (typically > 28° C) within a relatively shallow thermocline. This has profound ecological effects, as is already known, but as is becoming increasingly better understood, profound coupled influences also manifest through air-sea interactions, with associated strong influences on the weather. For example, cyclone genesis and energetics over the region are intrinsically linked to the amount of thermal energy that can be derived from the warm sea surface. Hence, the temperature characteristics of the thermocline ridge are vitally important in terms of (i) being able to characterise, and (ii) predict/model both them and their influence on climate/weather. In terms of the relevance of this, the societal impact of cyclones on the human communities of the west Indian Ocean is especially important[51].

The Saya de Malha Bank, together with the Nazareth Bank, concentrates the flow of the SEC into a narrow passage between them at 12.5-13°S. The bank thus has a major influence on the oceanography of the WIO and regions to the west. Only a small proportion of the SEC passes north of the bank as a slow, broad current, and island wakes and eddies in the lee of the bank may result in higher oceanic productivity due to mixing and upwelling[31] [4], including by internal solitary waves that propagate for several hundred kilometres in deep water[32].

New et al. (2005)[33] estimate that around 40% of the volume of water flow of the SEC is channelled between the Saya de Malha and Nazareth Banks. The remainder is diverted around the north of the Saya de Malha Bank and southwestwards, between the Cargados Carajos Bank and Mauritius[8]. There is some evidence for topographically induced upwelling on the lee side of the Mascarene Plateau, but this is highly variable and has not been consistently or conclusively established[34]. What is of particular importance to the management and monitoring in this area (in relation to the likelihood of it being a discrete Large Marine Ecosystem (LME)) is the ability of the Plateau, acting as a major topographic barrier across the SEC, to sustain its own western boundary current and produce an associated upwelling around itself which directly affects productivity (as well as downstream flow).

Carbonate platforms are built mainly by corals living in shallow light-saturated tropical waters. The Saya de Malha Bank, one of the world's largest carbonate platforms, lies in the path of the SEC. Its reefs do not reach sea level, and all carbonate production is mesophotic to oligophotic. New geological and oceanographic data unravel the evolution and environment of the bank, elucidating the factors determining this exceptional state. There are no nutrient-related limitations for coral growth. A switch from a rimmed atoll to a current-exposed system with only mesophotic coral growth is proposed to have followed the SEC development during the late Neogene. Combined current activity and sea-level fluctuations are likely controlling factors of modern platform configuration[35].

# 1.4. OCEAN-CLIMATE INTERACTIONS

The Indian Ocean is the warmest ocean in the world[36]. Long-term ocean temperature records show rapid, continuous warming in the Indian Ocean, at about 1.2 °C (34.2 °F) (compared to 0.7 °C (33.3 °F) for the warm pool region) during 1901-2012. Research indicates that human-induced greenhouse warming and changes in the frequency and magnitude of Indian Ocean Dipole (IOD) events are a trigger to this strong warming in the Indian Ocean[37]. South of the Equator (20-5°S), the Indian Ocean is gaining heat from June to October, during the austral winter, while it is losing heat from November to March, during the austral summer[38].

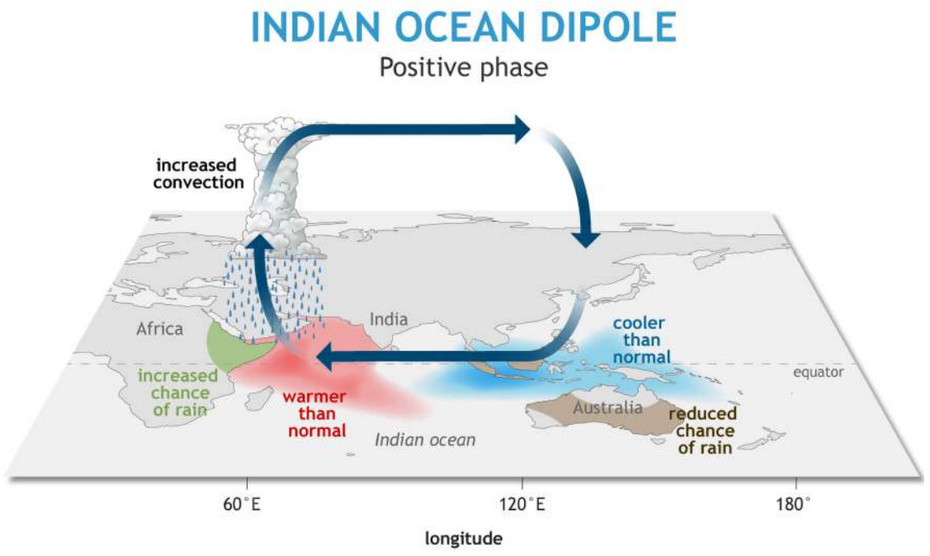


Figure 12a: The Indian Ocean Dipole: Positive Phases (NOAA)

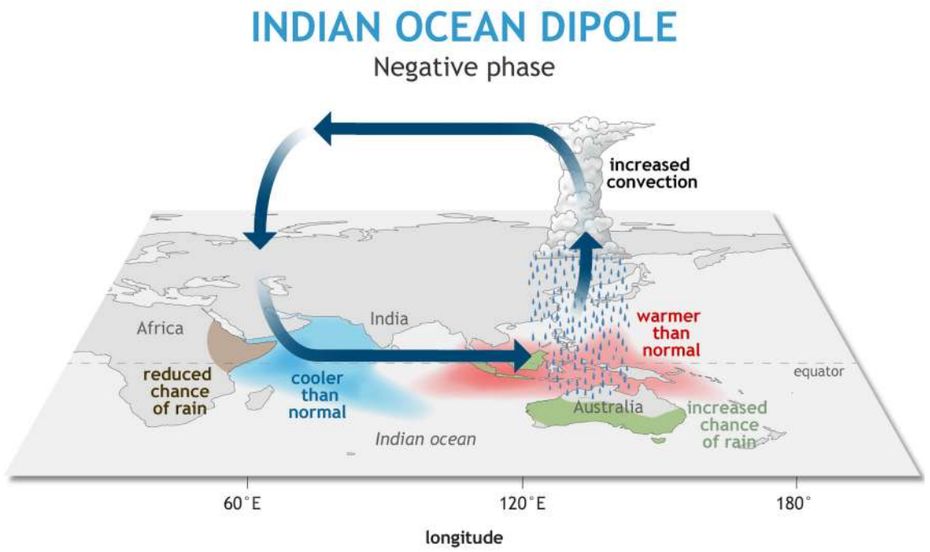


Figure 12b: The Indian Ocean Dipole: Negative Phases (NOAA)



The WIO interacts with regional and global climate systems on three scales – seasonal, interannual to decadal, and over the longer term. The monsoon seasonality of the Indian Ocean is perhaps one of the strongest ocean-climate interactions on the planet. Driven by the summer-winter oscillation of solar heating over Asia, it results in oscillating trade winds and associated shifts in currents in the Indian Ocean. During the southern winter, when the sun is over Asia and North Africa, the resulting low pressure system sucks in air masses from the south resulting in southeasterly winds, associated with cooler temperatures and generally rough conditions in the Indian Ocean.

During the southern summer, northeasterly winds are established drawing hotter, dry air from Asia and the Sahara southwards. In between these seasons, calmer inter-monsoon doldrum conditions prevail. The alternating winds cause current reversals in the northern part of the Indian Ocean, where the Somali Current and northern Indian Ocean gyre oscillate between the seasons. The monsoon does not reverse currents in the south, but it does strongly modulate their speed and variability. Year-to-year variability is due to the Indian Ocean's equivalent of the IOD. As with the Pacific Ocean's El Niño Southern Oscillation (ENSO), the IOD reflects differences in sea surface temperature, and therefore rainfall and winds, between the eastern and western parts of the ocean, moderating seasonal conditions across the ocean.

These patterns of variability are further influenced by other oceanographic features of the WIO, including a Seychelles-Chagos 'ridge' in the thermocline that affects sea surface temperatures and thereby ocean-atmosphere interactions, and decadal features similar to the Pacific Decadal Oscillation (PDO). With relevance to long-term global climate trends, leakage of Agulhas Current rings into the South Atlantic may be among the main controlling factors affecting global climate dynamics historically, and perhaps under a changing climate, due to their role in the ocean circulation conveyor belt[4].

# 2. BIOLOGY OF MAIN SPECIES, ECOLOGY, INCLUDING ECOSYSTEM FUNCTIONS AND CONNECTIVITY

## 2.1. BIOGEOGRAPHY

### 2.1.1. INDIAN OCEAN

The distribution of species in the marine environment is driven principally by ocean currents, which themselves are constrained by geology. The main patterns of species distributions found in the Indian Ocean[4] are:

- an Indo-Pacific fauna common across all tropical Indo-Pacific realms, carried on the South Equatorial Current from the centre of biodiversity located in Southeast Asia;
- a high-diversity region in the northern Mozambique Channel apparently related to the eddies that retain larvae there, the complex coastlines and its geological history;
- decreasing diversity north and south as currents flow out of the northern Mozambique Channel, with transitions towards the northern and southern extremes due to mixing with other water masses and climatic regions: in the north with the extreme environments and habitats in the Red Sea, Gulf of Aden and Persian Gulf, and in the south, with the temperate systems off the Madagascar Plateau, South Africa and the Southern Indian Ocean;
- relative isolation of the islands (Seychelles in the north, and the Mascarene islands in the south) in ocean gyres, resulting in distinct species assemblages and higher endemism due to their isolation.
- Seychelles, mixing with tropical provinces to the north results in a distinct fauna with mixed affinities. In the Mascarene Islands, isolation from the SEC and the higher diversity ecoregions in the Mozambique Channel, and no other adjacent tropical fauna to the south, results in higher levels of endemism.

Enhanced oceanic productivity caused by the interaction of the banks with the SEC is likely important for ocean food webs, and as indicated by seabirds using the Seychelles Basin (shown for wedge-tailed shearwaters and white-tailed tropicbirds), and for the pygmy blue whale (*Balaenoptera musculus brevicauda*) as a feeding and breeding ground.

### 2.1.2. SAYA DE MALHA BANK

The area of the Bank in shallow depths normally occupied by coral reefs and seagrasses comprises 2,098 km$^2$ less than 10 m, 5,683 km$^2$ less than 20 m and 8,907 km$^2$ less than 30 m depth. From 30-50 m deep, the total area is about 4,100 km$^2$. In the clear oceanic waters bathing the banks it is possible for typically 'shallow' habitats to be found relatively deep[39]. Still, a further constraint is that coral reef habitats are likely to be found only on heterogeneous/sloping surfaces. At the same time, seagrasses dominate the flat areas of the shallow bank with seagrass beds covering > 90% of shallow areas of the bank[10]. Interestingly, the Ritchie Bank is entirely within the photic zone and accounts for a large proportion of the shallow area of the larger bank. It is likely that coral reefs are relatively restricted to <10% of the 8,907 km2 that is less than 30 m depth, perhaps some 900 km2, with seagrass beds or other rubble or sandy habitats covering the remainder (some 8,000 km2).

The deeper portions from 30-50 m may host patchy coral reefs and/or seagrass beds. Below 50 m, by far the majority of the bank, the dominant habitats might be sand and rubble-dominated, with some soft-bodied invertebrate communities (e.g., sponges, soft corals, ascidians, etc.). The most-quoted area of the bank (40,000 km2)[40] is approximated by the 200 m contour. The largest area on the bank is between 100-200 m deep (26,494 km2) in a sheltered bowl behind the north and east rim of the bank. It is likely that this comprises both hard and soft-substrate environments with high sedimentation rates, enhanced by water column productivity[58] and low currents in the midwaters over this bowl. Thus, while not supporting seagrass beds that fix carbon, this central bowl may play a significant role in carbon sequestration through sedimentation, over an area > 27,000 km2 [41].



## 2.2. SPECIES DIVERSITY

Historically, species diversity across the Indo-Pacific region has been seen as one of generally linear decline in all directions from the high-diversity centre in the Southeast Asian region, or Coral Triangle, illustrated for corals by analyses up to the early 2000s that found decreasing diversity towards the African coast, with in some cases, a higher peak of diversity in the Red Sea due to endemism. However, recent reviews of the biodiversity literature note the exceptionally large gaps in species distribution records across the WIO and the Indian Ocean, such as on the East African coast. Thus, even today, prioritization exercises for conservation based simply on species counts should not be done without strong supporting evidence and ancillary information on ecology, oceanography and other processes that support biodiversity. Emerging evidence shows that the northern Mozambique Channel is a centre of diversity for the WIO, very likely due to high levels of connectivity due to the South Equatorial Current and Mozambique Channel eddies. Because the WIO may also have the highest diversity of the Indian Ocean (except for the Andaman Seas, which are faunistically more related to the Central Indo-Pacific Realm, or Coral Triangle), the northern Mozambique Channel may support the second highest peak of shallow marine biodiversity in the world, after the Coral Triangle[4].

## 2.3. ENDEMISM

The degree of endemism of reef fish in the Mascarene fauna is among the highest for reef fish, ranked fifth globally, comparable to levels reported for the remote island groups of the eastern part of the Pacific, such as the Hawaiian islands, the Galapagos and Easter/Pitcairn islands. Among 2,086 reef fish known from the Indian Ocean, 25% are endemic. The highest level of endemism occurs in the Mascarene islands with 37 endemic species out of a total of 819 species. Other reef taxa, particularly invertebrates, are too poorly sampled in the Indian Ocean to make meaningful regional comparisons. The life history of marine taxa is also important in understanding endemism – for example in the remote islands of the WIO there is a high percentage (70%) of hydrozoan species that lack the medusa stage in their life cycle, further contributing to high diversity through endemism[4].

## 2.4. CONNECTIVITY[42]

The Mascarene Plateau has a major impact on the region's ecology, in terms of its role in the transport and mixing of biota and related substances and in being intrinsically important to the region's biodiversity status. Regional hydrodynamic traits (see 1.3. Oceanography and Currents) are intrinsic in cause-effect pathways that link biodiversity health/sustainability with threats and pressures that may derive from natural or human causes. For example, after spawning, currents and mixing processes play very important roles in moving sperm, eggs and then larvae around to eventual settlement (recruitment) sites. The trophic structure that frames primary productivity pathways and underpins food supply to organisms from micro (e.g., planktonic) to macro (e.g., megafauna) scales, is inextricably linked to water movement and mixing processes: for example, in upwelling heaving and mixing processes of nutrients and small biota to the photic zone and in horizontal advective/diffusive transport from one area to another.

For the area from Madagascar southward, Crochelet *et al.*[43,44] provide significant insight into the potential for larval stages (e.g., for fish and corals) and plant seeds to travel from sources to receiving habitats over very large distances (>1,000 km). For the Mascarene Plateau area, it seems that little is known beyond these general considerations since no specific information nor papers have been identified dealing with ecological connectivity.

## 2.5. CORAL REEFS

### 2.5.1. INDIAN OCEAN[4]

Coral reefs in the WIO extend from the most northern parts of the Indian Ocean to the South African coast at 32°S. They are found along the continental coastlines of East Africa and Madagascar where there are no major river systems, on all the small islands, and on parts of the submerged banks that are both shallow enough and have some variation in topography. They are intimately associated with seagrass beds, with much of what is called 'coral reef habitat' being flat open seagrass and sand beds in between rocky outcrops and true reef structures. In sheltered locations mangrove stands are often associated with reef and seagrass habitats, though the high-sediment and freshwater conditions supporting the largest mangrove systems in East Africa

prevent the growth of immediately adjacent coral reefs. The coral reef fauna of the WIO is a mainstream component of the Indo-Pacific region, with very high faunal affinities stretching across the Indian Ocean to the Southeast Asian and West Pacific regions. However, new insights into the fossil record of reefs suggest a distinct evolutionary history of coral reefs in the WIO, and by extension, of other shallow marine habitats and their species, raising the possibility of a unique regional fauna. In terms of reef geomorphology, the process of transition from fringing to barrier to atoll reefs was first described by Charles Darwin, partly from observations in the Indian Ocean, including the Chagos Archipelago and Aldabra Atoll. The WIO has a variety of offshore bank reefs and island/continental reef systems, representing a range of reef formations:

- fringing reefs are found around all the islands and the East African coast;
- barrier reefs are most strongly developed at Tulear (Madagascar) and around Mayotte (which also contains a second/inner barrier within its lagoon), and partially developed or poorly described in several locations - the west coast of Mauritius (Mahebourg), south side of Mohéli (Comoros);
- atolls are found in Seychelles (e.g., Aldabra, Cosmoledo, Farquhar, Alphonse) and in the Iles Éparses (Europa, Bassa da India), and submerged atolls at Zélée and Geyser; and
- coral banks are numerous, such as those offshore of major coastlines (e.g., Malindi – Kenya, Leven and Castor – NW Madagascar, African Bank – Mozambique), and the very large banks of the Mascarene Plateau - Cargados Cajaros, Nazareth and Saya de Malha, and the North Seychelles Bank.

The Millennium Coral Reef Mapping Project developed a single global classification of geomorphological classes for reefs, defining 800 different classes. Application of this method to the WIO islands conducted by the RAMP-COI project (Réseau des Aires Marines Protégées – Commission de l'Océan Indien) resulted in identification of 199 classes (25% of the global geomorphological diversity). Madagascar had the highest diversity with 86 geomorphological classes, followed by Seychelles and Mauritius with 54 and 53 classes respectively, then Mayotte (42), Comoros (28), the Iles Éparses (16) and Réunion (4). Using these classes, the sum of reef and non-reef areas in the islands equalled approximately 14,000 km2 and 50,000 km2 respectively. Madagascar and Seychelles had the largest reef areas, with 5,000 and 5,400 km2 of reef area respectively. The atolls, banks and islands had approximately 9,000 km2 of reef. The Seychelles Bank alone represented 42,800 km2 of non-reef area. The East African continental coast has not yet been classified.

Continental reefs in the WIO are distinguished from other Indo-Pacific reefs by the dominance of mono-specific stands in genera such as *Galaxea*, *Lobophyllia*, *Montipora* and *Porites*. More typical Indo-Pacific reef assemblages are also common on the islands and mainland, dominated by branching corals in the genera *Acropora* and *Isopora*, and mixed communities including genera in the families *Faviidae*, *Mussidae*, *Petiniidae*, *Fungiidae* and others. Endemic coral species in the WIO (with the ranges of some extending to the northern Indian Ocean) include *Ctenella chagius*, *Craterastrea laevis*, *Horastrea indica*, *Gyrosmilia interrupta*, *Anomastrea irregularis* and *Parasimplastrea sheppardi* with the first two species only recorded recently from Chagos and Mauritius, and Mayotte and Madagascar, respectively. Regional endemics that are so rare they have not been recorded in decades include *Astreosmilia*, *Erythrastrea* and *Machadoporites*. The taxonomic position of these species is in question, raising the possibility of endemism at higher taxonomic levels than previously thought, and a unique lineage of corals in the WIO. Recent genetic research has shown that the genera *Stylophora* and *Siderastrea* have ancestral species in the WIO/Red Sea region compared to younger species farther east in the Pacific, and in the former case, higher levels of genetic diversity in the WIO/Red Sea. These results are also suggestive of so-far-unknown levels of diversity in the WIO and a distinct evolutionary heritage compared to the broader Indo-Pacific.



## 2.5.2. ALDABRA

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Aldabra Atoll is a large (34 km long, maximum 14.5 km wide) raised atoll. Raised reef limestones, averaging 2 km in width and up to 8 m above sea level, enclose a shallow central lagoon. A tidal range of 2 to 3 m results in large-scale hydrodynamic exchanges between the lagoon and the open ocean through two main channels and several small ones.

The reef front areas of Aldabra Atoll are classified into six morphological categories, based on exposure to wave and storm action in the shallower depths, and on light attenuation in the deeper reef zones[45] [46]. The western reefs are characterized by a 460 m wide reef flat, a reef ridge margin and reef front slopes of 20° to 45°. The topography of reefs on the northern coast of Aldabra varies very little[47]. Characteristically, there is a very short reef flat that slopes gently down to 10 m, below which the reef drops at an incline of approximately 35° - 45°. At between 20 m and 25 m the reef shelves off to form a sandy ledge with patches of coral growth and then drops off steeply again at between 35 m and 40 m. The east and southeast coasts are the most severely exposed and have neither a reef flat nor a reef ridge. No hermatypic corals are present. Finally, the reef flat is present on the southern less exposed shore but not delimited by a prominent ridge. The reef front itself is characterized by large areas of dead coral which vary greatly in extent.

Aldabra being the second largest raised atoll in the world, was built by corals. There used to be extensive coral reefs surrounding the whole atoll and large coral patches inside the lagoon in particular along the channels. Coral bleaching and subsequent death have taken a large toll on the reefs of Aldabra. After the first catastrophic bleaching in 1998/1999, there have been a number of subsequent heating episodes that have seen a continuing decline in the health of the corals. Coral cover was reduced by 38% and 66% at the seaward reefs at 10 m and 20 m depth respectively in 1998.

In 2016 another very serious bleaching event occurred, and more than half of the reef-building corals died and over 90% of soft corals succumbed. The fringing reefs have been the most impacted and coral cover is now down by more than half from the already reduced 2014 cover. The lagoon is faring a bit better with a reduction of only 34%. Recovery there has also been considerably faster and by 2019 the lagoon reefs had recovered relatively well. The deeper reefs have not seen a similar recovery and soft corals have hardly recovered at all. Despite the very low fishing pressure and the absence of marine pollution and nutrient loading the reefs of Aldabra are a pale shadow of what they were before 1998. The reefs that have evolved with large fluctuations in temperature, inside the lagoon, are clearly coping better with the warming waters and the more frequent heatwaves[48].

### 2.5.3. SAYA DE MALHA[9 10 39]

In the shallower waters of the Saya de Malha Bank corals form small clumps to reefs up to 100m long and elevated just 1m-2m above the surrounding sea floor or occur as scattered individuals or small clumps in seagrass. There are also observations of coral hills and ridges located in the flat on top of the bank. Observations indicate that unlike other areas of the Indian Ocean coral communities were very mixed rather than dominated by a few taxa. The diversity observed by scuba divers is high. Larger coral colonies reported in 2002 were *Porites* sp. as well as *Heliopora*, and *Millepora* spp. Russian work indicates the presence of acroporids and *Montipora*. Observations suggest that rates of bioerosion of stony corals by sponges and other organisms were very high, a phenomenon attributed to elevated nutrients and organic material that support boring sponges, worms and molluscs[10]. Vortsepneva (2008)[39] also indicates that the steep eastern, current-exposed slopes are favourable for the growth of octocorals (Gorgonaria).

### 2.5.4. SAINT BRANDON

According to a 2004 survey[49] using remote sensing images, Saint Brandon coral reef covers 227 km2, of which 74.2% (168.5 km2) is sand, 11.1% (25.1 km2) rubble, 8.9% (20.2 km2) is lagoon coral, 3.3% (7.5 km2) is reef flat and 2.5% (5.7 km2) is reef front. The eastern side of the Saint Brandon Bank consists of a reef slope extending down from a depth of between 10 and 40 m to the ocean floor. Above the reef slope is a gently sloping low-relief reef terrace at a depth of 3-40 m, dominated by coral rock, sand patches and variable cover of hard corals and encrusting coralline algae, with deep grooves parallel to the reef. Typical corals are *Porites*, *Favia*, *Montipora*, *Acropora hyacinthus*, *Astreopora* and *Hydnophora*. Shallow spur and groove regions between 0 and 3 m are formed from alternating ridges of rock and deep grooves exposed to the breaking waves. Large numbers of sharks and parrotfish occupy a 1.5 m channel parallel to the back of this zone. The reef crest comprises reef rock and rubble, extending to several 100 m wide, composed of calcareous algae on the lagoon side. A back reef is composed of large colonies of *Heliopora*, *Acropora palifera* and *Porites cylindrica* on sandy rubble, and small colonies of *Stylophora pistillata*, *Pocillopora damicornis* and *Acropora* spp. harbouring small reef fish, clams, holothurians, *Halimeda* and sponges. Two large passes cut into the lagoon and are regularly occupied by white-tip reef sharks and other larger reef fish.

Saint Brandon has three main lagoons up to 7 m deep, separated by reef crest walls. The lagoons have sand floors either heavily bioturbated by worms, crustaceans, bivalves and gastropods, or covered by blue-green algal mats. Patch reefs grow to 3 m in diameter in the lagoons, often having dead or rubble tops, around which larger fish aggregate.

The Saint Brandon Bank has a less-developed western reef crest standing ca.1.5 m above the lagoon floor and 4 m above the Saint Brandon Sea seabed. The main corals in the habitat are *Acropora hyacinthus, Acropora cytherea, Acropora latistella, Favia stelligera, Stylophora pistillata, Alveopora, Cyphastrea, Platygyra* and soft corals. The Saint Brandon Sea is a shallow area 4-40 m deep bounded by the western reef margin, lagoons and islands, and has a sandy-mud bottom with rocky patch reefs dominated by algae, foliose sponges and soft corals and some hard corals such as *Platygyra, Acropora hyacinthus, Heliopora* and *Hydnophora*. To the west of the Saint Brandon Sea, the seabed slopes into the deep Mascarene Basin.

A research trip conducted in April 2010 in the framework of Tara Oceans Expeditions[50], recorded around 160 species of corals, belonging to more than 40 genera, around Saint Brandon. The most represented genera are *Acropora, Dipsastrea, Favia, Favites, Montipora, Pavona* and *Porites*. Compared with other coral reef areas of the WIO, Saint Brandon is at the lower end of the diversity scale, consistent with the following:

- small island size relative to the large islands and continental coastline;
- isolation in the path of the South Equatorial Current;
- partial habitat diversity and restricted depth range of reefs.

Interestingly, some species and genera were utterly absent. The endemic monospecific genera characteristic of the WIO and found in Madagascar and the mainland coast (*Horastrea indica, Gyrosmilia interrupta, Anomastrea irregularis*) were not found, while a population of the endemic species *Ctenella chagius*, known only from the Chagos Archipelago was found at North Island.



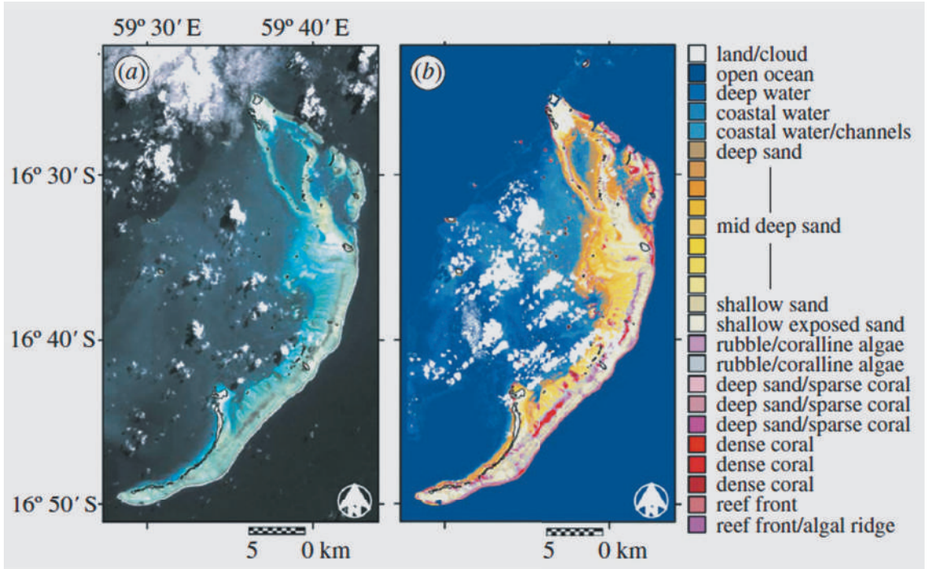



Figure 13: (a) Landsat 7 ETM+ images of Saint Brandon and (b) biotope classification map[87].

## 2.6. OTHER INVERTEBRATES[9 39]

The diversity of other benthic invertebrates has been reported to be low[10] but it is unclear as to how much sampling of the macrofauna of seagrasses, coral reefs and other habitats has been undertaken. Furthermore, previous studies have focused mainly on shallower parts of the Saya de Malha Bank with little sampling or observations having been made below scuba diving depths.

A summary of Russian work by Vortsepneva (2008)[39] identified sponges, bryozoans and tunicates as dominating slope habitats. Areas of flat sediment in the "lagoon" are reported to be populated by deposit feeders such as *Spatangus purpureus*, and *Priapulus* sp. which feed on plant and algal detritus, and which can occur at high densities (14 individuals m-2). *Spatangus purpureus* is a heart-urchin for which most records have been observed in the NE Atlantic with scattered records throughout the southern hemisphere. Whether the species observed on Saya de Malha Bank is *Spatangus purpureus* must therefore be treated with some suspicion. Non-selective deposit feeders including *Brisaster* sp. (another heart urchin) and *Trochostoma* sp. (a sea cucumber) are reported from the foot of reef areas where they feed on organic detritus. Polychaetes reported include multiple species of *Prionospio* from finer sediments in flat areas of the reef and lagoon as well as *Spiophanes soderstromi*. A community characterized by *Anomia ephippium* (saddle oyster) is also described from the "lagoon entrance" where there is a coarse sediment of mollusc/algae sand. This is another species with a distribution focused in the NE Atlantic / Mediterranean with only a few scattered records elsewhere. A broader survey of the scientific literature revealed relatively recent descriptions of species of invertebrates from the Saya de Malha Bank most notably a giant clam species (*Tridacna rosewateri*) which appears to be endemic[51]. Vortsepneva (2008)[39] reports 142 molluscs from the Saya de Malha Bank (including 89 Gastropoda, 7 Bivalvia). Most of these species were found at 12-15m depth whilst 15 were found at 70m depth and only two at 200m. This paper also identifies 11 new species of molluscs have been described from the bank, all of which are endemic to Saya de Malha Bank or the Mascarene Ridge. Molluscs described from the bank include: *Lyria doutei*, *Lyria*

*surinamensis*, *Murex surinamensis*[52]; *Conus primus*[53]; *Haustellum danilai* [54]; *Amalda danilai*, *Amalda trippneri* [55] and *Prionovolva melonis* [56]. Of these species only *Prionovolva melonis* is known outside of the Saya de Malha Bank (i.e., is not endemic). Bouchet & Bail (1991)[53] note that for *Lyria surinamensis* the species is likely to have large, crawl-away young (i.e., no pelagic larval development) suggesting a limited dispersal capacity and likely endemism to Saya de Malha Bank.

Two groups of cephalopods have been observed at the Saya de Malha Bank. The first group are typically associated with seamounts at depths of 100 – 400 m and includes the octopus *Scaeurgus* (175 – 250 m depth) that is found on the top of the bank, the squid *Abralia* and *Enoploteuthis* which inhabit the slopes, near bottom squids including *Moroteuthis* (518 – 1720 m depth), *Ancistrocheirus* (518 - 1,720 m depth), *Histiotheuthis* (518 - 1,720 m depth), *Todaropsis* (170 – 400 m depth), *Nototodarus* (170 – 400 m depth), *Ornithoteuthis* (518 - 1,720 m depth), the near bottom squids *Heteroteuthis* and *Alloposus* (960 – 1,650 m depth) and the near-bottom octopuses *Opisthoteuthis*, *Grimpoteuthis* (960 – 1,650 m depth) and *Benthoctopus* (960 - 1,650 m depth). The second group are shallower water species associated with the reef habitat at up to 200 m depth and include: *Sepia, Sepiola, Sepioteuthis, Loligo* and *Octopus*[39].

Crustaceans found on the bank include: *Puerulus carinatus* [57], *Nephropsis malhaensis* [58 59] and *Oreophorus holthuisi* [60]. A thorough evaluation of endemism amongst invertebrates found on the bank is not possible because the region is so poorly studied that these species may occur across a wider area of the Mascarene Ridge or elsewhere in the WIO or beyond (see 2.9 for fish).

Vortsepneva (2008)[39] notes that many other groups of invertebrates are poorly studied or not studied at all from the Saya de Malha Bank including: *Poriphera*, *Nematoda*, *Nemertini*, *Tunicata* and *Hemichordata*. Significant amounts of zoological material collected by Russian expeditions lie in the Zoological Institute of the Russian Academy of Sciences in St. Petersburg, the collection of the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences and the Zoological Museum of the Moscow University.

Vortsepneva (2008)[39] provides two maps reporting on the seabed physical composition and occurrence of some species in their publication (see Fig 14 and 15).

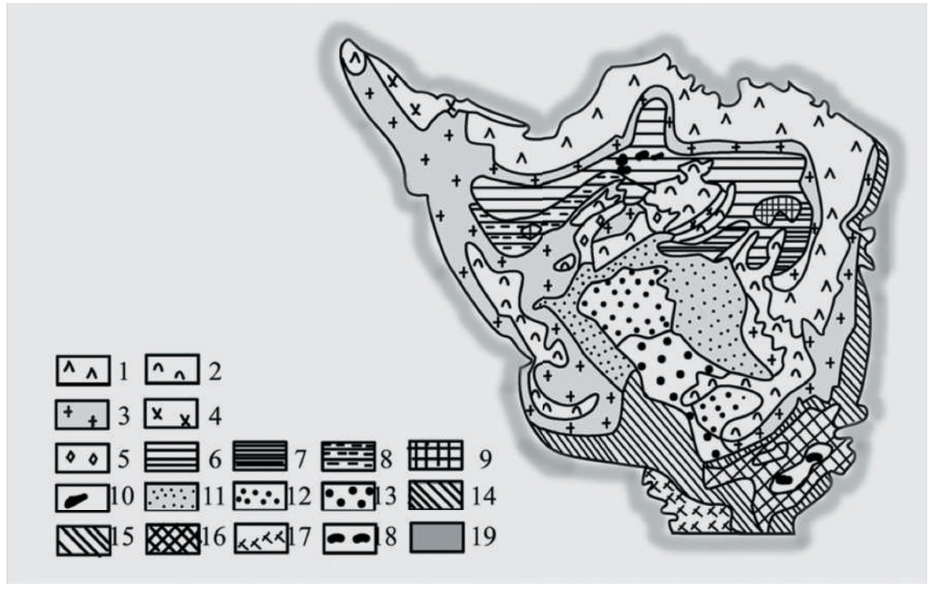



Figure 14. Landscape of Saya de Malha Bank. (Vortsepneva)



**Landscape of Submerged Circular Reef.**

- 1. Upper terrace. Bottom consists of float stone – gravel – pebble. Dominant taxa: macrophyte, madreporarian corals (*Madreporaria*), *Spongia.*
- 2. Low terrace. Bottom consists of sand- gravel foraminifera – algae ground. Dominant taxa: calcareous algae, benthic foraminifera.
- 3. Slopes and foot of reef. Bottom consists of foraminifera – algae sand. Dominant taxa: *Spatangus purpureus* (*Echinoidea*), *Priapulus* sp.
- 4. Slopes of reef. Bottom consists of silt – sand. Dominant taxa: *Spiophanes soderstromi.*
- 5. Shallow gullies. Bottom consists of silt – sand. Dominant taxa: *Prionospio* sp.

**Landscape of Shallow Coral Lagoon.**

- 6. Bottom accumulative flat. Bottom consists of fine-dispersed silt. Dominant taxa: *Brisaster* sp. (Echinoidea) and *Trochostoma* sp.
- 7.Bottom accumulative flat. Bottom consists of silt. Dominant taxa: *Prionospio* sp.
- 8. Bottom accumulative flat. Bottom consists of sand – silt. Dominant taxa: *Prionospio* sp.
- 9. Bottom accumulative flat. Bottom consists of sand – silt and fine-dispersed silt. Dominant taxa: *Pelosina* sp.
- 10. Intra-lagoon coral mount and ridge. Bottom consists of coral – algae gravel and pebble. Dominant taxa: acropores, tunicates, sponges, calcareous algae.

**Landscape of Deep Coral Lagoon.**

- 11. Bottom-dwelling accumulative flat. Bottom consists of silt – sand. Dominant taxa: *Prionospio* sp.
- 12. Bottom-dwelling abrasive flat. Bottom consists of foraminifera sand. Dominant taxa: detritophage.
- 13. Bottom-dwelling abrasive flat. Bottom consists of mollusc-algae sand. Dominant: *Anomia ephippium* (Bivalvia).

**Landscape of the Reef Top.**

- 14. Limestone flat. Bottom consists of thin layer foraminifera sand. Dominant taxa: *Spiophanes soderstromi.*
- 15. Limestone flat. Bottom consists of calcareous – algae sand. Dominant taxa: *Spatangus Purpureus*, *Priapulus* sp.
- 16. Limestone flat. Bottom consists of rock with thin layer algae – foraminifera sand. Dominant taxa: immovable seistonophage.
- 17. Limestone flat. Bottom consists of foraminifera sand. Dominant taxa: horny coral.
- 18. Intra-lagoon rises. Bottom consists of coral limestone with gravel – pebble algae ground. Dominant taxa: calcareous algae and sponges.

**Landscape of Slopes.**

- 19. Slopes with steep steps. Bottom consists of sand. Dominant taxa: *Spiophanes soderstromi.*

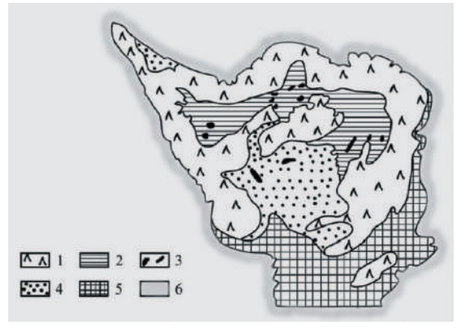



Figure 15: Zoning of Saya de Malha Bank by results of trawl. 1. coral reefs. 2. shallow lagoon 3. coral rises. 4. shallow lagoon and accumulative slopes. 5. limestone flat of the reef. 6. Slopes with steep steps.

## 2.7. SEAGRASSES

Underwater view of Saya de malha Bank © Tommy Trenchard / Greenpeace

Seagrasses are marine angiosperms widely distributed in both tropical and temperate coastal waters creating one of the most productive aquatic ecosystems on earth. The distribution of seagrasses ranges from high intertidal to subtidal soft and hard bottoms, including sandy bays, mud flats, lagoons, estuaries, coral reef patches and sheltered and exposed reef platforms. They often form extensive mono- and multi-specific meadows in depths < 12 m, and in the WIO tend to be closely associated with coral reefs and mangroves. With sufficient water clarity they grow in depths of up to 70 m. Extensive seagrass beds are found in all countries of the WIO, where they have received limited scientific attention compared to mangroves and coral reefs. Of the 24 seagrass species in the tropical Indo-Pacific, the WIO holds 12 species. The greatest diversity of seagrass species is along the Mozambique, Tanzanian and Kenyan coastlines, and decreases eastwards into the islands[4].

The Saya de Malha Bank[4] supports the largest contiguous seagrass beds in the world with 80–90 % of shallow surfaces being covered by seagrasses, which thrive on the relatively flat bank in depths shallower than 20 m. Mixed seagrass beds with high diversity are common, between 8 and 10 species at the same locality have been reported for Mozambique, Tanzania and Madagascar. Two of the most common species are *Thalassia hemprichii* and *Thalassodendron ciliatum* both forming extensive beds in most parts of the region. *Thalassia hemprichii* is found in more protected habitats or on intertidal flats, whereas *T. ciliatum* normally inhabits exposed or semi-exposed habitats and can anchor on both sandy and rocky substrates. Also common in the region are *Halophila ovalis*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Syringodium isoetifolium* and *Halodule uninervis*. *Enhalus acoroides*, *Halophila stipulacea* and *Halophila minor* are mainly recorded from northern Mozambique to Tanzania and in some locations in Kenya. *Zostera capensis* is a more temperate species and is only common in southern Mozambique and South Africa where large monospecific stands may occur, although the species has also been recorded in Kenya, Madagascar and Mayotte. *Halophila beccarii* is only known in Madagascar, *Halophila decipiens* is a new but relatively common species and widespread.

Unlike other localities where seagrass tends to grow on sediments, the shallow areas of the Saya de Malha Bank are made up of rhodoliths and successive layers of calcareous algae. *Thalassodendron ciliatum* can grow directly on hard substrata by attachment of rhizomes by thin rhizoids. Diver observations on the 2002 Lighthouse Expedition indicate that the leaves of this seagrass were frequently missing suggesting considerable grazing pressure from green turtles and other unidentified grazers[10].



## 2.8. ALGAE[9] [10]

Encrusting and branching calcareous red algae cover most surfaces in the shallower reaches of the Saya de Malha Bank. Genera include potentially *Neogoniolithon*, *Hydrolithon*, *Sporolithon*, *Mesophyllum* and *Lithophyllum* although detailed work on the algae of the Saya de Malha Bank is very sparse and some is very old (e.g., Foslie, 1907[61]). The soft green alga *Microdictyon* sp. is also present on the bank as is the calcareous green alga *Halimeda opuntia*. Some of these algae are capable of growing at considerable depths and so it is likely that they grow well into the mesophotic zone (30 – 150 m depth) and possibly into the rariphotic zone (150 – 300 m depth). A significant effort in the identification/description of algal taxa and their distribution on the bank should be a priority for investigation.

Hilbertz et al. (2002)[10] observed two diseases affecting coralline algae on the bank. These were Coralline Algae Lethal Disease (CLD) which appears as an expanding ring of dying white tissue surrounded by healthy pink tissue. The dead area becomes colonised by green filamentous algae. There was also Coralline Lethal Orange Disease (CLOD) which was rarer than CLD and in which the dying ring is bright orange. Whether a background occurrence of these diseases is normal or whether it is driven by climate change (e.g., due to rising sea temperatures) has not been investigated.

## 2.9. FISHES[9]

Skunk anemonefish, *Amphirion akallopisos* © Rich Baxter

A high diversity of fish was observed on the Saya de Malha Bank with the greatest concentrations near the sea floor and close to coral reefs / clumps[10]. This is also apparent from Russian investigations of the banks which recorded the following families and species of fish: jack scads (Carangidae) including: *Trachurus indicus* (40 – 290 m depth in the winter and 10 – 80 m in the summer), *Decapterus kiliche* (shelf zone, 10 – 280 m depth), *Decapterus macarellus*, *Decapterus russelli* and *Carangoides equula*; flintperch or roughies (Trachichthyidae) including: *Hoplostethus atlanticus*, *H. latus*, *H. shubnicovi*, *H.tenebricus*, *H.rubelopterus*, *H.mediterraneus*, *Paratrachichthys sajademalensis*, *Gephyroberyx darwini*; 10 species of emperors

(Lethrinidae); driftfishes (Stromateoidei) including: *Cubiceps squamiceps*; lizardfishes (Saurida) including: *Saurida undosquamis*; threadfin breams (Nemipteridae) including: *Nemipterus peronii*; sea breams (Sparidae) including: *Polysteganus coeruleopunctatus* (reported at high densities in certain times of the year, depths from 105 – 250 m); greeneyes (Chlorophthalmidae) including: *Chlorophthalmus* sp.; grenadiers (Macrouridae) including *Malacocephalus laevis* (500 – 560 m depth) and rabbitfish (Chimaeridae) including *Chimera monstrosa* (800 - 1,300 m depth[39]). What is notable from the literature is the large number of relatively recent new species descriptions of fish from the bank including: cardinalfish (*Apogon quartus*), dragonets (*Callionymus dragonae*); flatfish (*Tosarhombus nielseni*, *Engyprosopon hensleyi*, *Arnoglossus sayaensis*, *Parabothus malhensis*, *Samariscus leopardus*, *Brachirus sayaensis*), goat fishes (*Parupeneus procerigena*); gurnards (*Lepidotrigla sayademalha*); lizard fish (*Saurida tweddlei*); sand lances (*Protammodytes* ventrolineatus, *Bleekeria profunda*); scorpion fish (*Ebosia saya*); serranids (*Odontanthias dorsomaculatus*), shovelnose ray (*Rhinobatos nudidorsalis*), sparids (*Polysteganus cerasinus*, also another new species from the Nazareth Bank). Many of these fish have only been reported from the Saya de Malha Bank raising the possibility of endemism in this locality. However, the region is so poorly studied that these species may occur across a wider area of the Mascarene Ridge or elsewhere in the WIO or beyond. Further investigation of the levels of endemism associated with the bank is clearly very urgently required given the damage to the feature by fishing. This is likely to have impacted some of these fish species directly (e.g., *Saurida tweddlei*) or their habitat.

## 2.10. SHARKS AND RAYS[4]

Reef Blacktip sharks, *Carcharinhus melanopterus* © Fotonatura

One hundred and thirty-seven species of sharks and rays occur in the WIO, of which 15 are endemic to the region. The highest elasmobranch diversity in the region has been recorded from Mozambique waters, with 108 species (73 sharks and 35 rays). Ten species are endemic just to South African waters. Sharks are at the top of the food chain especially in the coral reef environment. Sharks have slow reproductive rates with many species only producing a handful of offspring when the adults are 10-15 years old. The more primitive species lay eggs, while the most advanced species are viviparous, meaning the foetal sharks are connected by the placenta in utero, and born live. Published references on sharks and rays in the WIO are very rare, and the available data are based primarily on grey literature and testimonies, and are often inaccurate. In the last decade, however, this situation has been changing as interest in sharks from an ecological standpoint, and for conservation, has increased.

Sharks are widely dispersed in tropical waters, including the WIO, but heavy mortality from fishing has dramatically reduced their numbers in many locations. At present, the most important locations for sharks are the islands of the Mozambique Channel, and the southern islands of Seychelles, likely due to their relative isolation.



## 2.11. MARINE TURTLES[4]

Hawksbill turtle, *Eretmochelys imbricata* © Tommy Trenchard / Greenpeace

Five out of seven species of marine turtle worldwide occur in the WIO: green turtle *Chelonia mydas*, hawksbill *Eretmochelys imbricata*, loggerhead *Caretta caretta*, leatherback *Dermochelys coriacea*, and olive ridley *Lepidochelys olivacea*. The most abundant species in the WIO is the green turtle, and the second most common is the hawksbill. On the International Union for Conservation of Nature (IUCN) Red List of Threatened Species all are currently listed either as Critically Endangered (hawksbill, leatherback), Endangered (green turtle), Vulnerable (olive ridley) or Near Threatened (loggerhead)[62]. The complicated life cycles of marine turtles require them to utilize a variety of habitats. Eggs are laid and incubate in beach sand, but post-hatchlings are pelagic and inhabit the surface waters of convergence zones and major gyre systems throughout tropical and temperate ocean basins. These juvenile stages migrate with ocean currents over thousands of kilometres. Most adult turtles also migrate over such distances, though post-nesting hawksbills in Seychelles do not migrate as far as do adult green or loggerhead turtles. The feeding grounds of the bottom-feeding marine turtles include seagrass, coral reef, sand and mud flats, and mangrove ecosystems, while the pelagic leatherback feeds in oceanic surface waters of tropical, temperate, and even polar seas. Thus, the state of turtle populations is a good indicator of the overall health of coastal and marine ecosystems. Turtles may also be crucial for the functioning of healthy marine ecosystems; findings from the Caribbean suggest that the demise of the macro-herbivorous green turtles following European colonization had significant effects as few other species feed on seagrasses. There has been extensive marine turtle research since the early 1990s in the region, but this information is still relatively scattered and not always standardized. Genetic research has shown that there is a mixing between the Atlantic green turtle and those of the Mozambique Channel, and the southern population of green turtles in the WIO (i.e., central Mozambique Channel and southwards). Green turtles in the north of the channel and northwards are distinct, and there may be a distinct Seychelles population as well, with links to the Southeast Asian region. Interestingly, green turtles found between the islands of Europa and Juan De Nova were from both southern and northern genetic populations. The genetic differences could result from oceanographic features that affect the movement of the juveniles, suggesting a separation between the northern and southern parts of the Mozambique Channel. Species-specific information,

on marine turtles is provided below, though there are still significant gaps, particularly for parts of Madagascar and Mozambique.

Up to 10,000 female green turtles nest annually in Seychelles, predominantly in the southern islands, especially Aldabra, Assumption, Cosmoledo, Astove and Farquhar. The species has become rare in the inner islands and Amirantes due to continuing exploitation. The Aldabra green turtle population which has been protected since 1968 has increased by 500-800% since 1968 and now numbers approximately 5,000 females nesting annually, and the population is increasing exponentially. Important feeding grounds for green turtles are adjacent to virtually all the islands of Seychelles. Active conservation programmes involving nesting green turtles are underway in the Amirantes Group at Alphonse/St. Francois atolls, D'Arros/St. Joseph atoll, and Desroches at a number of the inner islands. In the Cargados Carajos, a recent study recorded 539 nests of green turtles at Saint Brandon's Rock[63].

Most hawksbill nesting in the WIO occurs in the inner Islands (on the Seychelles Bank) and the Amirantes Group. Approximately 2,000 females are estimated to nest annually in Seychelles. Satellite telemetry indicates the Seychelles Bank is the primary feeding ground for the hawksbills that nest in the Granitic Seychelles, but hawksbills feed in habitat < 60 m deep throughout Seychelles and important feeding grounds for immature hawksbills are found adjacent to virtually all islands in Seychelles. All marine turtles are legally protected in Seychelles and active conservation programmes are underway at nearly all the inner islands (especially Aride, Bird, Cousin, Cousine, Curieuse, Denis, Fregate, North, Silhouette, Ste. Anne, and parts of Mahé and Praslin) and in the Amirantes group at Alphonse/St. Francois atolls, D'Arros/St. Joseph atoll, and Desroches, as well as at Aldabra Atoll in the southern islands.

There is limited information on the olive ridley turtle (*Lepidochelys olivacea*) in the WIO especially on specific nesting, feeding grounds and their juvenile movements. Olive Ridleys have been recorded in the waters of the inner islands of Seychelles and in the Mascarenes, and a few nest reports have been provided from Kiunga Marine National Reserve and Malindi in Kenya.

## 2.12. SEABIRDS[4]

Greater Flamingoes flight. *Phaenicopterus roseus* © Martin van Rooyen

Seabirds, (i.e., species that spend a large part of their lives at sea) off the coast of mainland East Africa, associated islands and the open sea are abundant and diverse, though they have received little attention in the region until the last 5–10 years. Recently, growing interest in how they can serve as indicators of patterns of oceanic productivity, and thereby to fisheries, has led to a rapid increase in studies. Further, the impacts of growing fishing efforts have led to increasing concern about impacts on the marine environment as well as on seabirds.

Globally, there are over 300 species of true seabirds, with about half occurring in the WIO. The main groups of seabirds are albatrosses, petrels, shearwaters, tropicbirds, boobies, frigatebirds, gulls, terns, cormorants and penguins, many of which typically breed in large colonies on small islands or remote portions of continents. At least 31 species of seabirds breed on WIO islands, and others (such as African penguins and cormorants) are also known from the mainland coast of eastern and southeastern Africa.

### Breeding and nesting

A recent regional survey of the seabird species that breed in the WIO estimated a total seabird population of 7.4 million pairs with the main breeding grounds located in Seychelles (Aldabra and the granitic islands) and in the Mozambique Channel (Juan de Nova, Europa and Glorieuses). The Mascarene Islands also have significant breeding populations, at smaller numbers but for rarer species. In 2005, 16 species were recorded breeding in the Mozambique Channel with an extraordinarily high density of over 3 million breeding pairs, of which 99% were sooty terns (*Sterna fuscata*), concentrated at Juan de Nova (66%, 2 million pairs), Europa (25%, 760,000 pairs) and Glorieuses (9%, 270,000 pairs). Thirteen thousand pairs spread among 13 seabird species breed on islets off the west coast of Madagascar, but population sizes are small and threatened by poaching. Europa is of particular conservation interest as it holds some of the last colonies of large Pelecaniforme species (frigatebirds, red-footed boobies and red-tailed tropicbirds), which have experienced dramatic declines in most islands of the WIO. In 2010, a study identified large nesting colonies of sooty tern (136,000 nestlings), lesser noddy (*Anous tenuirostris*) (13,000 nestlings), brown noddy (*Anous stolidus*) (4,700 nestlings) and fairy tern (*Sternula nereis*) (4,800 nestlings) at Saint Brandon's Rock[122].

### Foraging

Many tropical seabirds associate with tuna, as both groups feed in areas of high productivity, determined by ocean circulation patterns, and also because top predators such as tuna drive the primary seabird prey to the surface, where they become accessible to the birds. This interaction makes seabird populations highly dependent on the health of tuna and other open ocean top predators. They can also serve as indicators of the health of these top predators. Based on foraging grounds, and their overlap with the nesting grounds, the following five areas were identified as priority regions for seabirds in the WIO: Seychelles Basin – the Seychelles Plateau and a wide oceanic region around the Plateau is the main area occupied by wedge-tailed shearwaters (95,000 pairs that breed in Seychelles) and white-tailed tropicbirds (6,500 pairs). The Seychelles Archipelago (excluding Aldabra and Cosmoledo) supports the greatest abundance of seabirds in the tropical Indian Ocean with 14 breeding species totalling 2.2 million pairs.

The Mascarene Islands (Réunion, Mauritius, Rodrigues) and Tromelin Island are the only breeding ground of two endemic petrels, the Endangered Barau's petrel (*Pterodroma barau*i) and the Critically Endangered Mascarene petrel (*Pseudobulweria aterrima*), as well as other species that breed on Réunion.

The Central Indian Ocean – is an important foraging region for at least four migratory seabirds: Barau's petrel, the red-tailed tropicbird, the wedge-tailed shearwater and the white-tailed tropicbird. There are two main subregions, both associated with seamounts and undersea topography that enhance upwelling, and therefore productivity.

# 2.13. MARINE MAMMALS – DUGONG, WHALES AND DOLPHINS[4]

Dugong, *Dugong dugon* © Shutterstock

There are 36 species of whales and dolphins in the WIO region, of which eight are baleen whales, two sperm whales, 13 toothed whales and 13 dolphins. Dugongs are reduced to scattered remnant populations, probably totalling no more than 500 animals in the WIO, of which over 300 occur in the Bazaruto Archipelago. Species known to be very reduced in numbers in the WIO include the dugong (*Dugong dugon*), blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*), and humpback whales (*Megaptera novaeangliae*). The severe depletion of almost all stocks of 'great whales' in the Southern Hemisphere is well documented.

## 2.13.1. ECOLOGY OF LARGE MARINE PREDATORS[64]

Large-bodied marine predators such as sharks (see 2.10 Sharks and Rays) are widely considered to occupy the highest trophic level in ocean food chains, playing an important role in structuring food webs[65], both directly through predation, and indirectly by influencing prey behaviour[66] [67]. Recent advances in stable isotope techniques have shown that sharks in fact span a range of trophic levels[68], with many common reef sharks occupying a similar trophic niche to other reef associated teleost meso-predators such as groupers (Serranidae), trevallies (Carangidae), snappers (Lethrinidae) and emperors (Lutjanidae). Isotope analyses have also shown that true apex marine predators, such as large predatory shark species (e.g., tiger shark, great hammerhead shark, great white shark) occupy higher trophic levels than initially estimated[69] and that there is far greater trophic complexity among sharks than previously realized. Like large sharks, other wide-ranging predatory marine species such as tuna and billfishes, consume primarily pelagic prey and are considered top predators throughout their entire ranges[70].

The high functional redundancy in complex coral reef ecosystems and associated pelagic systems is hypothesized to mask clear trophic cascade effects caused by the removal of predatory species[68], making the detection of strong top-down effects challenging. The functional complexity in predatory guilds also results in varying degrees of predator-prey interaction strength, making predation pressure on coral reefs diffuse rather than concentrated[71], and therefore too nuanced to be described by oversimplified linear models of trophic cascade.

The important ecological role of apex predatory sharks, pelagic predators, and reef-associated mesopredatory sharks and teleost species remains significant despite the challenges in describing these complex interactions in diverse coral reef ecosystems such as those of the WIO. Through direct predation, sharks and other large predators remove weak and sick individuals from prey populations, maintain prey population numbers, and assist in the control of invasive species[65]. They can also exert non-consumptive or 'fear' effects that disrupt the foraging of potential prey[72] and create habitat disturbance and heterogeneity by impacting corals while hunting. The localized movement of reef associated predators and the large-scale movement of highly mobile apex predators also result in nutrient flux between reef, coastal, pelagic and ocean food webs[73].

## 2.13.2. ECOLOGY OF MARINE GRAZERS

Herbivory is key to maintaining ecosystem function, trophic structure and nutrient cycling across both terrestrial and aquatic ecosystems[74] [75]. On coral reefs, herbivory is a critical process that ensures the maintenance of coral-dominated states through grazing of algae, with herbivorous fishes clearing space for the settlement of coral larvae[76]. This is particularly important on reefs that are frequently disturbed, and on reefs that have regime-shifted to a macroalgae-dominated state, as grazing can help reverse this shift back to a coral-dominated state[77] [78].

Herbivorous fishes in coral reef ecosystems such as those of the WIO can be categorized into two broad groups: browsers that eat established foliose macroalgae, and grazers that feed on the algal turfs and microbial communities on surfaces[79]. The grazer functional group can be further split into cropping species and scraping species[80]. Cropping species (e.g., Acanthuridae, Siganidae) graze algal turf down by removing the upper portions of the algae, preventing growth into a macroalgal state[81]. Scraping species (e.g., Serranidae, Scarinae) gouge into the underlying reef substrate when feeding, removing microscopic plant material on and in the reef substrate[82]. Together, these processes are essential to maintaining coral-dominated states on coral reefs. Maintaining healthy herbivorous fish functional groups within coral reef fish assemblages is therefore crucial to reef resilience.

In Seychelles, East Africa, and other parts of the WIO, small herbivorous coral reef fish species are also commercially important fisheries species and a vital source of protein in coastal subsistence fisheries[83] [84]. The rabbitfish constitute a significant portion (>40% by weight) of the inshore reef fishery catch[85], with the shoemaker spinefoot (*Siganus sutor*), a WIO endemic, being one of the most sought-after, commercially-important and subsequently well-studied herbivorous fishes in the region[86] [87].

# 3. ECONOMY, ETHNO-SOCIOLOGY, SOCIO-ECOSYSTEM

## 3.1. SEYCHELLES

Seychelles, officially the Republic of Seychelles (French: République des Seychelles; Creole: La Repiblik Sesel), is an archipelagic island country in the Indian Ocean at the eastern edge of the Somali Sea. It consists of 115 islands. Its capital and largest city, Victoria, is 1,500 km (932 mi) east of mainland Africa. Other nearby island countries and territories include Comoros, Madagascar, Mauritius, and the French overseas regions of Mayotte and Réunion to the south; and Maldives and the Chagos Archipelago (administered by the United Kingdom as the British Indian Ocean Territory) to the east. Its estimated population of 98,462 (Mid-2020 National semi-annual estimate) is the smallest population of any sovereign African country[88].


Figure 16: Map of Seychelles (Rainer Lesniewski)

Seychelles was uninhabited prior to being encountered by Europeans in the 16th century. It faced competing French and British interests until coming under full British control in the late 18th century. Since proclaiming independence from the United Kingdom in 1976, it has developed from a largely agricultural society to a market-based diversified economy, characterized by rapidly rising service, public sector, and tourism activities. From 1976 to 2015, nominal gross domestic product (GDP) grew nearly 700% and purchasing power parity almost 1,600%. Since the late 2010s, the government has taken steps to encourage foreign investment[89].

Today, Seychelles boasts the highest nominal per capita GDP of any African nation and is considered a high-income country. It has the second-highest Human Development Index of any African country after Mauritius. It is one of only two African countries classified as a high-income economy by the World Bank (the other being Mauritius)[153].

Seychellois culture and society is a mix of French, British and African influences, with more recent infusions of Chinese, Iranian and Indian elements. The country is a member of the United Nations, the African Union, the Southern African Development Community and the Commonwealth of Nations.

The economy of Seychelles is based on fishing, tourism, processing of coconuts and vanilla, coir (coconut fibre) rope, boat building, crafts, printing, furniture and beverages. Agricultural products include cinnamon, sweet potatoes, cassava (tapioca), bananas, poultry and tuna[90] [91]. Seychelles tuna cannery is the main processing activity of the country and generates over 90 % of exports' revenue.

The public sector, comprising the government and state-owned enterprises, dominates the economy in terms of employment and gross revenue, employing two-thirds of the labour force. Government consumption absorbs over one-third of Seychelles' GDP.

The economy is primarily dependent on upmarket tourism, fisheries and financial services. There is a high dependency on tourism as a means of generating employment, foreign exchange and economic activity in Seychelles. This reliance on tourism has also spread across sectors, with resources in agriculture and forestry largely being seen as a means to generate activity in tourism, while further growth in ports and coastal transport now directly hinges on increased activity from cruise and leisure vessels. For the most part, there does not appear to be any sign that this reliance on tourism will subside. According to UNDP, due to the COVID pandemic, loss in the tourist sector is estimated at 70%, and there is a projected fiscal deficit of up to -7% due to foregone tax revenue across various sectors[92]. Thus, coastal communities are clearly vulnerable to fluctuations in tourist activity, which could become problematic in the future. The overwhelming importance of tourism for economic activity and employment in the country, both directly and indirectly, makes evident the importance of sustainable tourism, particularly as a means of preserving the entire Seychelles economy.

Outside of tourism, economic activity also appears highly concentrated in the fishery. The small-scale fishery does, however, face several obstacles. High investment costs, low returns and limited value-added development are obstacles in the sector, which have had a negative impact on the ability of producers to compete internationally. Anything causing a reduction in, or impacting, the small-scale fishery would also be detrimental to Port Victoria, which relies heavily on the spillovers of demand generated by small-the scale activity. The sector has also recently seen an influx of government subsidies and support, which, while helpful in providing incentives for production in the present, could, however, lead to overcapacity in the future. The industrial tuna fishing industry is an increasingly significant factor in the economy, with Port Victoria now being one of the most important trans-shipment and canning ports in the Indian Ocean.

Despite this dependence on mainly two sectors, there are clearly strengths and opportunities apparent in Seychelles that could be utilized to diversify the economy and subsequently strengthen livelihoods in the coastal zone. In relevance to the economy as a whole, the government has also recognized the necessity of increasing private-sector activity in the future, which, along with a stable and strong investment climate, should promote growth in foreign investment. However, because of its direct dependence on coastal tourism and nearshore and offshore fisheries, Seychelles' economy is also extremely vulnerable to external shocks and particularly those that impact the coastal and ocean environment[6].

Seychelles is clearly very dependent on fisheries and tourism for its economy and to the livelihoods of its people. Both of these sectors account for nearly 50% of GDP. Unsurprisingly then, the country is very focused on sustainability in the marine sectors. Nearly all economic activity depends on the country's reliable access to renewable and sustainable coastal and ocean resources, which leaves the population extremely vulnerable to any impacts on these resources. There is a clear recognition within the country of the need for a sustainable management approach involving both government and the private sector[6].

## Seychelles national governance and institutions[93]

*Ministry of Agriculture, Climate Change and Environment*

In the context of an offshore joint management area, this Ministry deals with the following areas:

- Biodiversity
- Wildlife (Trade and Conservation, Enforcement and Permits)
- National Parks
- Environmental Assessment and Permitting
- Risk and Disaster Management
- Meteorology, Climate Change, Mitigation and Adaption, and Information
- Environmental Information and Data
- Public Education and Community Outreach
- Multilateral Environmental Agreements (MEAs)

The Ministry aims to promote, coordinate and develop an ecologically balanced natural environment in keeping with constitutional exigency and in line with national sustainable socio-economic development objectives of the Seychellois community and beyond, and gradually reduce dependence on fossil fuel by promoting renewable energy and energy efficiency[6].

Seychelles has 17 Marine Protected Areas (MPAs) which are managed by six different organizations based on the legislation under which the protected area was designated. The Seychelles Parks and Gardens Authority (SPGA) is responsible for six, the Seychelles Fishing Authority is responsible for the four shell reserves, Nature Seychelles and the Royal Society for Nature Conservation (RSNC) jointly manage one (Cousin Island), the Seychelles Islands Foundation (SIF) manages the World Heritage Site of Aldabra Atoll (Special Reserve) and three are managed by the IDC (Island Development Company) in collaboration with Island Conservation Society (ICS). MPAs or "Marine parks" in Seychelles are regions in which human activities have been restricted in order to conserve the natural environment including habitats and ecosystems of special concern. MPAs help to protect the marine ecosystem from long-term human impacts, and maintain the marine biodiversity of areas, as well as the current food chains and webs. The main purpose of MPAs is to provide refuge/shelter for many species in their native habitats, including their related ecological processes, to recover from the pressures imposed from the non-protected regions of the ocean.

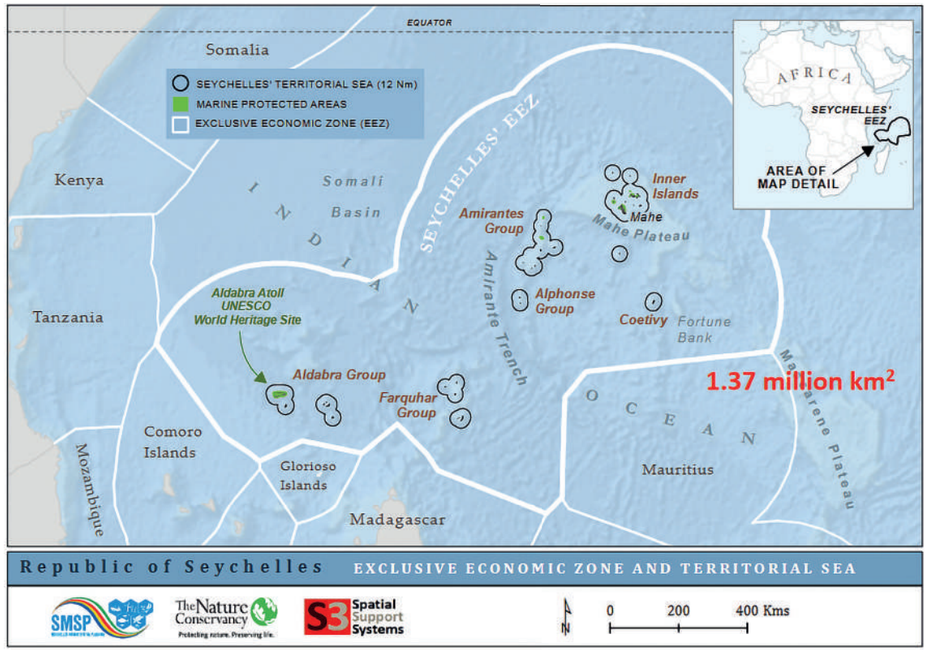



Figure 17: Seychelles Exclusive Economic Zone and Territorial Sea, with Marine Protected Areas.

Island Conservation Society promotes the conservation and restoration of island ecosystems of Seychelles, the sustainable development of islands, and awareness of their vulnerability and vital importance to the planet's biodiversity. Founded in 2001, ICS today runs conservation centres on five islands across Seychelles, with more planned for the future when funding permits[94].

With the support of Save Our Seas Foundation, Seychelles' Ministry of Environment recently proposed the designation of the beautiful coralline islands of St Joseph Atoll and its surrounding waters as a part of a larger zone 2 MPA. Formal protection of these tiny pockets of pristine wilderness will provide a sanctuary for some of the world's last remaining giant tortoises and healthy communities of sharks, rays and turtles, making D'Arros and St Joseph the '*Aldabra of the Amirantes*'.[95]

*Ministry of Fisheries and Blue Economy*

The Ministry of Fisheries is responsible, among other areas, for the National Fisheries Policy and Strategy (2019) which implements Seychelles Fisheries Act 2014. The policy objective is "to *provide effective, efficient, transparent and accountable service delivery through a participatory approach to ensure long-term sustainable fisheries and aquaculture management and conservation so that the sector continues to play a key role in the sustainable development of the country and the socio-economic well-being of the Seychellois nation*". The Policy focuses on ecosystem-based fisheries management and the introduction of rights-based approaches, optimizing revenue from sustainable fisheries and aquaculture, providing employment and promoting local ownership.

In 2018 the Government approved Seychelles Blue Economy Strategic Policy Framework and Roadmap 2018-2030 to guide the sustainable development of its large ocean domain (See 3.3. Blue Economy). The Roadmap is a strategic whole-of-government framework which guides implementation at several levels of the national administration, including the Ministries of Fisheries, Tourism, Environment and Climate Change, and in that acknowledges that a key priority of the government

going forward is to work with the private sector to create opportunities for Seychellois entrepreneurs and to reduce socio-economic vulnerabilities. The Blue Economy Department, now under the Ministry of Fisheries, has responsibility for coordinating whole of government implementation and reporting.

**Seychelles Fishing Authority**

The Seychelles Fishing Authority (SFA) is a parastatal organization which functions as the executive arm of Government for fisheries and related matters. The Authority was created in August 1984 by the Seychelles Fishing Authority (Establishment) Act, at a time of intense development in the sector.

The long-term policy of the Government of Seychelles for the fishing industry is the "*promotion of sustainable & responsible fisheries development & optimization of the benefits from this sector for present and future generations*". It is anticipated that this will be achieved via the following:

- Conservation & management of marine resources in order to ensure the sustainability and long-term viability of the industry.
- Maximum generation of employment.
- Maximization of revenue from fisheries & other related activities.
- Promotion of an integrated economy.
- Food supply and food security enhancement.
- Promotion of safety at sea.

The SFA is committed to achieving the above objectives via the following activities and services:

- Policy Development & Planning.
- Fisheries Research.
- Fisheries Management.
- Fisheries Infrastructure Development.
- Monitoring, Control and Surveillance.
- Economic planning and management.

The SFA works in close collaboration with the Ministry of Agriculture and Fisheries, Ministry Natural Resources, Ministry of Environment and Energy, Seychelles Coast Guard, Seychelles Ports Authority, other Government institutions, fishermen and boat owners' associations, NGOs as well as various overseas partners. Stakeholder consultations are held on a regular basis regarding the development of the sector[6].

*Ministry of Finance, Economic Planning and Trade*

The Ministry of Finance and Trade is responsible for developing and implementing the National Development Strategy Vision 2033 and the 5 years National Development Strategy 2019-2023. The Strategy goal is "*a resilient, responsible and prosperous nation of healthy, educated and empowered Seychellois living together in harmony with nature and engaged in the wider world*". It is implemented through the three key pillars of innovative economy through science, economic transformation for shared prosperity, and environmental sustainability and resilience.

**Department of Risks and Disaster Management (DRDM)**

Seychelles has several emergency response plans related mainly to impacts of severe weather that fall under the jurisdiction of the DRDM and the National Disaster Committee and National Emergency Operations Centre (NEOC). The DRDM is responsible for reviewing the Tsunami/cyclone Response Plan and also other National Disaster Response Plans such as oil spills. DRDM also plays a key role in directing the response operations at the national level from the NEOC located at the Central Police Headquarters in Victoria, Seychelles.

Seychelles Coast Guard is the designated authority for oil spills. Oil spill contingency plans are made up of basic guidelines and maps which are easy to understand, and anyone can follow the steps for the clean-up teams. On these maps, essential information for the oil spill responders are provided which show where the various resources are and indicate environmentally sensitive areas as well. The main uses of sensitivity mapping programmes range from planning practical site-specific bay/shore protection and clean-up to strategic planning for larger less accessible areas. Furthermore, these maps show the resources of great importance in a 360° direction from the event that the oil slicks can possibly travel. As a result, this alerts the responsible parties/authorities to prepare for the potential environmental issues that can arise, and the plan shall provide the practical information for spill response and shoreline clean-up (e.g., dispersants or booming points). Such contingency plans and associated maps aim to deal with subtidal habitats as well as sensitive shoreline areas. These would include coral reefs, seagrass beds and kelp beds. The sensitivity maps therefore need to identify sensitive areas related to relatively shallow water fishing areas (e.g., crabs, lobsters); shellfish beds; fish and crustacean nursery areas; etc.

**National Foundations**

*Seychelles Islands Foundation (SIF)[96]*

The SIF is a non-profit charitable organization that was established as a public trust by the government of Seychelles in 1979. It manages and protects the UNESCO World Heritage Sites of Aldabra Atoll and the Vallée de Mai as well as the Fond Ferdinand reserve. It has the President of Seychelles, Wavel Ramkalawan, as Patron. The foundation is mandated and dedicated to ensuring that the World Heritage Sites of Seychelles are well-managed protected areas where conservation, research, education and tourism are sustainably balanced. A major focus is on scientific research to direct, support and improve conservation management of the unique biodiversity and ecosystems of these two very different sites.

*Island Conservation Society (ICS)[162]*

In late 2000, a small group of committed individuals came together to create the first conservation body dedicated to working in the outer islands of Seychelles. In April 2001, ICS was legally declared an NGO. Island Conservation Society promotes the conservation and restoration of island ecosystems of Seychelles, the sustainable development of islands, and awareness of their vulnerability and vital importance to the planet's biodiversity. Today, ICS runs conservation centres on five islands across Seychelles, with more planned for the future when funding permits.

*Nature Seychelles[97]*

Nature Seychelles is a leading environmental organization in the WIO. It is the largest and oldest environment NGO in Seychelles, where it is involved in environmental conservation and management. Nature Seychelles manages the Cousin Island Special Reserve, one of the oldest marine protected areas in Seychelles.

The primary objective of Nature Seychelles according to its statutes is to improve biodiversity conservation through scientific, management, educational and training programmes.

To achieve the above primary objective, Nature Seychelles has the following sub-objectives:

- To study, research and assess the status of biodiversity.
- To manage areas important for conservation.
- To seek ways and means to assist official efforts for the management and conservation of biodiversity.
- To increase and propagate scientific knowledge of biodiversity and educate the public.
- To implement relevant training programmes.
- To fund-raise for conservation programmes.
- To promote partnership/ cooperation between like-minded individuals and organizations.

*The James Michel Blue Economy Research Institute and the James Michel Foundation[98]*

Located in the University of Seychelles, they conduct marine research in collaboration with international partners and have participated in a number of international expeditions in the region (e.g., Nekton and Greenpeace). Together with IUCN, this Foundation supports the Great Blue Wall Initiative, a regionally connected network to develop a regenerative blue economy[99].

*The Danny Faure Foundation[100]*

Its mission is to contribute towards the sustainable development of Seychelles and to join the global community in its efforts to achieve a more equitable, just, sustainable, and healthy planet, for the present generation and the future generations to come, by promoting ocean governance, blue economy, and good governance.

# 3.2. MAURITIUS

Mauritius (French: Maurice; Mauritian Creole: Moris), officially the Republic of Mauritius, is an island nation in the Indian Ocean about 2,000 km (1,200 mi) off the southeast coast of the African continent, east of Madagascar. It includes the main island (also called Mauritius), as well as Rodrigues, Agaléga and Saint Brandon. The islands of Mauritius and Rodrigues, along with nearby Réunion (a French overseas department), are part of the Mascarene Islands. The capital and largest city, Port Louis, is located in Mauritius, where most of the population is concentrated. The country spans 2,040 km2 (790 mi2) and has an exclusive economic zone covering 2.3 million km2 [101].


Figure 18: Map of Mauritius

By some accounts, Arab sailors were the first to discover the uninhabited island, around 975 AD, and they called it Dina Arobi, but this has not been confirmed. The earliest confirmed discovery was in 1507 by Portuguese sailors, who otherwise took little interest in the islands. The Dutch took possession in 1598, establishing a succession of short-lived settlements over a period of about 120 years, before abandoning their efforts in 1710. France took control in 1715, renaming it Isle de France. In 1810, the island was seized by Great Britain, and four years later France ceded Mauritius and its dependencies to Britain. As a British colony, Mauritius included Rodrigues, Agaléga, Saint Brandon, Tromelin, the Chagos Archipelago, and, until 1906, Seychelles[102]. Sovereignty over Tromelin is disputed between Mauritius and France, as it was not specifically mentioned in the Treaty of Paris[103]. Mauritius remained a primarily plantation-based colony of the United Kingdom until independence in 1968.

In 1965, three years before Mauritius became independent, the UK split off the Chagos Archipelago from Mauritian territory, and also split off the islands of Aldabra, Farquhar, and Desroches from Seychelles, to form the British Indian Ocean Territory (BIOT)[104]. The local population was forcibly expelled and the largest island, Diego Garcia, was leased to the United States. The UK has restricted access to the Chagos Archipelago, barring entry to casual tourists (boats are allowed to visit), the media, and former inhabitants[105]. The sovereignty of the Chagos is disputed between Mauritius and the UK. In February 2019, the International Court of Justice issued an advisory opinion ordering the UK to return the Chagos Islands to Mauritius as rapidly as possible to complete the decolonization of Mauritius.

Owing to its geographic location and centuries of colonialism, the people of Mauritius are highly diverse in ethnicity, culture, language and faith. It is the only country in Africa where Hinduism is the most practised religion[106] [107]. The island's government is closely modelled on the Westminster parliamentary system, and Mauritius is highly ranked for democracy and for economic and political freedom. Mauritius is the only African country to be in the "very high" category on the Human Development Index. According to the World Bank, the country is classified as a high-income economy[108]. Mauritius is also ranked as the most competitive, and one of the most developed economies in the African region[109]. The country is a welfare state. The government provides free universal health care, free education up through the tertiary level and free public transportation for students, senior citizens, and the disabled[110]. In 2019, Mauritius was ranked the most peaceful African country by the Global Peace Index[111].

The economic history of Mauritius is characterized by two eras: Sugar and Textiles. Since the Dutch colonization and up to 2006/2007, sugar production shaped the economic, social and environmental landscape. The peak years were 1974/1975 which was the sugar boom for the Sugar Industry. The textile era which started in 1983 superseded sugar within a couple of years to reach its peak in 1988 in terms of employment creation and its subsequent multiplier effect on the economy. Textiles, just as sugar, had its share in the transformation of the socio-economic life of the Mauritians with the creation of about 80,000 jobs for women in the textile factories.

This change in emphasis (as a consequence of the collapse in demand and price for Mauritian sugar) resulted in a new strategy to restructure the sugar industry through centralization and transformation of the sugar industry into a cane industry. This required a paradigm shift from sugar production to that of electricity, ethanol, refined sugar, rum and other by-products.

So, in the past, the Mauritian economy was mainly driven by the agricultural sector focused on sugar production and export. At present, manufacturing, tourism and financial services are the major sectors of the economy in addition to the agricultural sector. Emerging activities include a land-based oceanic industry (e.g., oceanarium, salt extraction, land-based aquaculture, etc.), marine industry (seafood and aquaculture), biotechnology, and medical hubs.

Tourism is a strong sector in the Mauritius economy and has grown at a rate of 9% annually between 1985 and 2005. While the development of the sector has been less steady since 2005, growth is still apparent with investment in the hotel and restaurant sector increasing from Rs 4.2 billion to Rs 12.2 billion between 2005 and 2009, and total arrivals increasing from 761,063 to 871,356 during the same period. The growth rate in the sector for 2016 was 7.8% of GDP compared to 3.8% of the national GDP average. Tourism growth for 2017 was around 6.6% whereas the national GDP was around 3.9%. Tourist arrivals in 2016 grew by 10.8%, exceeding the growth of international tourist arrivals, which according to the United Nations World Tourism Organisation (UNWTO) reached 3.9%[112], and it was expected to go on growing, but the COVID crisis stopped this. Numerous environmental issues have been raised in relation to the sector, including coastal erosion and coral reef depletion, both of which threaten the unique natural base that drives the sector. Poorly regulated land development and inadequate wastewater management have also been highlighted as significant environmental issues in the sector. There are many opportunities for ecotourism, which could facilitate a tourism-conservation nexus and produce greater asset protection on the coast.

The Fisheries sector in Mauritius employs an estimated 11,000 people and contributes 1.5% to GDP. Total domestic production in the sector is valued at Rs 1 billion. The artisanal sub-sector supplies the majority of fish produced domestically. However, 60% of all domestic fish consumption is still imported. It is estimated that artisanal fishing contributes about 1,500 tonnes annually out of an estimated annual total fish production of 9,000 tonnes. Fisheries resources are mainly exploited by registered fishers, which highlights some degree of management in the sector. New institutions such as the Fishermen Training and Extension School, the Fishermen Welfare Fund and the Fishermen Investment Trust have been set up to consolidate the sector and specially

to build the capacity of the artisanal fishermen and enhance their socio-economic condition. The potential for value addition, as well as product development, is also promising for export growth. Thus, while resources, to this point, appear somewhat strained, there are clearly attainable opportunities to expand the sector sustainably[6]. However, due to the current probable overexploitation of the Bank fish stocks as well as tuna stocks, Mauritius fisheries expansion must be qualified by the need for any future fisheries to be sustainable.

Financial services are a growing business in Mauritius, which is far less dependent on fisheries than Seychelles. Most of its GDP (>70%) comes from services (including tourism). There has been some focus on ecotourism but coastal degradation, habitat destruction and land-based impacts generally have taken their toll on the coastline and reef systems. Mauritius is looking for further opportunities to expand its service industry and to make the best use of any available resources,

Notwithstanding the inevitable challenges, there are many examples of progress being made. Positive engagement in local development by the private sector can be found in both the energy and coastal mining sectors. Oil and gas companies are engaging in a wide variety of social development activities in the region and all the mainland countries such as the construction of community clinics, rehabilitation of roads and community buildings, and support to cyclone-affected populations. Similar contributions have been made by companies engaged in coastal mining[6].

## Mauritius national governance and institutions

There is presently no specific ocean management policy adopted for Mauritius, but Mauritius Oceanography Institute (see below) envisages the formulation of an ocean management policy in the coming five years and a new department of Ocean Affairs (also below) has been established in the last 12 months within the Office of the Prime Minister. A recent framework study commissioned by the Ministry of Environment and Sustainable Development has made a recommendation to amend the law to make provision for the authorization and regulation of the construction, operation and use of any installation or structure within the territorial sea, internal waters, archipelagic waters and historical waters of Mauritius. This would include requirements that specified activities may not be carried out within the maritime zones of Mauritius except within an area leased for that purpose and in accordance with that lease.

The Fisheries and Marine Resources Act provides for sustainable methods of exploitation of marine resources. The Act defines the management, conservation and protection of fisheries and marine resources and the protection of marine ecosystems within the Republic of Mauritius and its territorial waters[6].

### *Department for Continental Shelf, Maritime Zones Administration[113]*

This Department of the Ministry of Public Service, Administrative and Institutional Reforms formerly Office of Ocean Affairs and Development, Prime Minister's Office, was established in 2013 with the vision to undertake the effective development and management of ocean resources of the maritime zones ensuring their sustainable uses and long-term benefit for the nation.

It functions as a focal point for all activities concerning the Joint Management Area (JMA) in the Mascarene Plateau region and has the following objectives:

- Ensure orderly, safe, rational management of ocean resources including the seabed area and the underlying sub-soil.
- Ascertain sovereign right for the purpose of exploring and exploiting our ocean resources.
- Carry out the delimitation of our maritime boundary as provided for, under international conventions.
- Develop regulatory and operational frameworks to enable exploration and exploitation activities in our maritime zones and oversee upstream activities of the Petroleum sector.
- Rationalize and harmonize all ocean-resources related matters.
- Contribute to food & energy security and maritime safety.

As the focal office for the JMA, it has coordinated the establishment of a legal and regulatory framework for developing offshore petroleum activity in the JMA. In concert with the Commonwealth Secretariat, it has worked under the Joint Commission to formulate a Model Agreement for offshore petroleum, a Fiscal & Taxation code, Environmental and Safety codes and best practices. The office is presently finalizing the Strategic document for the Management of the JMA.

### *Mauritius Oceanography Institute[114]*

Established in 2000, the Mauritius Oceanography Institute (MOI) has several strategic activities for which it is responsible. These include:

- Coordination of all oceanographic activities.
- Provide technical support for the delimitation of the Continental Shelf and Exclusive Economic Zone.
- Undertaking advanced scientific research in oceanography.
- Facilitating capacity building.
- Transforming research to make it more accountable and visible.

The MOI aims to undertake quality scientific research in collaboration with local and international institutions, to contribute to the regional and global matrix of oceanographic science. In this respect, MOI recognizes that the Mascarene Plateau is an important area for oceanographic research. It is one of the few places where a large ocean plateau is isolated from any continental land mass.

### *Ministry of Environment, Solid Waste Management and Climate Change[115]*

It is responsible for a range of activities:

- Devise appropriate legal and policy frameworks regarding environment related issues such as climate change, solid and hazardous waste management, disaster risk reduction and beach management to effectively respond to emerging challenges.
- Incorporate climate change adaptation and mitigation measures to ensure sustainable development initiatives.
- Preserve beaches through integrated coastal zone management.
- Devise an effective waste management policy to minimize the negative impacts of solid and hazardous wastes.
- Ensure effective disaster preparedness and response to enhance the safety and security of the citizens.

This Ministry is responsible for ocean-related (non-natural) disasters, including oil spills. In case of such incidents, the ministry alerts all the relevant authorities and actions are taken according to established rules and regulations. In particular, the National Oil Spill Contingency Planning (NOSCP) provides the framework for oil spill response. It is activated in the event of a spill occurring in the territorial zone of the Republic of Mauritius. This NOSCP document is regularly updated by the Ministry of Environment Sustainable Development, Disaster and Beach Management.

In July 2020, the Japanese bulk carrier *Wakashio* ran aground on a coral reef offshore of Pointe d'Esny, south of Mauritius[116], close to the Marine Protected Area designated as the Second Wetland of International Importance under the 'Ramsar Convention' which is renowned for its remarkable coral garden and is home to more than 1,000-year-old brain corals (*Lobophyllia* sp.), the largest brain coral in the Indian Ocean[117]. The government activated its NOSCP the following day. Despite the deployment of preventive measures and pumping the oil from the ship's tanks, some days after the grounding, an estimated 1,000 tonnes of oil spilled into the ocean. Two weeks after the incident, the Mauritian government declared the incident a national emergency[118]. It is considered by some scientists as the worst environmental disaster ever in Mauritius.

The Department of Environment (DOE) of the parent Ministry is responsible for oil pollution preparedness and response. Being the focal point for receipt and transmission of oil pollution reports, the DOE is entitled to act on behalf of the state to request or provide assistance as required, following approval by the Prime Minister's Office. A National Coordination Committee at the Ministry of Environment and Sustainable Development is responsible for developing, implementing, reviewing and updating the NOSCP. The Committee, chaired by the Permanent Secretary of the Ministry of Environment Sustainable Development, Disaster and Beach Management, comprises representatives from various Ministries, the Mauritius Ports Authority, as well as oil/petroleum companies. The national plan integrates local plans, such as Port-Louis and Rodrigues and petroleum companies' contingency plans and is integrated in the regional oil spill contingency plan.

So far, the main constraints to effective oil spill response have been a lack of effective coordination and a lack of awareness or communication of the existing plans and their implementation mechanisms (See

above: the *Wakashio* oil spill). There is a general lack of meteorological data as well as an absence of good hydrodynamic models for tracking oil spills. Regularly updated high resolution sensitivity and vulnerability maps are needed. Some of these gaps could be addressed by encouraging and developing integrated approaches, including strengthening intersectoral coordination in disaster management, developing models that could be adapted for different areas and for a broad spectrum of events, promoting more use of space technology for more efficient communication, and establishing a central communications unit.

### *Ministry of Blue Economy, Marine Resources, Fisheries and Shipping*[119]

The mission of this ministry is to strengthen governance and harness the marine resources in the Mauritius Exclusive Economic Zone for fostering sustainable development as a contribution to human well-being, food security and poverty alleviation.

Its objectives are:

- To ensure long-term benefits of the sustainable use of marine resources.
- To develop local capacity in the blue economy.
- To improve ocean hazards management for greater climate resilience.
- To enhance efficiency as a Maritime Safety Administration.

This ministry is also responsible for identifying and proposing the designation of protected and/or sensitive areas. In January 2008, the Ministry commissioned a study of Environmentally Sensitive Areas (ESA) in Mauritius and Rodrigues and this was completed in April 2009. The study identified, classified and demarcated all the environmentally sensitive areas in Mauritius and Rodrigues, and prioritized ESAs for protection. The project also created a database for all ESAs to support and enhance decision making. In addition, the project also prepared a comprehensive management plan for ESAs. Furthermore, any attempts to increase areas designated as 'sensitive' or to expand any levels of protection can frequently lead to conflict and resistance.

In order to protect the marine biodiversity and conserve marine resources, several marine protected areas exist in the waters of the Republic of Mauritius. So far, there are two marine parks namely the Blue Bay Marine Park (3.53 km2) which is also a Ramsar site of international importance and the Balaclava Marine Park (4.85 km2). In addition, six Fishing Reserves, five Fisheries Reserved Areas, four Marine Reserves and a multiple Marine Protected Area in the southeast of Rodrigues are managed[120].

Environment Impact Assessments (EIAs) are a requirement for any form of development and aim to encourage developers to consider environmental issues at the conception and planning stage. They also stimulate developers to compare alternative technologies and adopt pollution prevention and control strategies. Many marine-related activities such as the construction of hotels, dredging, and building of walls and other hard structures are now regulated through the EIA mechanism as per the Environment Protection Act (EPA) 2002 and amended 2008[121].

In all cases, both Seychelles and Mauritius possess a functional legal system. Both countries possess environmental legislation, which is implemented and enforced with differing degrees of success, depending primarily on the ability to adequately monitor, control and survey relevant activities and then respond to and adequately prosecute transgressors. In some cases, current legislation may not adequately reflect the provisions of Conventions and Protocols to which a country has agreed and/or the provisions currently in force reflect those of a prior instrument which has since been updated, revised or replaced. In many cases, there may be a need for many legal instruments to be revisited and for a broad review of legal frameworks pertaining to the marine sector.

In addition, enforcement of current laws and regulations pertaining to the marine environment is far from effective. This concern has been highlighted by a number of regional fisheries projects in the region with a lack of monitoring, compliance and enforcement given as the primary reason for the failure of effective fisheries management throughout the WIO.

In many cases penalties are outdated, too small to act as a deterrent and not enforced by the courts. In fact, the current understanding of the importance of the marine environment is often not appreciated by local magistrates and there is a clear need for dissemination of information on the relevance of the marine environment to the well-being and the economy of the region, with a concomitant need to take transgressions more seriously, and strictly enforce regulations.

The overall WIO Large Marine Ecosystems Strategic Action Programme (SAP) has identified the need throughout the region for policy harmonization and realignment along with institutional strengthening and reforms in order to effectively implement a regional ecosystem-based management approach. Both Mauritius and Seychelles are party to this regional SAP process and therefore it will be important to continue to link the planned Joint Management Approach with ongoing and future efforts to implement, monitor and adaptively manage the agreed regional SAP (see 4.1.4.3 Regional Projects and Programmes).

## National Foundations

### *Mauritian Wildlife Foundation (MWF)*[122]

MWF is the largest NGO in Mauritius to be exclusively concerned with conserving and preserving the nation's endangered plant and animal species.

Its goals are:

- To save threatened Mauritian species through the restoration of entire ecosystems.
- To seek new information through field research, data management, captive studies and scientific collaboration for direct application to restoration methods and management.
- To share knowledge gained through restoration programmes with fellow Mauritian and international conservationists.
- To share the joys and benefits of native wilderness and wildlife with the Mauritian people.
- To secure the future of Mauritian species through income generation and sound management of human, fiscal and capital resources.

MWF's conservation projects are carried out in Mauritius including the offshore islets and Rodrigues. MWF works closely with local and international partners, with the long-term aim of recreating lost ecosystems by saving some of the rarest species from extinction and restoring the native forest. Another important part of MWF's work is to raise awareness about conservation issues through an education programme.

### *Environmental Protection and Conservation Organization (EPCO)*[123]

EPCO is a Mauritian NGO, founded in 1988, it has more than 30 years of experience working in the field of environment.

EPCO's goals are:

- To improve the conservation of biodiversity through educational, scientific management and training programmes.
- To improve the quality of life of the local community through management and conservation of natural resources.
- To ensure that the natural environment is used wisely and continues to be available for the benefit and enjoyment of future generations.
- To decrease vulnerability and improve adaptation capacity among poor local communities associated with climate change.

Its main areas of work are:

- 1. Awareness campaigns with the public.
- 2. Educational campaigns with primary and secondary schools.
- 3. Event management and organization – World Environment Day/World Wetlands Day.
- 4. Workshops on a wide range of environmental problems (climate change, marine ecosystem, environment awareness).
- 5. Poverty alleviation projects / Community-based projects.
- 6. Scientific and technical projects.
- 7. Data collection – Beach monitoring, snail trail of destruction, vulnerability indexes.
- 8. Corporate Social Responsibility Projects.
- 9. Consultancy in environmental management.
- 10. Internship/Volunteering Programmes.
- 11. Handmade/recycled crafts (Made in Heaven).

*Marine Megafauna Conservation Organization (MMCO)*[124]
The aims and objectives of MMCO, are the surveys, studies and protection of large endangered marine creatures. MMCO mainly focuses on whales, turtles and sharks in Mauritian waters. Its objective is to educate fishers, marine operators and local communities as to the importance of protecting and respecting these creatures. Since 2011 MMCO has been studying the population of resident sperm whales and migrating humpback whales that visit Mauritian waters between May and October each year.

*Mauritius Marine Conservation Society (MMCS)*[125]
MMCS's mission is "Conservation through Education". Its main objective is to promote awareness and appreciation of marine life and an interest in the need for marine conservation.

Since its creation, MMCS has developed various programmes aimed at preserving the ecosystem, for example: attributing greater value to submarine archaeology, stopping fishing practices using dynamite or underwater weapons, creating artificial reefs, identifying protected marine areas, keeping records of marine mammals driven ashore, identifying and protecting cetaceans as well as creating educational games based on the marine environment.

## 3.3. BLUE ECONOMY[6]

The exclusive economic zone (EEZ) of Seychelles comprises over one million km2 of ocean. Seychelles' comparative advantage for the 'blue economy' is clearly found in its natural environment. For example, the country's proximity to the migratory path of tuna in the WIO, along with its rich source of other pelagic and demersal fish, both highlight the great strengths of the small-scale fishery. Furthermore, the country's extraordinary biodiversity and conserved habitats have also been identified as key factors in attracting activity in the tourism sector. This is, however, why sustainability issues should not be undervalued, particularly in relation to the country's economy in the long term. Most, if not all, economic activity clearly depends on the country's coastal and ocean resources; thus, all measures to sustainably manage the use of these resources should be taken by both government and the private sector.

The Government of Seychelles recognizes the importance of its oceanic area as a space for sustainable development. It has been further noted formally that too often, economic development is separated from the context of the people it is supposed to benefit, and from the natural environment on which its future depends.

Seychelles is pursuing an overarching approach of Blue economic development whereby it will endeavour to empower its people to own a greater share of the blue economy and to get more value-added products from marine resources, whilst also ensuring their long-term viability. It has recognized the need to seek foreign investment and skills which are compatible with this ideal and to encourage associated joint ventures. The long-term aim would be to increase the national share of benefits from the use of Seychellois marine resources and building the resilience of marine ecosystems to the impact of climate change, recognizing that the Islanders are heavily dependent on the ocean not only for food security, but also for transportation and tourism activities.

The Seychelles blue economy roadmap is the overarching strategic framework for the sustainable development of the ocean which includes economic, social, environmental, and enabling objectives. The debt swap and the blue bond are financing mechanisms to be implemented by responsible ministries, in order to implement Marine Spatial Planning, as well as the designation and management of protected areas and the transition to sustainable small-scale fisheries.

In 2015, Seychelles entered into an agreement with the Paris Club to restructure its debt to the amount of USD21.6 million with the technical support of the Nature Conservancy. It committed the government to place 30% of its EEZ in marine protected areas and complete a marine spatial plan of its entire EEZ by 2020. According to the Seychelles News Agency[126], Seychelles reached its target of 30% ocean protection around some of its outer islands after 13 new areas were gazetted in March 2020 and, the implementation phase of the Marine Protected Areas in Seychelles is expected to start in 2022. The proceeds of the debt swap are managed by an independent Trust fund, The Seychelles Conservation and Climate Adaptation Trust (SeyCCAT) which disbursed annually USD700,000 in grants to community conservation and blue economy projects[127].

In 2018, the Republic of Seychelles launched the world's first sovereign blue bond–a pioneering financial instrument designed to support sustainable marine and fisheries projects.


Figure 19: Blue Bond, the Seychelles Model

The bond, which raised USD15 million from international investors, demonstrates the potential for countries to harness capital markets for financing the sustainable use of marine resources. The World Bank provides technical expertise and a bank guarantee in support of the blue bond with the Global Environment Facility (GEF) providing additional finance from its non-grant programme to bring down the costs to Seychelles. Three investors purchased the Blue Bond: Calvert Impact Capital, Nuveen, and U.S. Headquartered Prudential Financial, Inc. The use of the proceeds contributes to improved governance of priority fisheries and a transition to sustainable methods in particular artisanal fisheries. Grants and loans are disbursed through the Blue Grants Fund and Blue Investment Fund, managed respectively by SeyCCAT and the Development Bank of Seychelles (DBS)[128].

In 2018, the government of Seychelles approved the Seychelles Blue Economy Strategic Policy Framework and Roadmap (2018-2030). The Roadmap objective of creating sustainable and resilient wealth, sharing prosperity, and securing a healthy and resilient ocean is supported by a strong enabling agenda including integrated planning, good governance, research and development, maritime security, and financing[129]. Aware of its high dependence on fisheries and tourism, the Roadmap advocates diversification of those activities to generate greater revenue (e.g., though value chains) and explore new emerging sectors such as biotechnology, renewable energy, and oil and gas, in particular in the JMA shared with Mauritius.

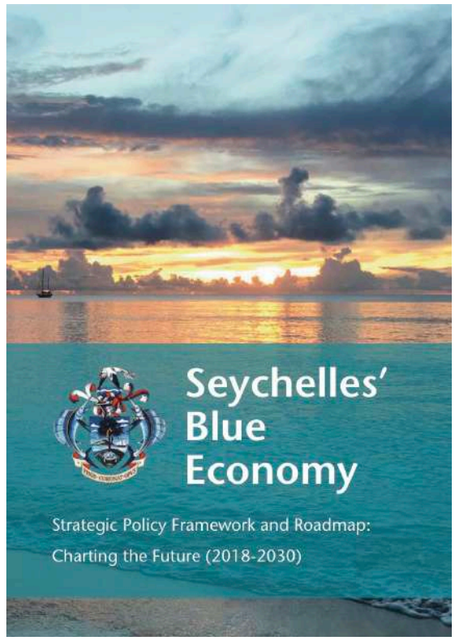



Figure 20: Seychelles' Blue Economy. Strategic Policy Framework and Roadmap: Charting the Future (2018-2030)

Seychelles has recognized some of the principal concerns that threaten its strategy as:

- Insecure food supplies from the ocean.
- Ocean acidification resulting from climate change.
- Coral bleaching resulting from climate change.
- The effects of sea-level rise resulting from climate change.

Seychelles' Blue Economy recognizes the importance of areas that support high levels of biodiversity and living marine resources as well as areas that act as key carbon traps (such as mangroves, seagrass beds and marshes) and that a blue economic approach must focus on management and protection of such areas, whilst also noting that the blue economy does not call for an end to development but rather aims for the development of resources in a balanced and sustainable manner.

As such, the rational exploitation of non-renewable resources such as hydrocarbon and mineral deposits also form an important component of the blue economy.

Seychelles' Blue Economy recognizes the need to build knowledge and technological capacity to fully realize the benefits of the resources within its EEZ and sovereign areas. Common to many Small Island States with large ocean domains Seychelles lack sufficient resources to document their ocean territories and effectively monitor activities, in particular illegal activities. They are therefore dependent on regional and international partnerships to inform management decisions and support effective monitoring, control and surveillance activities to ensure the effective and sustainable development of the blue economy[130 6].

Mauritius has an EEZ of 1.9 million km2 and an additional expanse of 396,000 km2 co-managed on the Continental Shelf with the Republic of Seychelles.

The Government of Mauritius has the vision to promote the ocean economy as one of the main pillars of development by optimizing the opportunities available to the country as an Ocean State. Such opportunities include:

- Fisheries sector.
- Development of deep ocean water applications (DOWA)[131].
- Commercial marinas.
- Bunkering.
- Aquaculture, etc.

A road map has been developed to encompass seven main areas of activities:

- Petroleum & mineral exploration.
- Fishing, seafood processing and aquaculture.
- Deep ocean water applications.
- Marine services.
- Sea port-related activities.
- Marine renewable energy.
- Ocean knowledge.

Mauritius realizes that the development of its ocean economy hinges on adopting the core principles of economic efficiency, social equity and partnership, and ecological sustainability and safety. It ensures the roadmap incorporates these principles while committing to fully developing the potential of the ocean economy[132].

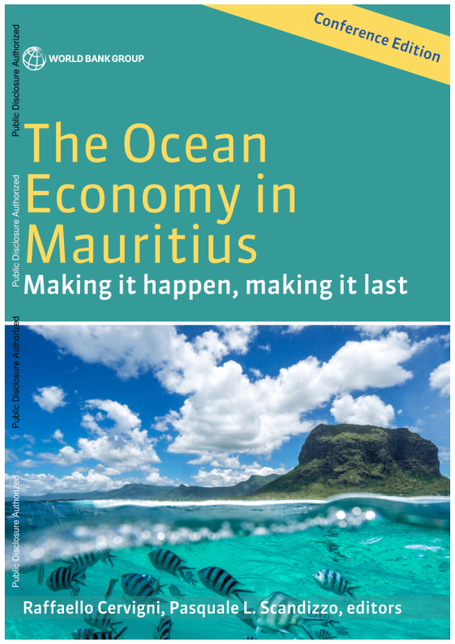



Figure 21: The Ocean Economy in Mauritius: Making it Happen, Making it Last

These two separate visions of an Ocean Economy (Mauritius) and a Blue Economy (Seychelles) are far from incompatible and can serve to reach their objectives through mutual cooperation and management.

# 4. GOVERNANCE OF THE REGION, MARITIME ZONES, INTERNATIONAL BODIES, POLICY, AND MANAGEMENT SCHEMES

## 4.1. MARITIME ZONES - JURISDICTIONS

### 4.1.1. EXCLUSIVE ECONOMIC ZONES

Countries have already agreed on many maritime boundaries in the region (Figure 21). Several agreements are outstanding: including Comoros / Mozambique; Comoros / Tanzania; Comoros / Madagascar; Mozambique / South Africa and Madagascar / Mozambique.

| Parties | Date | Agreement |
|---|---|---|
| Kenya/ Tanzania | "17 Dec 1975 to 9 Jul 1976" | Exchange of Notes between the United Republic of Tanzania and Kenya concerning the Delimitation of the Territorial Waters Boundary between the two States, 17 Decembre 1975 - 9 July 1976 |
| Mozambique / Tanzania | 28 Dec 1988 | Agreement between the Government of the United Republic of Tanzania and the Government of the People's Republic of Mozambique regarding the Tanzania / Mozambique Boundary |
| France / Seychelles | 19 Feb 2001 | Agreement between the Government of the French Republic and the Governement of the Republic of Seychelles concerning Delimitation of the Maritime Boundary of the Exclusive Economic Zone and Continental Shelf of France and of Seychelles |
| Seychelles / Tanzania | 23-janv-02 | Agreement between the United Republic of Tanzania and the Governement of the Republic of Seychelles on the Delimitation of the Maritime Boundary of the Exclusive Economic Zone and Continental Shelf |
| France / Madagascar | 14 Apr 2005 | Agreement between the Government of the French Republic and the Governement of the Republic of Madagascar concerning the delimitation of maritime spaces located between the Reunion Island and Madagascar |
| Mauritius / Seychelles | 29-juil-08 | Agreement between the Government of the Republic of Mauritius and the Governement of Seychelles on the Delimitation of the Exclusive Economic Zone between the Two States |
| Kenya/ Tanzania | 23-juin-09 | Agreement between the United Republic of Tanzania and the Republic of Kenya on the Delimitation of the Maritime Boundary of the Exclusive Economic Zone and Continental Shelf (with map) |
| Mauritius / France | 2 Apr 1980 | Agreement between the Government of the French Republic and the Governement of the Republic of Mauritius concerning Maritime Boundary Delimitation between Reunion Island and Mauritius Island |
| Mauritius / Maldives | na | ITLOS Case No. 28. Dispute concerning delimitation of the maritime boundary between Mauritius and Maldives in the Indian Ocean (Mauritius/Maldives) |

Figure 22: Maritime Boundary agreements in the WIO[133]



### 4.1.2. CONTINENTAL SHELVES AND EXTENSION OF THE CONTINENTAL SHELVES

All countries, except Comoros (which does not have a claim), have lodged claims for an extended continental shelf with the United Nations Commission on the Limits of the Continental Shelf (CLCS).

| Country | Date | CLCS ref. |
|---|---|---|
| Joint submission by the Republic of Mauritius and the Republic of Seychelles - in the region of the Mascarene Plateau | 1 December 2008 | CLCS/62. 66, 70 |
| Yemen - in respect of south east of Socotra island | 20 March 2009 | CLCS/68 |
| South Africa - in respect of the mainland of the territory of the Republic of South Africa | 05 May 2009 | CLCS/68, 83, 98 |
| Joint submission by France and South Africa - in the area of the Crozet Archipelago and the Prince Edward Islands | 06 May 2009 | CLCS/68, 80, 83 |
| Kenya | 06 May 2009 | CLCS/64, 85, 90 |
| Mauritius - in the region of Rodrigues Island | 06 May 2009 | CLCS/64, 83 |
| Seychelles - concerning the Northern Plateau Region | 07 May 2009 | CLCS/64, 93, 105 |
| Mozambique | 07 July 2009 | CLCS/70 |
| Somalia | 21 July 2014 | CLCS/95 |
| Mauritius - concerning the Southern Chagos Archipelago region | 26 March 2019 | |
| Madagascar | 29 April 2011 | CLCS/72 |
| united Republic of Tanzania | 18 January 2012 | CLCS/76 |

Source: https://www.un.org/Depts/los/clcs_new/comission_submissions.htm.
Submissions with CLCS reference in bold have been adopted

Figure 23: Extended Continental Shelves (ECS) Claims[208]

The 2050 Africa Integrated Maritime Strategy (AIMS)[134] proposes the establishment of a Combined Exclusive Maritime Zone of Africa (CEMZA)[135]. However, the formal process for identifying how this might be achieved has not been initiated. In this regard, it can be noted that, although the EU legislates (EU Marine Strategy Framework Directive) for the governance of 'EU waters', there is no EU combined maritime zone, as the EU Member States retain sovereignty over their maritime areas. They share only a common fisheries policy.

In 2012, Mauritius and Seychelles agreed to establish a JMA (see 4.1.3 Mauritius – Seychelles JMA) in which the two States exercise sovereign rights jointly for the purpose of exploring the continental shelf and exploiting its natural resources. The JMA is enforced by two treaties, namely the Treaty Concerning the Joint Exercise of Sovereign Rights over the Continental Shelf, and the Treaty Concerning the Joint Management of the Continental Shelf, both signed on 13 March 2012 (entry into force, 18 June 2012)[208].

Historically considered to be beyond national jurisdiction, the Mascarene Plateau was the subject of a successful joint application by the governments of Seychelles and Mauritius, under the United Nations Convention on the Law of the Sea (UNCLOS) Commission on the Limits of the Continental Shelf, to extend their Outer Continental Shelf. Hence, the seabed is jointly managed by Mauritius and Seychelles, while the water column remains in the high seas. The Joint Management Treaty gives the governments the opportunity to exploit the marine resources in an additional maritime zone of 396,000 km2 on the Mascarene Plateau[4].

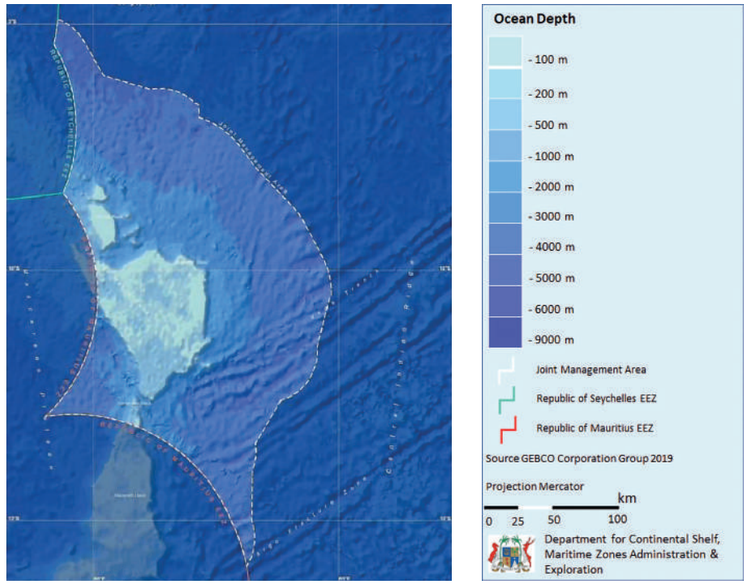



Figure 24: Geographic Location and Extent of the Joint Management Area (in UNDP JMA Demonstration Project Document)

The continental shelf as defined by UNCLOS is that part of the seabed over which a coastal State exercises sovereign rights with regard to the exploration and exploitation of natural resources including oil and gas deposits as well as other minerals and biological resources of the seabed. The legal continental shelf extends out to a distance of 200 nautical miles from its coast, or further if the shelf naturally extends beyond that limit.

Where the continental shelf extends beyond 200 nautical miles a State is required by UNCLOS (Article 76) to make a submission to the CLCS. This submission sets out the coordinates of the outer limits of the shelf and is accompanied by technical and scientific data to support the claim. The Commission assesses the limits and data submitted by the coastal State and makes recommendations. The outer limits of the continental shelf established by a coastal State based on these recommendations are final and binding under UNCLOS.



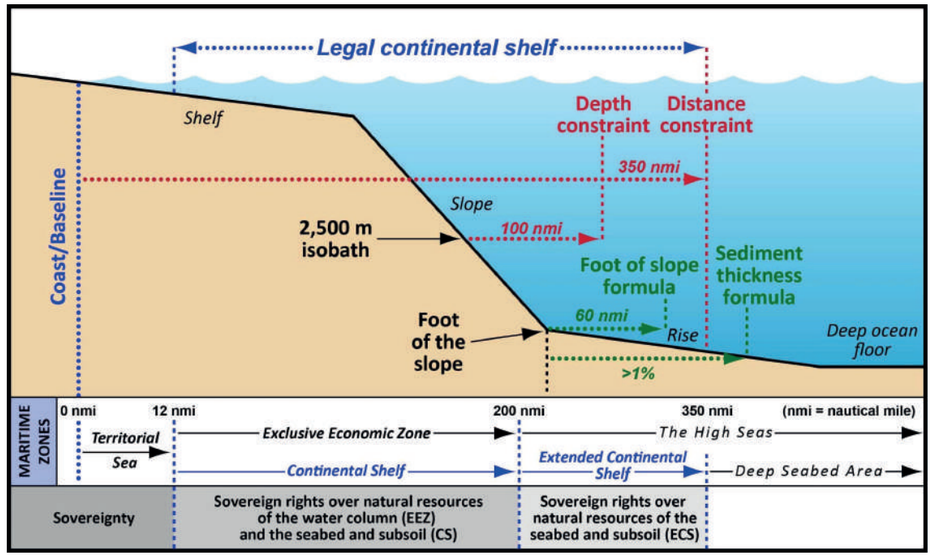



Figure 25: Maritime zones under the UNCLOS (Geoscience, Australia)

Most of the Mascarene Plateau falls within the EEZs of either Mauritius or Seychelles, or within the newly designated JMA for their extended continental shelves (ECS). Under UNCLOS, a coastal State can extend its territorial claim to the ocean floor if the surrounding continental area or the natural prolongation of its land territory extends more than 200 nautical miles offshore. The maximum limit of this additional area is defined by the outer limit of the continental margin (but not exceeding 350 nautical miles from the baseline or 100 nautical miles from the 2,500 m isobath[136]).

Management of ECS areas has specific complexities that can impact on any effective intent for sustainable development and resource exploitation within the context of an ecosystem-based management approach. Although the coastal State exercises sovereign rights over the ECS for the purposes of exploring it and exploiting its natural resources, living or not, the State has no control over any living organisms above the shelf that are beyond its EEZ. Furthermore, the rights of the coastal State over the continental shelf do not extend to or affect the legal status of the super-adjacent waters (i.e., the overlying water column) or of the air space above those waters. So, there is a potential legal conflict when fishing activities such as trawling under the jurisdiction of Regional Fisheries Management Organizations (RFMOs) managing high seas fisheries has an impact on seafloor ecosystems and the marine genetic resources which are managed by the coastal State.

The exercise of the rights of the coastal State over the continental shelf must not infringe or result in any unjustifiable interference with navigation and other rights and freedoms of other States as provided for in UNCLOS[6].

### 4.1.3. MAURITIUS – SEYCHELLES JOINT MANAGEMENT AREA

In accordance with Article 76 of UNCLOS, both Mauritius and Seychelles could have applied to the Commission on the Limits of the Continental Shelf for extensions to their continental shelf areas in the Mascarene Plateau region as the natural prolongation of their respective land mass. In such a situation a maritime dispute would have arisen in which case the CLCS would not have considered the examination of submissions until the dispute had been resolved. The two coastal States, in a spirit of mutual understanding, innovated by setting their legitimate differences apart and made a joint

submission. The CLCS made its recommendations in March 2011 which resulted in Mauritius and Seychelles being jointly conferred upon the jurisdiction of an area of the continental shelf of approximately 400,000 km2. Since then, Mauritius and Seychelles have finalized an undertaking to manage the area jointly. In 2012, the Prime Minister of the Republic of Mauritius and the President of the Republic of Seychelles signed two Treaties to this effect. The first treaty deals with the joint exercise of sovereign rights in the JMA and the second defines the framework for the co-management of the area. These two treaties allow, through agreed mechanisms, the countries to jointly explore the extended continental shelf and to sustainably exploit its resources[6].

The 'Treaty Concerning the Joint Management of the Continental Shelf in the Mascarene Plateau' was signed by both countries in March 2012[137]. Under this treaty the countries have agreed to establish a three-tiered joint administrative structure consisting of a Ministerial Council, a Joint Commission, and a Designated Authority. The Ministerial Council consist of an equal number of Ministers designated by the Contracting Parties (the two countries). The Ministerial Council meets at the request of either Contracting Party or the Commission. The treaty establishes the responsibility of the Ministerial Council, and the Council adopts its own procedures[6].

The Joint Commission consists of an equal number of commissioners appointed by the Contracting Parties. Its function is to establish policies and regulations relating to petroleum and other natural resource activities in the JMA. It also oversees the work of the Designated Authority. The Treaty also includes a non-exhaustive list of detailed powers and functions of the Commission. The Designated Authority has been established by the Joint Commission. The Authority has legal and judicial power to carry out its duties within the JMA. The Authority is responsible to the Joint Commission and carries out the day-to-day regulation and management of natural resource activities within the JMA. The Authority is also responsible for issuing regulations to protect the living natural resources and seabed environment in the JMA and for establishing a contingency plan for combating pollution from natural resource activities in the JMA[6].

The main relevant elements include[6]:

- Agreement to exercise sovereign rights jointly for the purpose of exploring the continental shelf and exploiting its natural resources.
- Importance of jointly managing the natural resources of the continental shelf in the Mascarene Plateau Region in a manner that is sustainable and consistent with the precautionary principle and the protection of the marine environment and the biological diversity of the continental shelf. These elements within the treaties also reflect UNCLOS (as ratified by both countries) which recognizes that:
  - Coastal states have a sovereign right to exploit oil and gas contained in their continental shelf.
  - Coastal states are required to minimize, to the fullest possible extent, pollution from installations and devices used in the exploration or exploitation of the natural resources of the seabed and subsoil.
  - Coastal states are obliged to adopt laws and regulations to prevent, reduce and control pollution of the marine environment arising from or in connection with seabed activities subject to their jurisdiction and from artificial islands, installations and structures under their jurisdiction and any other measures as may be necessary to prevent, reduce and control such pollution.

Having established a Joint Management Commission, the two countries now plan to adopt a Strategic Action Plan for the management of the JMA along with a Designated Authority to undertake the day-to-day regulation and management of natural resource activities in the JMA.

The real constraints to the development of a management regime (and associated legal, institutional and capacity to support such management) for the Mascarene Plateau region lies in:

- The massive increase in the area of jurisdiction for both countries.
- The paucity of comprehensive data and knowledge on the new ECS area (its oceanography, biodiversity, the value of the resources, vulnerability, potential impacts, etc.).
- The complications of managing a 'sovereign' seabed underlying a water column that is a 'high seas' commons.
- The fact that this will be the first incidence of development and trial of such a management regime, with no existing 'precedents' to fall back on.

However, this should also be balanced favourably against the following:

- There are initial data from the national Marine Ecosystem Diagnostic Analysis (MEDA) and Transboundary Diagnostic Analysis (TDA) for the Agulhas and Somali Current Large Marine Ecosystem project (ASCLME)[138] process and other studies done in the region that can inform a 'gaps analysis' and allow for rapid and urgent improvements in knowledge to underpin a management process.
- The countries have demonstrated, at the highest level, a willingness and intent to manage and share the resources of this area cooperatively. This is unique in terms of coastal and ocean transboundary management and deserving of encouragement and support.
- Globally, LMEs and Regional Seas Programmes and Conventions need demonstrations of such management approaches as more and more ECS agreements can be expected to come on-line. The real 'on-the-ground' challenges will be:
  - The capture of a sufficiently comprehensive baseline to support the Strategic Action Plan (SAP) for management.
  - Adoption of effective monitoring indicators and mechanisms to ensure sufficient guidance for management and decision-making.
  - Development of sustainable capacity for the overall management process (from monitoring through to adaptive management guidelines and policy reforms).
  - Developing and maintaining workable management practices that recognize and protect the interests of all stakeholders at a cross-sectoral level, particularly with industry stakeholders.
  - Linking the Joint Management SAP into the overall regional SAP for the WIO LMEs to ensure complementarity of actions in the presence of what could be slightly different priorities. In fact, this should not raise any significant problems as both Seychelles and Mauritius have endorsed the regional SAP. Hence their commitment is already fully confirmed to managing the JMA under the same objectives as the regional LME SAP.

#### 4.1.3.1. LIST OF RELEVANT INTERNATIONAL AGREEMENTS TO WHICH MAURITIUS AND SEYCHELLES ARE SIGNATORIES

**Multilateral Environmental Agreements**

Many Multilateral Environmental Agreements have been signed by countries in the WIO region.

*Marine related*

- Convention on the High Seas, 1958.
- Convention on the prevention of pollution from Ships (1973), as modified by the Protocol of 1978 (MARPOL).
- Convention on the Continental Shelf, 1970.
- United Nations Convention on the Law of the Sea (UNCLOS), 1982.
- Convention on the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region and related protocols (Nairobi Convention), 1985.
- Convention on Fishing and Conservation of the Living Resources of the High Seas, 1958.
- Convention on the Territorial Sea and Contiguous Zone, 1958.
- International Convention on Civil Liability for Oil Pollution Damage (CLC), 1969 Protocol of 1976 to amend the CLC (PROT-CLC), 1976.
- Convention for the Safety of Life at Sea (SOLAS), 1974.
- Agreement on the Organization for Indian Ocean Marine Affairs, 1990[139].

*Biodiversity related*

- African Convention for the Conservation of Nature and Natural Resources (Algiers Convention), 1968; Revised African Convention (Algiers Convention), 2003.

- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), 1973.
- Convention on Biological Diversity (CBD), 1992:
  - Jakarta Mandate on Marine and Coastal Biological Diversity, 1995 (programme of action)[140].
- Bonn Convention on Migratory Species (CMS), 1994:
  - African-Eurasian Waterbird Agreement (AEWA), the largest agreement developed so far under CMS.
  - The Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and Southeast Asia (MT-IOSEA).
- United Nations Framework Convention on Climate Change (UNFCCC), 1992 UNFCCC Protocol, Kyoto, 1997.

*Pollution, chemicals related*

- Stockholm Convention on Persistent Organic Pollutants, 2001.
- Basel Convention on the Control of Transboundary Movement of Hazardous Wastes, 1989.
- Rotterdam Convention, 1988.
- Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, 1991.
- Ban Amendment to the Basel Convention, 2005.

*Other Agreements*

- New Economic Partnership for Africa's Development (NEPAD), 2001.
- Agenda 21 and Johannesburg Plan of Implementation, 2002.
- ACP-EU partnership agreement, 2000, European economic partnership agreement with African, Caribbean, and Pacific countries (ACP-EU), also known as Cotonou Agreement.
- World Trade Organization (WTO).
- General Agreement on Tariffs and Trade (GATT), 1947.

*Regional Economic and Political Agreements*

- African Union (AU).
- Common Market for Eastern and Southern Africa (COMESA).
- Indian Ocean Commission (COI-IOC).
- Southern African Development Community (SADC), 1992.

## 4.1.4. INTERNATIONAL BODIES AND COOPERATION

Overall, the entire WIO area is extremely well provided for in terms of international, regional and sub-regional organizations. The most relevant include the United Nations Environment Programme (UNEP) Regions Seas Convention (the Nairobi Convention), three Regional Fisheries Bodies (IOTC, SIOFA and SWIOFC) as well the regional COI-IOC and the Sub-Commission of IOC-UNESCO (the Intergovernmental Oceanographic Commission). However, it is not certain at present how the roles and mandates of these organizations may engage with the management of extended continental shelf areas and the new JMA[6] (see 4.1.3 Mauritius – Seychelles JMA), although RFMOs keep the responsibility for the fisheries management of the JMA.

The region also has several scientific and technical research organizations, including those run by governments, academic institutions and NGOs. The WIO Marine Science Association (WIOMSA) is a regional professional, non-governmental, non-profit, membership organization, registered in Zanzibar, Tanzania. The organization is dedicated to promoting the educational, scientific and technological development of all aspects of marine sciences throughout the region of WIO, - Comoros, Kenya, Madagascar, Mauritius, Mozambique, Réunion (France), Seychelles, Somalia, South Africa and Tanzania,- with a view toward sustaining the use and conservation of its marine resources, and will play a pivotal role in assisting in the coordination of activities for SAPPHIRE (see 4.1.4.3 Regional Projects and Programmes). A large number of NGOs, Community-Based Organizations and other similar civil society groups are active in the WIO region, along with over 140 marine and coastal projects.



### 4.1.4.1. REGIONAL BODIES AND RELEVANT INTERNATIONAL BODIES

The following provides information on some of the more pertinent international bodies that may relate to a joint management process for the Mascarene Plateau region.

Within the International Agreements to which both countries are signatories, the one most applicable to any Joint Management process would be UNCLOS. Other existing agreements to which the countries are a party, and which may well have legal or ethical implications in terms of management of the ECS include:

UNEP Convention on the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (Nairobi Convention)[141]

Currently based in Nairobi, Kenya, the Nairobi Convention makes provisions for the protection and management of the marine and coastal environment of the Eastern African Region. Both Mauritius and Seychelles are party to this Convention. It includes the following Protocols:

- Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region.
- Protocol Concerning Co-operation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region.
- Protocol for the Protection of the Marine and Coastal Environment of the WIO from Land-Based Sources and Activities (LBSA Protocol).
- An ICZM (Integrated Coastal Zone Management) Protocol has been drafted (as of Sept 2013) and is currently under negotiation.

There are a number of potential implications of this Convention for the JMA which are captured within it in the following Articles:

- Pollution from Ships.
- Pollution from Dumping.
- Pollution from Seabed Activities.
- Pollution resulting from Transboundary Movement of Hazardous Wastes.
- Biological Diversity.
- Cooperation in Combating Pollution.
- Environmental Damage from Engineering Activities.
- Environmental impact Assessment.
- Scientific and Technical Cooperation.

Some recent Nairobi Convention decisions are especially relevant to regional ocean governance[136]:

- Decision CP8/10 (Blue and Ocean Economy) urges Contracting Parties to cooperate in improving the governance of areas beyond national jurisdiction (ABNJ), building on existing regional institutions including the Nairobi Convention and developing area-based management tools such as marine spatial planning to promote the blue economy pathways in the WIO region.
- Decision CP8/6 (Support to implementation of projects) requests Contracting Parties, the GEF and other partners, to support projects on, amongst others, conservation and sustainable exploitation of seamount and hydrothermal vents ecosystems of the Southwest Indian Ocean in ABNJ and collaborate in the management of activities in their adjacent waters with IUCN.
- Decision 8/5 (Agenda 2063 and Africa Integrated Maritime Strategy 2050) urges Contracting Parties to implement the Cairo Declaration of the 15th Session of the African Ministerial Conference on Environment (AMCEN) on Africa Integrated Maritime Strategy 2050 and Agenda 2063 on ecosystem-based management approaches for marine resources in the EEZs and adjacent waters and inform on progress at AMCEN sessions.

*Convention on Biological Diversity (CBD)*

The CBD is a multilateral treaty[142]. It has three main goals: the conservation of biological diversity (or biodiversity); the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources. Its objective is to develop national strategies for the conservation and sustainable use of biological diversity. The CBD was opened for signature at the Earth Summit in Rio de Janeiro on 5 June 1992 and entered into force on 29 December 1993. It has two

supplementary agreements, the Cartagena Protocol and Nagoya Protocol.

In 2008, the CBD COP 9 adopted scientific criteria for identifying ecologically or biologically significant marine areas (EBSA)[143] in need of protection in open-ocean waters and deep-sea habitats. The EBSAs are special areas in the ocean that serve important purposes, in one way or another, to support the healthy functioning of the ocean and the many services that it provides.

The EBSA criteria are:

- 1. Uniqueness or Rarity.
- 2. Special importance for life history stages of species.
- 3. Importance for threatened, endangered or declining species and/or habitats.
- 4. Vulnerability, Fragility, Sensitivity, or Slow recovery.
- 5. Biological Productivity.
- 6. Biological Diversity.
- 7. Naturalness.

In 2010, COP 10 noted that the application of the EBSA criteria is a scientific and technical exercise, that areas found to meet the criteria may require enhanced conservation and management measures, and that this can be achieved through a variety of means, including marine protected areas and impact assessments. The COP further noted that the application of the EBSA criteria is an open and evolving process that should be continued to allow ongoing improvement and updating as improved scientific and technical information becomes available in each region.

COP 10 emphasized that the identification of EBSAs and the selection of conservation and management measures is a matter for States and competent intergovernmental organizations, in accordance with international law, including UNCLOS.

COP 10 emphasized that the identification of EBSAs should use the best available scientific and technical information and integrate the traditional, scientific, technical, and technological knowledge of indigenous and local communities, and requested the Executive Secretary to facilitate availability and inter-operability of the best available marine and coastal biodiversity data sets and information across global, regional and national scales.

COP 10 requested the Executive Secretary to organize a series of regional workshops with a primary objective to facilitate the description of EBSAs through the application of scientific criteria as well as other relevant compatible and complementary nationally and inter-governmentally agreed scientific criteria, as well as the scientific guidance for the application of EBSA criteria.

COP 10 requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to prepare reports based on scientific and technical evaluation of information from the regional workshops, setting out details of areas that meet the scientific criteria for consideration in a transparent manner by the Conference of the Parties to the Convention, with a view to include the report in the repository and submit the report to the United Nations General Assembly (UNGA), particularly the Ad Hoc Open-ended Informal Working Group, as well as relevant international organizations, Parties and other Governments.

COP 10 encouraged Parties, other Governments, and competent intergovernmental organizations to cooperate collectively or on a regional or subregional basis, to identify and adopt appropriate measures for conservation and sustainable use in relation to EBSAs, including by establishing representative networks of marine protected areas in accordance with international law, including UNCLOS, and based on best scientific information available, and to inform the relevant processes within the UNGA.

In agreement with this process, a workshop was held in Mauritius, from 31 July to 3 August 2012. Its primary objective was to facilitate the description of EBSAs for the Southern Indian Ocean, through the application of scientific criteria in annex I of decision IX/20, and other relevant compatible and complementary nationally and inter-governmentally agreed scientific criteria, as well as the scientific guidance on the identification of marine areas beyond national jurisdiction, which meet the scientific criteria in annex I to decision IX/20. It was organized with Parties and other Governments as well as competent organizations and regional initiatives, such as the Food and Agriculture Organization of the United Nations (FAO), regional seas conventions and action plans, and, where appropriate, RFMOs with regard to fisheries management.

The workshop participants agreed on the descriptions of 39 areas meeting EBSA criteria[144]. Amongst them were Tromelin Island (N°28), Mahe, Alphonse and Amirantes Plateau (N°29) and Saya de Malha Bank (N°32)[229]. These three areas were adopted at the CoP of the CBD in Pyeongchang, Republic of Korea, in October 2014[145]. At the Mauritius Workshop, a list of 'Areas considered but not described for EBSA criteria due to data deficiency and lack of analysis was drawn up. This list includes the Coco de Mer, the North Seychelles Oceanic Basin, and Saint Brandon[229]. It seems that nothing has happened since 2012 for documenting these three sites.

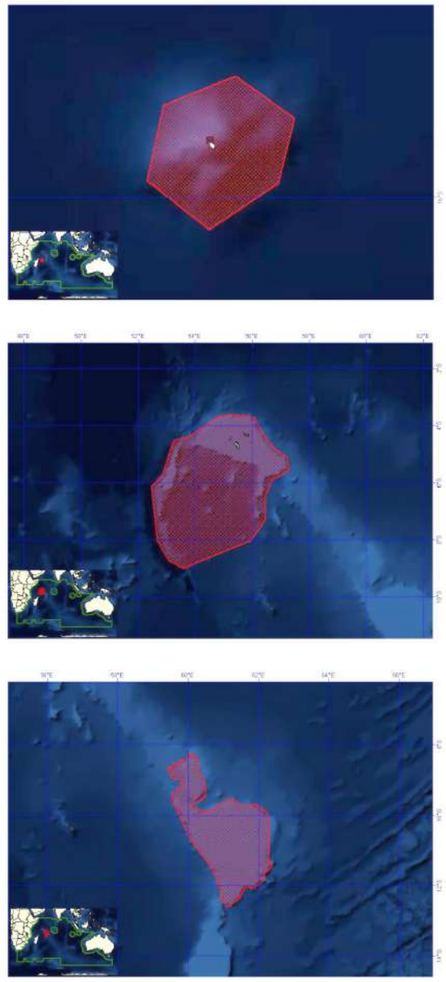


Figure 26: Maps of EBSAs n°28, n°29 and n°32[146]

In relation with the EBSA process, WIOMER[147] is a programme of the Indian Ocean Commission implemented by WWF, funded by the French Facility for Global Environment (FFEM), WWF and Conservation International. Based on the compilation of scientific data and information and on the mapping of anthropogenic drivers of change, it came as a support of the EBSA process. WIOMER followed both a MARXAN process and expert consultation to derive maps for priority conservation and a list of priority seascapes and sites.

The list of 45 sites (plus five open-sea zones) includes:

- Oceanic Basin North Seychelles (1)
- Mahe Plateau (2)
- Amirantes Plateau (3)
- Oceanic Basin Amirantes (4)
- Coco de mer (5)
- Aldabra (6)
- Cosmoledo (7)
- Astove (8)
- Saya de Malha (12)
- Agaléga (13)
- Saint Brandon (20)
- East Soudan Bank (26)
- West Soudan Bank (27)
- Mascarenes Eel Conservation Areas (49)

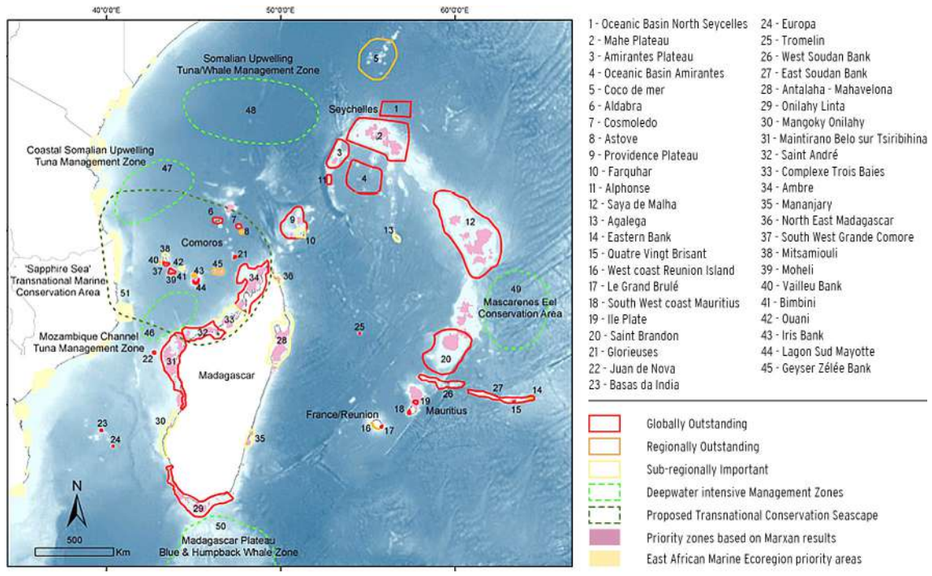



Figure 27: WIOMER Proposed Priority Seascape & Sites[148]

### *Intergovernmental Oceanographic Commission - UNESCO (IOC)[149]*

The Intergovernmental Oceanographic Commission (IOC) of UNESCO was established in 1960. As part of the development of regional programmes and groups, an IOC Regional Committee for the Cooperative Investigations in the North and Central WIO (IOCINCWIO) was established in 1979. The name was later changed to the IOC Regional Committee for the WIO (IOCWIO). In 2011 the IOC Assembly decided to establish the IOC Sub-Commission for Africa and the Adjacent Island States (IOCAFRICA), as a framework to ensure the efficient implementation of the IOC programme in Africa, in line with the African Union's regional integration principle. IOCAFRICA replaced both the IOCWIO and the IOC Regional Committee for the Central and Eastern Atlantic (IOCEA) that had been established in 1984. An IOC Regional Office for Africa has been established at the UNESCO Nairobi Office to act as the Technical Secretariat for the Sub-Commission. IOCAFRICA is responsible for the promotion of regional and international cooperation, and the development and coordination of the Commission's marine scientific and research programmes, the ocean services, the ocean observing systems, capacity development and related activities in the region by taking account of the specific interests and priorities of Member States from Africa.

### *UN Decade of Ocean Science[150]*

Following the First World Ocean Assessment released in 2016, the UNGA proclaimed on 5 December 2017 a Decade of Ocean Science for Sustainable Development (in short, the "Ocean Decade"), to be held from 2021 to 2030. The aim of the Ocean Decade is to provide a common framework to ensure that ocean science can fully support countries' actions to sustainably manage the ocean and more particularly to achieve the 2030 Agenda for Sustainable Development. The IOC was mandated to coordinate the Ocean Decade.

### *UNESCO World Heritage Convention[4]*

The 1972 World Heritage Convention conserves and protects the cultural and natural heritage of Outstanding Universal Value (OUV). Today, the World Heritage List contains 936 terrestrial and marine sites, in 153 countries. World Heritage natural sites protect almost 2.5 million km2 of the planet's lands and waters. Because of the recent addition of large marine sites to the World Heritage List, some 57% of the total area is marine, though in only 45 sites (5% of the number of World Heritage Sites).

For the Indian Ocean, the report by Obura, D.O., Church, J.E. and Gabrié, C. in 2012[4], *Assessing Marine World Heritage from an Ecosystem Perspective: The Western Indian Ocean*, identified two principal features in the WIO that stand out as globally unique– the Mozambique Channel and the Mascarene Plateau. The Mascarene Plateau, being more remote than the Mozambique Channel, and with emergent land and small islands only at its southern extreme, is less well-known, but with indications of unique oceanographic features and habitats, including the largest seagrass beds in the world, species endemism and significant aggregations of marine mammals and seabirds. Mauritius and Seychelles have individual or joint jurisdiction over the waters and the entire seabed of the plateau, though the waters over the Saya de Malha Bank are beyond national jurisdiction and in the High Seas.

Importantly for the region, and potentially foretelling the future of marine World Heritage, the two primary areas identified – the Mozambique Channel and Mascarene Plateau – show the opportunity for inter-governmental cooperation and set a precedent toward a more comprehensive approach when identifying potential new marine sites. An ecosystem approach – as opposed to the more traditional country-by-country approach – can considerably enhance future conservation of exceptional marine features on the World Heritage List because this approach is more meaningful from an environmental perspective. For the Saya de Malha Bank, in addition to the Nairobi Convention, initiatives under the CBD and UNCLOS offer avenues for multi-country cooperation and new approaches to High Seas governance.

### *United Nations Convention on the Law of the Sea (UNCLOS)[151]*

The UNCLOS is an international agreement that establishes a legal framework for all marine and maritime activities. As of June 2016, 167 countries and the European Union are parties[152].

After several years of unformal negotiations, in 2017, the UNGA voted to convene an intergovernmental conference (IGC) to consider establishing an international legally binding instrument (ILBI) on the conservation and sustainable use of biodiversity beyond national jurisdiction (BBNJ). The IGC will convene for a series of four sessions between 2018 and 2020 (IGC4 postponed to 2022 because of the COVID pandemic) to work towards an agreement.

Although the Saya de Malha Bank is within the Joint Managed Area (JMA) that was established by the governments of Seychelles and Mauritius after which the jurisdiction of the joint ECS area of 396,000 km2 was conferred to both States, the water column remains in the high seas because the ECS includes only the soil and subsoil of the ocean. Therefore, the current UNCLOS BBNJ negotiations are key for the future conservation of the Saya de Malha Bank, as it could be one of the most important examples of MPA designation in the high seas.

### *International Hydrographic Organization (IHO)[153]*

The International Hydrographic Organization (IHO) was established in 1921 under its former name "International Hydrographic Bureau". The development of activities at the regional level started with the introduction of the concept of International (INT) Charts in the late 1960s. It

was felt that, instead of several different hydrographic offices each producing different charts of the same ocean area, often with differing data, scales, and limits, it would be both more economical and safer if one hydrographic office would compile and produce an original chart to internationally agreed specifications. The implementation of the concept required the development of agreed schemes, at agreed scales, to provide harmonized world-wide coverage. To that effect the Ocean was divided into INT Charting Regions and the establishment of Regional Hydrographic Commissions (RHC) was encouraged to coordinate INT charting as well as other hydrographic activities and cooperation at the regional level.

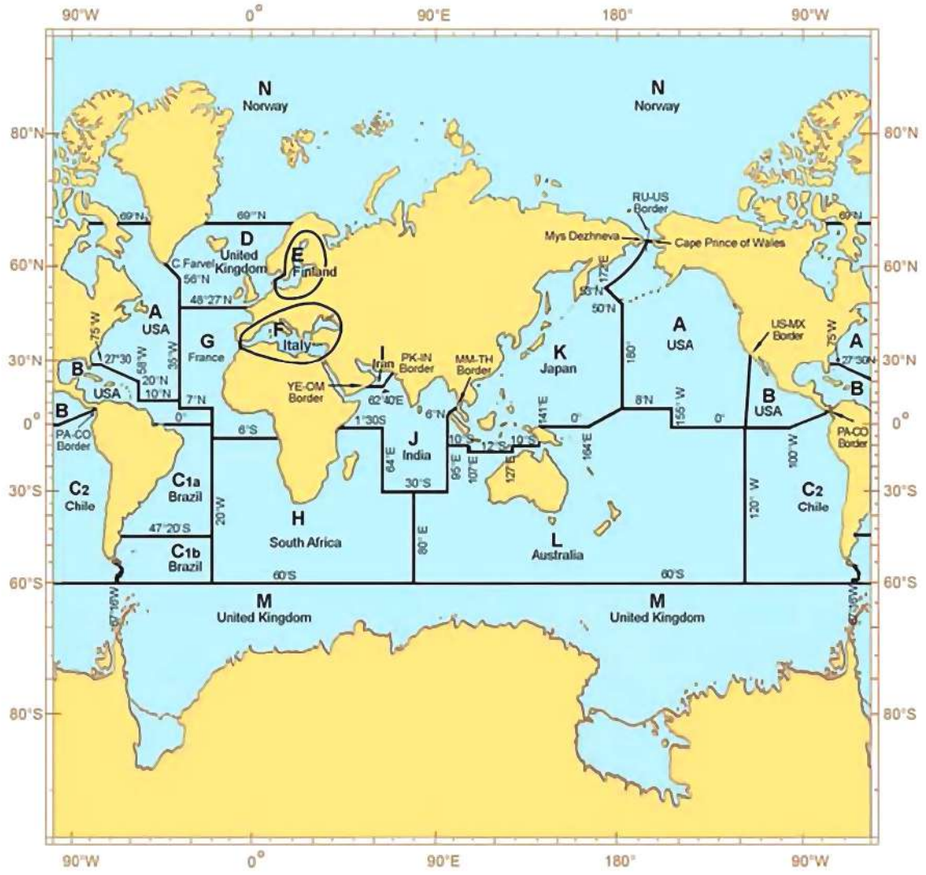



Figure 28: IHO International Charting Regions The States mentioned in the diagram are the coordinators of the regional charting schemes.

Source: Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO - Edition 4.9.0 - March 2021 - © Copyright International Hydrographic Organization 2021[154]

The Indian Ocean is subdivided into five International Charting Regions (Figure 27) under the responsibility of respectively:

- NT Charting region H: Southern African and Islands Hydrographic Commission, established in 1996.
- INT Charting Region I: ROPME Sea Area Hydrographic Commission, established in 2000.
- INT Charting Region J: North Indian Ocean Hydrographic Commission, established in 2002.
- INT Charting Region K: East Asia Hydrographic Commission, established in 1971.
- INT Charting Region L: Southwest Pacific Hydrographic Commission, established in 1993.

The IHO jointly with the IOC operates the General Bathymetric Chart of the Oceans (GEBCO) programme which was initiated by Prince Albert I of Monaco in 1903. GEBCO aims to provide the most authoritative publicly-available bathymetry of the world's ocean. Yet by the mid-2010s only about 8% of the seafloor had been mapped. In 2017, the Nippon Foundation (Japan) and GEBCO launched the Seabed 2030 initiative with the ambition to produce the "definitive map" of the world's ocean floor by 2030. Seabed 2030 is formally endorsed as a Decade Action of the UN Decade of Ocean Science for Sustainable Development. It is implemented through four Regional Centres and a Global Centre. The Regional Centres are responsible for championing mapping activities, assembling and compiling bathymetric information and collaborating with existing mapping initiatives within their regions. The Global Centre is responsible for producing and delivering global GEBCO products. The Regional Centre responsible for the Indian Ocean is the Atlantic and Indian Oceans Regional Centre hosted at the Lamont Doherty Earth Observatory (LDEO), Columbia University, USA.

### *Indian Ocean Tuna Commission (IOTC)[155]*

The IOTC is an intergovernmental organization established under article XIV of the FAO constitution in 1996 and has the mandate to manage tuna and tuna-like fisheries in the Indian Ocean and adjacent seas. The objective of the Commission is to promote cooperation among its members with a view to ensuring, through appropriate management, the conservation and optimum utilization of stocks covered by this Agreement and encouraging sustainable development of fisheries based on such stocks. IOTC's interests would extend into the JMA as IOTC deals with high seas fisheries beyond the EEZs, and the water column within the JMA would fall within IOTC's jurisdiction.

### *Southwest Indian Ocean Fisheries Commission (SWIOFC)[156]*

The SWIOFC was established in 2004 by Resolution 1/127 of the FAO Council as an Article VI FAO Regional Fishery Body. Consideration is being given to transforming SWIOFC into an Article XIV body. It only covers (non-tuna) fishing activities within EEZs. It is uncertain as to whether the interest of SWIOFC would extend into the JMA for the ECS. Pelagic and demersal fish are outside of SWOIFC jurisdiction as they are in the high seas area but any fish and fishery on the seabed or associated with the sub-soil may fall within their jurisdiction.

### *South Indian Ocean Fisheries Agreement (SIOFA)[157]*

The SIOFA was signed in Rome on the 7th of July 2006 and entered into force in June 2012. To date, SIOFA has 10 Contracting Parties: Australia, China, the Cook Islands, the European Union, France on behalf of its Indian Ocean Territories, Japan, the Republic of Korea, Mauritius, Seychelles and Thailand, one Participating fishing entity: Chinese Taipei, and one cooperating non-Contracting Party: Comoros. Kenya, Madagascar, Mozambique and New Zealand are also signatories to this Agreement but have not ratified it. The objectives of the SIOFA are to ensure the long-term conservation and sustainable use of the fishery resources in its area of competence through cooperation among the Contracting Parties, and to promote the sustainable development of fisheries, taking into account the needs of developing States that are Contracting Parties to the Agreement, and in particular the least developed amongst them and small island developing States. SIOFA area of competence excludes waters under national jurisdiction, but its mandate includes the water column and the demersal fisheries resources overlaying the ECS seabed. SIOFA is charged with managing non-tuna fisheries in areas beyond national jurisdiction, including on the Saya de Malha Bank[158].

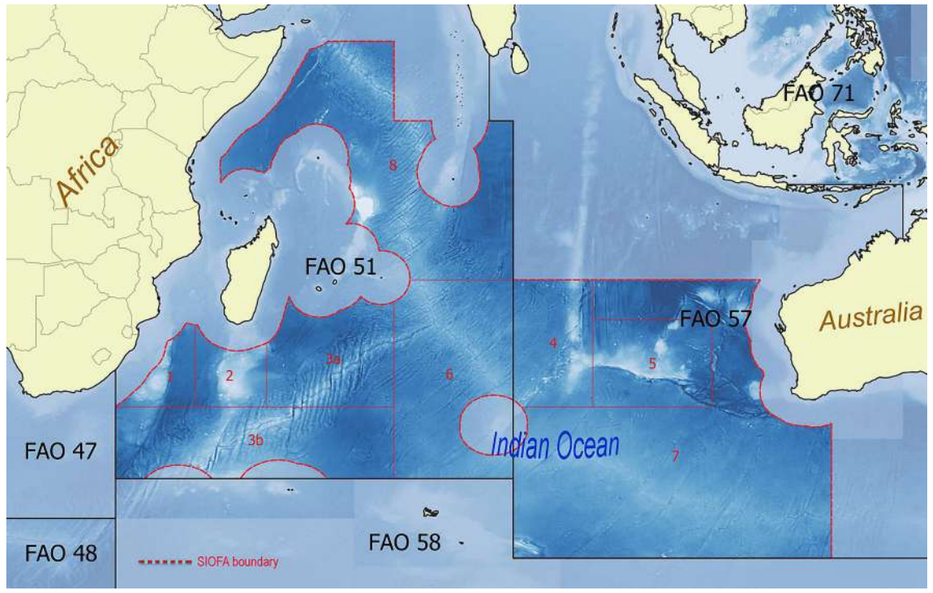



Figure 29: The SIOFA Area (https://www.apsoi.org/)

The initial parties to the agreement did not include Mauritius and several other countries have now signed up to the agreement including Thailand and China. A review of the papers related to meetings of SIOFA indicates that much of the resources and time of the organization have been concerned with stock assessment and management of orange roughy and alfonsino stocks in the region.

In terms of ecosystem management SIOFA has pursued a strategy which is similar to other RFMOs. This has involved establishing Interim Protected Areas for locations where Vulnerable Marine Ecosystems (VMEs) are known to exist and the establishment of VME encounter protocols whereby when bycatch of listed VME taxa exceeds a threshold value fishing vessels report the encounter and move away from the encounter area. VMEs listed for the SIOFA region include[159]:

- Chemosynthetic organisms (CXV) (no taxa specified).
- Cnidaria (CNI), which can be, if possible, detailed in recording as: Gorgonacea (GGW) (Order), Anthoathecatae (AZN) (Order), Stylasteridae (AXT) (Family), Scleractinia (CSS) (Order), Antipatharia (AQZ) (Order), Zoantharia (ZOT) (Order), Actiniaria (ATX) (Order), Alcyonacea (AJZ) (Order), Pennatulacea (NTW) (Order).
- Porifera (PFR), which can be, if possible, detailed in recording as: Hexactinellida (HXY) (Class), Demospongiae (DMO) (Class).
- Ascidiacea (SSX) (Class).
- Bryozoans (BZN) (Phylum).
- Brachiopoda (BRQ) (Phylum).
- Pterobranchia (HET).
- Serpulidae (SZS) (Family).
- Xenophyophora (XEF) (Phylum).
- Bathylasmatidae (BWY) (Family).
- Stalked crinoids (CWD) (Class).
- Euryalida (OEQ) (Order).
- Cidaroida (CVD) (Order).

It must be noted that seagrass is not on the list of VME indicator species although seagrass beds are extremely vulnerable to the impacts of trawling.

Based on these VME taxa, encounter rules have been established in the SIOFA area of competence although what these protocols are based on in terms of science is unclear (likely drawn from the protocols of the Convention for Conservation of Antarctic Marine Living Resources (CCAMLR) or other RFMOs). These measures are triggered on levels of bycatch reaching threshold values[248]:

- The threshold that triggers the encounter protocol for longline gears shall be the catch/recovery of 10 or more VME-indicator units of species listed in Annex 1 (listed above) in a single line segment.
- The threshold that triggers the encounter protocol for the trawls shall be more than 60 kg of live corals and/or 300 kg of sponges in any tow.

VME-indicator units are either one litre of those VME indicator organisms that can be placed in a 10-litre container, or one kilogram of those VME indicator organisms that do not fit into a 10-litre container[248]. As described in past literature there are many issues with VME encounter protocols which render their effectiveness questionable[160] [161]. This is especially the case where the encounter threshold values and VME taxa have been drawn from geographic regions outside the area where they are applied and where they are not based on sound scientific assessment. At present SIOFA is still mapping where potential VMEs may be distributed in the region and also undertaking an assessment of potential trawl impacts of the Saya de Malha Bank, both due to be delivered in 2022[248]. The development of a framework for assessing and preventing significant adverse impacts on VMEs will be undertaken after these studies are completed and is due for delivery in 2023[162]. SIOFA has also undertaken work on shark bycatch in the area of competence[9].

SIOFA has recently launched a study about the impacts of fisheries in the Saya de Malha area.

### *International Maritime Organization (IMO)[163]*

The IMO has a large number of conventions and treaties of relevance to an integrated approach to the management of marine and coastal regions and the economical use of these areas. However, not all of these are necessarily ratified, nor are adequate domestic legislative provisions necessarily made for their effective implementation either as flag states, through port state controls or general legal processes for relevant activities taking place within EEZs. It is also likely that old statutes, acts or other domestic legal instruments relating to previous regulations or versions of Conventions and Protocols have not been repealed or replaced/updated and may complicate future legal proceedings.

Kenya has been hosting the office of IMO's Regional Coordinator for the Eastern, Central and Southern Africa region in Nairobi since 1999. The office serves 21 countries and has been pivotal in the implementation and delivery of technical assistance thereby greatly advancing the ratification and implementation of IMO conventions in the region.

### *International Seabed Authority (ISA)[164]*

UNCLOS established the International Seabed Authority (ISA) to organize and control activities in the Area. Financial and other economic benefits derived from activities in the Area must be equitably shared, particularly taking into consideration the interests and needs of developing countries. Entities that are interested in carrying out activities in the Area must apply to the ISA, following the detailed procedures set out in UNCLOS and the 1994 Implementation Agreement. States Parties (and relevant international organizations) must ensure that activities in the Area are carried out in accordance with UNCLOS Part XI. (Article 139)[165]. Five contracts have been approved by ISA for Deep Sea Mining (DSM) in the Indian Ocean ABNJ[166] [167]. The financial and technical requirements and liability issues for environmental damage may constrain direct engagement in DSM in the ABNJ by WIO countries. WIO countries would have direct responsibility for DSM in their jurisdictional waters. Within the JMA, Seychelles and Mauritius control prospecting and mining activities.

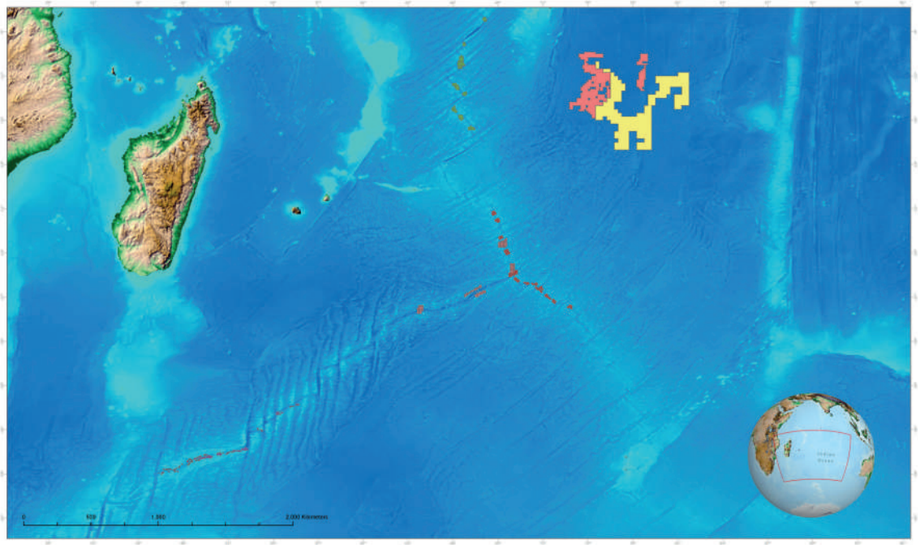



Figure 30: Indian Ocean Exploration Areas for Polymetallic Nodules and Polymetallic Sulphides[168]

### 4.1.4.2. REGIONAL INTEGRATION AND COOPERATION BODIES

There are also several regional integration and cooperation bodies which add another layer of institutional requirements and interactions, often seeking to coordinate the activities of subgroups of countries in their national activities and in the wider regional bodies. Notable for Mauritius and Seychelles are:

*Indian Ocean Commission (IOC)[169]*

The IOC's principal mission is to strengthen the ties of friendship between the countries and to be a platform of solidarity for the entire population of the African Indian Ocean region. IOC's mission also includes development, through projects related to sustainability for the region, aimed at protecting the region, improving the living conditions of the population and preserving the various natural resources that the countries depend on. Being an organization comprising only island states, the IOC has usually championed the cause of small island states in regional and international fora. The IOC is composed of five African Indian Ocean nations: Comoros, Réunion (a department of France), Madagascar, Mauritius and Seychelles. Notwithstanding their different characteristics, they share geographic proximity, historical and demographic relationships, natural resources, and common development issues. Originally created to encourage trade and tourism, more recently their cooperation has focused on marine conservation and fisheries management.

Common Market for Eastern and Southern Africa (COMESA)[170]



The COMESA is a free trade area with 20 member states and is considered to be one of the pillars of the African Economic Community.

*Southern African Development Community (SADC)[171]*

The SADC is an inter-governmental organization whose goal is to further socio-economic cooperation and integration as well as political and security cooperation among 15 southern African states. It complements the role of the African Union. SADC strives for regional integration to promote economic growth, peace and security in the southern African region. It aims to create common political values, systems and institutions among its member states, to build social and cultural ties, and to help alleviate poverty and enhance the standard of living among a regional population of over 250 million. It stands for the sovereignty of its member states, the upholding of human rights and the rule of law, and the peaceful settlement of disputes.

The African Union (AU) plays a key role in defining the African and regional approach to ocean governance. The AU Agenda 2063[172] makes numerous references to the ocean, particularly in relation to the blue economy, including the sustainable use of natural resources, offshore energy, ports and shipping. These references include, in particular, Aspiration 1 on a prosperous Africa based on inclusive growth and sustainable development, and Goal 6, which envisages a blue/ocean economy as a major contributor to continental growth and transformation. However, none of the Agenda 2063 flagship projects directly address ocean issues[208].

Agenda 2063 emphasizes the need for regional cooperation at all levels, adherence to international norms, knowledge management and capacity building. Agenda 2063 specifically identifies the Regional Economic Communities (RECs) as the fulcrum for cooperation, policy coherence and strategic alignment among their members. The role of the AU is seen as providing the overarching vision and policy guidance[173] at the African level, and where possible articulating an African position at the global level.

This key role of the RECs is evident in the 2050 Africa Integrated Maritime Strategy (AIMS), adopted by the AU in 2014. The vision or objective of the AIMS is: "to foster increased wealth creation from Africa's oceans and seas by developing a sustainable, thriving blue economy in a secure and environmentally sustainable manner".

The AMCEN has an important role in developing and promoting ocean governance initiatives, including by implementing the relevant parts of the AIMS[174].

*Other organizations[208]*

All African WIO countries are members of the Indian Ocean Rim Association (IORA), which is an intergovernmental organization (IGO) aimed at strengthening regional cooperation and sustainable development within the Indian Ocean region.

The current action plan 2017-2021 addresses six priority and two focus areas[175]:

- Maritime Safety & Security.
- Trade & Investment Facilitation.
- Fisheries Management.
- Disaster Risk Management.
- Tourism & Cultural Exchanges.
- Academic, Science & Technology Cooperation.
- Blue Economy.
- Women's Economic Empowerment.

A number of sectoral organizations also contribute to the regional governance seascape, including for shipping, maritime security, trade and tourism. Examples include:

- Port Management Association of Eastern and Southern Africa (PMAESA)[176].
- Association of African Maritime Administrations (AAMA)[177].
- Indian Ocean Memorandum of Understanding on Port State Control (IOMOU PSC)[178].
- The Association for Women in the Maritime Sector in Eastern and Southern Africa (WOMESA)[179], "a professional association spearheading the advancement of women as a key resource in the maritime sector".
- The Fisheries Transparency Initiative (FiTI)[180]. Secretariat based in Seychelles.

*Business associations include:*

- African Shipowners Association[181].
- Chambers of Commerce.
- Indian Ocean Tourism Organization (IOTO), which includes environmental sustainability among its objectives[182], including for cruises.
- Indian Ocean Tuna Operators Association (IOTOA)[183].

An extensive knowledge network contributes to a sound scientific basis for ocean governance. Many of the knowledge institutions have been fostered by the NC and may be heavily dependent on continued project funding by WIO partners in development, science, or marine conservation. Institutional fora (as opposed to ad hoc events) targeting innovation, marketing, business development and trade in the blue economy are still to emerge. The knowledge and scientific institutions include:

- Western Indian Ocean Marine Science Association (WIOMSA)[184].
- Coastal Oceans Research and Development in the Indian Ocean (CORDIO)[185].
- South African Institute of International Affairs (SAIIA)[186].
- Forum of Heads of Academic/Research Institutions in the WIO (FAR-WIO)[187].

Advancing ocean governance would not be possible without the support of other partners that backstop WIO governance in terms of financing and resources, capacity building, and technical support, for example:

- IGOs responsible for implementing or supporting international ocean conventions. These include the UN DOALOS, the ISA, the IMO and many others addressing specialized areas and issues, such as trafficking (UNODC) and maritime security.
- Agencies engaged in environmental conservation, ocean science and fisheries, such as UNEP, IOC-UNESCO and FAO multilateral financial institutions, such as the World Bank, the African Development Bank and the GEF (support for the LME projects).
- Bilateral partners, such as the EU, France and a range of global conservation NGOs (including IUCN, WWF, and Conservation International).

#### 4.1.4.3. REGIONAL PROJECTS AND PROGRAMMES

A number of relevant regional and bilateral projects and programmes are operating in the WIO region, which are dealing with marine and coastal issues. Other regional projects that would share common interests with the JMA Demonstration project include:

*The Second International Indian Ocean Expedition (IIEO-2)[188].*

The IIEO-2 (2015-2025) is organized under the auspices of the IOC, the Scientific Committee on Ocean Research[189] (SCOR) of the International Science Council, and the Global Ocean Observing System in the Indian Ocean (IOGOOS)[190].

IIEO-2 is a major global scientific programme which will engage the international scientific community in collaborative oceanographic and atmospheric research from coastal environments to the deep sea over the period of 2015-2025 revealing new information on the Indian Ocean (i.e., its currents, its influence upon the climate, its marine ecosystems) which is fundamental for future sustainable development and expansion of the Indian Ocean's blue economy. A large number of scientists from research institutions from around the Indian Ocean and beyond are involved in IIOE-2 in accordance with the overarching six scientific themes of the programme.

In relation, the Indian Ocean Observing System (IndOOS)[191] under the auspices of the Indian Ocean Region Panel of IOC-GOOS/CLIVAR (since 2005) has been providing data about the Indian Ocean thanks to the IndOOS Resources Forum, an international group of leaders from governments and institutions that contribute operational resources to IndOOS and/or facilitate resourcing for IndOOS, under the auspices of IOGOOS. Since 2010.

Also, the Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)[192], under the auspices of the Integrated Marine Biosphere Research (IMBeR) and IOGOOS has been working since 2010 to improve the understanding of the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics.

*SWIOFish*

The SWIOFish Project, funded by GEF[193], has as its objective to improve the management effectiveness of selected priority fisheries at the regional, national and community level. While all nine SWIO countries are to participate in regional activities under Component 1, Tanzania, along with Comoros and Mozambique, will be among the first countries to receive funding for targeted project activities at the national and community level. The primary Project beneficiaries in Tanzania are the coastal artisanal fishing communities on the mainland and islands of Tanzania and Zanzibar. These communities include ssmall-scalecommercial fishers, fish and seaweed farmers, households where fishing makes up a substantial part of their livelihoods and subsistence fishers. In addition, there are producer and professional organizations, industry or fisher organizations and local co-management fisher groups, including Beach Management Units (BMUs) on mainland Tanzania) and Shehia Fishing Committees (SFCs) who are also targeted by this project. SWIOFish1[194] has four components:

- Enhanced regional collaboration.
- Improved governance of priority fisheries.
- Increased economic benefits to the region from priority fisheries.
- Project management and coordination.

*SmartFish[195]*

The SmartFish Programme is financed by the European Union and implemented by the Indian Ocean Commission (IOC) in collaboration with the COMESA, the East Africa Community (EAC) and the Inter-Governmental Authority on Development (IGAD). SmartFish aims at contributing to an increased level of social, economic and environmental development and deeper regional integration in the ESA-IO through improved capacities for the sustainable exploitation of fisheries resources. Other regional institutions involved include SADC and the regional fisheries management organizations, such as IOTC, SWIOFC, the Lake Victoria Fisheries Organization (LVFO), and the Lake Tanganyika Fisheries Organization (LTFO). The ultimate beneficiaries of the Programme will be the fishermen, coastal communities and wider populations of the ACP States of the ESA-IO region covered by the 10th EDF Regional Indicative Programme. Furthermore, diverse stakeholder groups are expected to draw specific direct and indirect benefits from the SmartFish Programme.

*UNDP GEF 'Strengthening Global Governance of Large Marine Ecosystems and their Coasts through Enhanced Sharing and Application of LME/ICM/MPA Knowledge and Information' [196]*

This Project is now in the final stages of preparation. The Project's objectives are aimed at improving the global ecosystem-based governance of LMEs, generating knowledge, building capacity, harnessing public and private partners, and supporting south-to-south and north-to-south learning. The project will be structured around the following four components:

- 1. A Joint Management Support to Mascarene Plateau Region - Project Document 57 regional and global network of partners and a global community of practices for LMEs, while building a regional network to enhance networking and increase interaction among projects and collaboration between LMEs, Marine Spatial Planning (MSP), Integrated Coastal Management (ICM) within the different scales.
- 2. The incorporation of knowledge into policy making and the capture of best LMEs governance practices, and the development of new methods and tools to enhance the management effectiveness of LMEs and to incorporate ICM, MPAs and climate variability and change.
- 3. Capacity and partnership development through twinning and learning exchanges, workshops and training amongst LME practitioners, and similar initiatives.
- 4. The communication, dissemination, and outreach of GEFLME/ICM/MPA project achievement and lessons learnt.

*FAO GEF 'Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction' [197]*

The objective of this project is to achieve responsibility, efficiency and sustainability in tuna production and biodiversity conservation in the ABNJ, through the systematic application of an ecosystem approach in tuna fisheries through:

- Supporting the use of sustainable and efficient fisheries management and fishing practices by the stakeholders of the tuna resources.
- Reducing Illegal, Unreported and Unregulated (IUU) fishing.
- Mitigating adverse impacts of by-catch on biodiversity.

This project has four components for delivery as follows:

- 1. Promotion of sustainable management (including rights-based management) of tuna fisheries, in accordance with an ecosystem approach.
- 2. Strengthening and harmonizing monitoring, control and surveillance to address IUU fishing.
- 3. Reducing ecosystem impacts of tuna fishing.
- 4. Information and best practices dissemination, monitoring and evaluation.

*SAPPHIRE*[198]

The Overall Objective of the WIO LME Strategic Action Programme Policy Harmonisation and Institutional Reforms (SAPPHIRE) is to identify and demonstrate new management approaches and techniques for the Mascarene Plateau. This will need to address some of the unique management challenges associated with such an extended continental shelf area. Now that the ECS has been formally approved and the Joint Management approach has been formally declared by both countries, they will now have to manage large portions of the seabed (often significantly greater than their current EEZs), whilst recognizing that the water column above this 'sovereign' seabed falls under the definition of "High Seas' (as defined by UNCLOS) and is therefore beyond their jurisdiction.

This sub-component of the SAPPHIRE Project will focus on the newly established JMA between Mauritius and Seychelles for the Continental Shelf in the Mascarene region, as well as the associated Contiguous Adjacent High Seas Areas. It will assist the two countries in the development and demonstration of new management approaches for such extended continental shelf areas which can provide lessons and management techniques that can be replicated both within the WIO as well as throughout the global LMEs.

The primary areas of activity and support will be in the development of a management mechanism which demonstrates and institutionalizes co-management and co-existence of the various activities of the multiple sectors and stakeholders operating within or benefiting from this ocean space. The Mauritius-Seychelles Joint Management Committee has established five Strategic Objectives related to the development of an institutional framework, technical capacity, data acquisition in support of adaptive management and a 'blue ocean economy' approach, along with multi-sector, multi-use planning.

Component 1: Supporting Policy Harmonization and Management Reforms towards improved ocean governance.

Component 2: Stress Reduction through Community Engagement and Empowerment in Sustainable Resources Management.

Component 3: Stress Reduction through Private Sector/ Industry Commitment to transformations in their operations and management practices.

Component 4: Delivering best practices and lessons through innovative ocean governance demonstration.

Component 5: Capacity Development to realize improved ocean governance in the WIO region[199].

This UNDP GEF Project will provide direct support to achieving these objectives and capture lessons and best practices for the global LME community. The long-term benefits to the countries will be sustainable resource use alongside economic development, livelihood generation and poverty reduction.

The long-term benefits to GEF and globally will be a pilot/ demonstration of such an ECS management strategy which can then be replicated and transferred to other extended continental shelf areas around the world.

This also provides direct benefits to the overall UNDP GEF SAPPHIRE Project in piloting new management approaches for high seas areas that fall within the Large Marine Ecosystems themselves. Many of the other countries within the WIO will benefit from such a demonstration, both in dealing with their contiguous adjacent high seas areas and in the management of their extended continental shelves, some of which, if and when approved through UNCLOS, will triple the size of their existing EEZs.



# 5. CURRENT THREATS AND POTENTIAL MITIGATION ACTIONS

## 5.1. CURRENT THREATS IN THE INDIAN OCEAN

### 5.1.1. CORAL REEFS

Reef © Anna Koester

Coral reefs are highly valued for their ecosystem services, so they experience significant use and threat levels throughout the WIO. The exploitation of marine resources, urban pollution, terrigenous sedimentation, coastal development and tourism are among the main anthropogenic pressures that cause the degradation of ecosystems in the region. A classic example of the combined effects of these stresses is the Grand Recif at Tulear – the largest barrier reef in the Indian Ocean, which in the last 40 years has been degraded to a state of virtual death of the reef system, and the loss not only of ecosystem function, but of many species, including reef-building corals. Artisanal and small-scale commercial fishing, and urban pollution and massive sedimentation are all implicated in this loss. Fishing pressure is increasing in all countries with increasing local and global populations, and globalization of fisheries is resulting in mounting pressures on even the remote mid-ocean reefs and banks. Destructive fishing such as with small-mesh seine nets, poison and dynamite is pervasive where national governance mechanisms fail to keep them under control.

Shallow shipwrecks can have severe ecological and toxicological impacts on coral atolls[200]. In 2012, a tuna longliner ran aground on the reef crest of Saint Brandon's Atoll, broke up into three pieces which were moved by currents and storms into the lagoon. In the months following the grounding, the coral around the wreck became dead and black. The effects of shipwrecks on coral reefs must be considered a threat over periods of years.

Threats from pollution are less severe in the WIO than elsewhere, reflecting the low levels of industrialization and maritime trade by global standards, though these are increasing. Van der Schyff et al.[201] shows that, although coral and coral reef fish in Mauritian outer islands contain low concentrations of petroleum hydrocarbons (PHCs), many pollutants were found. For example, a potential Persistent Organic Pollutant (POP), i.e., Pentabromotoluene (PBT) is present in corals in Saint Brandon, Rodrigues and Agaléga, showing long-range transport of pollutants via plastic debris and aerial deposition.

The growing global energy demands have led to increased exploration for oil and gas within the WIO (Kenya, Tanzania, Mozambique, Madagascar and Seychelles). Exploration leases off the coast and onshore sedimentary basins cover the entire west coast of Madagascar and parts of the east coast. Currently, exploration results indicate significant reserves of heavy oil and the possibilities of lighter crude and gas. Extraction of these reserves will pose a serious threat to reefs and other ecosystems. The threats are direct (e.g., from oil spills and oil infrastructure development) and indirect in that extracting and burning more oil which increases global warming.

Climate change is now recognized as one of the greatest threats to coral reefs worldwide, particularly from rising sea surface temperatures, and ocean acidification. Coral bleaching has led to substantial damage to coral reefs on a global scale (16% of reefs suffered lasting damage in 1998 alone), with some parts of the WIO losing 50-90% of their coral cover (e.g., Kenya, Tanzania, Seychelles, Mayotte). Regional studies of coral bleaching have revealed differential histories of bleaching, indicating high- and low- vulnerability regions to potential future climate change. Reefs in hot stable temperature regime waters in the east of the Mozambique Channel and Seychelles, and in cooler but more variable regions in Kenya have suffered greater bleaching in the past. Regions with slight cooling from upwelling and oceanographic influences – along the Mozambique coast, or in the Mascarene Islands have suffered less bleaching, or more variable levels of bleaching. For the Indian Ocean as a whole, 65% of reefs are at risk from local and global threats, rising to > 85 % by 2030[4].

## 5.1.2. SEAGRASS BEDS

Seagrass beds are among the most productive aquatic ecosystems in the biosphere. They are important as nursery grounds, foraging areas for marine turtles, fish and dugong, and predation refuges for numerous fish and invertebrate species. Seagrass beds provide great benefits for commercial, subsistence and recreational fisheries. Due to the complex architecture of the leaf canopy in combination with the dense network of roots and rhizomes, seagrass beds stabilize bottom sediments and serve as effective hydrodynamic barriers reducing wave energy and current velocity, thereby reducing turbidity and coastal erosion. Further, seagrass beds trap large amounts of nutrients and organic matter in the bottom sediment. Through microbial decomposition, seagrass biomass may enter the marine food web as detritus and thus support productivity through the recycling of nutrients and carbon. Due to their high productivity, they are often a food source for animals resident in adjacent ecosystems such as coral reefs, and may increase the biodiversity in these systems.

Pressure on seagrass beds in the region is increasing due to growing coastal populations and human disturbance from, e.g., pollution, eutrophication, sedimentation, fishing activities and collection of invertebrates, though there is little quantitative evidence on specific threats. Reduced water clarity from land-based impacts reduces the depth at which seagrasses can grow.

Seagrass ecosystems in the WIO are valuable resources for fisheries at both local and regional scales, with much of the artisanal fishing in coral reef areas being focused on seagrass habitats on the reefs. However, seagrass research in the WIO lags behind other ecosystems and other regions and is mainly focused on plant diversity and ecology. Seagrasses have not been the focus of management in the region, though most MPAs focused on coral reefs include large areas of seagrass beds. From 2000-2005, die-back of seagrass beds (*Thalassondendron ciliatum*) as a result of sea urchin (*Eucidarus thouarsii*) predation in Kenya caused some concern, but natural recovery apparently occurred. In Kenya, sea urchin removal was found to assist seagrass recovery. In Mayotte, mortality of *T. ciliatum* on the inner barrier reef flat has been observed. More focused research, site selection and zoning of MPAs with seagrass beds as the prime focus are needed, as well as studies on land-based impacts. Restoration of seagrass beds is common practice in some parts of the world but has not been trialled in the WIO[4].

## 5.1.3. LARGE PREDATORS AND GRAZERS

Populations of predatory fish species are in severe decline around the world, primarily due to the impacts of industrialized fishing. For reef associated mesopredators, habitat degradation is another significant threat in coral reef ecosystems such as those of the WIO, driven by widespread effects of mass coral bleaching, destructive fishing practices (e.g., netting, trawling, dynamite fishing) and unregulated tourism. Such impacts may result in potential prey-switching and subsequent sub-lethal effects such as loss of condition, reduced fecundity and resilience, shortened food chains and altered trophic structure.



The widespread loss of top predators across marine and terrestrial ecosystems has been referred to as 'trophic downgrading' and can alter ecosystem structure, function, and resilience. Such disruptions, for example, can lead to impacts such as mesopredator release resulting in rapid increases in prey populations. The long generation times of many predatory species mean that it may take many years for population declines to become evident, making the subsequent consequences of trophic downgrading difficult to detect.

Sharks are particularly vulnerable to fishing due to their life history traits, including large body size, late age at maturity and low fecundity. While marine protected areas can play an important role in offering protection to reef-associated mesopredatory shark species, larger apex predatory sharks are generally transient, readily moving between coastal, reef, and pelagic ecosystems, making them especially vulnerable to exploitation from global fishing fleets.

Many other predatory species (e.g., Serranidae, Carangidae) are also highly mobile, with the degree of mobility changing with life-stage and seasonality. Numerous mobile reef-associated predators are known to travel vast distances to aggregate in large numbers for spawning at predictable times and places, which makes them especially vulnerable to exploitation. The iconic giant trevally (*Caranx ignobilis*) is a notable example. Relatively well-studied in the WIO, the species has been documented to travel over 650 km to reach spawning aggregations, numbering over 2,400 individuals in Southern Mozambique – among the largest such aggregations ever recorded. Similar findings have been documented in Seychelles, South Africa, and northern Mozambique. Improving our understanding of the key habitat requirements for spawning aggregations and predator movement dynamics such as these is crucial to ensuring the effective conservation of large marine predators on the offshore islands and banks of the WIO.

The heavy exploitation of herbivorous fish populations across the tropics has the capacity to compromise grazing function on coral reefs if the biomass of key herbivorous fish taxa falls below a certain threshold. And in the absence of sufficient grazing by herbivorous coral reef fishes, algae can proliferate on coral reefs and outcompete corals for space, leading to a regime shift.

The impacts of fishing pressure can, however, also be confounded by the bottom-up effect of benthic productivity on herbivorous fish populations, as well as by the effects of benthic composition and specific habitat associations of certain species. Bottom-up drivers can be particularly influential when small herbivorous fishes rely on reef structure and habitat for both shelter and food. Grazer populations on coral reefs are therefore susceptible to both the impacts of fishing pressure, and the effects of habitat degradation or alteration.

## 5.1.4. SHARKS AND RAYS

Blacktips at sunset © Wilfredo Falcon

Sharks are increasingly becoming a threatened fish group in the WIO, as they are highly vulnerable to fishing, and their misplaced reputation as man-eaters promotes an attitude of eradication or control rather than one of conservation, among the public and managers. Based on voluntarily declared FAO records there is evidence that shark catches in the WIO have more than halved after reaching a peak of 180,000 Mt in 1996. About 100 million sharks are fished annually in the world, either as accidental catch in seine and/or gill nets, or direct exploitation for their fins and other products. Of this total, 30% are from the Indian Ocean, and mainly from the southwestern part of the Indian Ocean. Catching of sharks for their fins, the most valuable part as they can be dried easily and sold at prices over USD100 per kg is the greatest threat to shark populations in the WIO and is banned in many countries.

From the first whale shark (*Rhincodon typus*) described in 1828 from the Indian Ocean, the region continues to be one of the most important areas for whale sharks. Whale sharks are a wide-ranging species with seasonal migration patterns over thousands of km, though some individuals may be resident year-round in equatorial zones. Globally they are found in many areas with surface seawater temperatures of 18–30°C, and range across the entire Indian Ocean. Unusually for sharks, females give birth to large numbers, even thousands, of young. The species has, however, been the subject of several targeted fisheries and thus sustained massive, rapid declines in population numbers. A number of fisheries targeting whale shark have developed within the Indian Ocean, some from traditional roots, such as in India, Pakistan and the Maldives that originated to supply the oil from the shark's liver for waterproofing boats This escalated especially in India during the 1990s to supply the demand in Taiwan for 'Tofu shark'. Reported figures indicate a peak in this Indian fishery of 279 sharks in 1999 but that despite increased effort only 160 were taken in 2000. This fishery was closed in 2001 when the species received protected status. The fishery in the Maldives previously took 20–30 whale sharks per year but proved unsustainable with declining catches and the fishery was stopped in 1995. Whale shark tourism has rapidly grown in importance in the WIO, with predictable seasonal sightings known in Kenya (e.g., Diani), Tanzania (e.g., Mafia) and Mozambique (e.g., Tofo). In the islands, two main aggregation areas (feeding and nursery) have been identified: the granite islands of Seychelles (Mahe in particular) and the northwest coast of Madagascar, especially near the island of Nosy Be. The dynamics and inter-relatedness of these populations are unknown, but represent a significant opportunity for blending conservation, research and economic development.

Reef and oceanic sharks are widely dispersed but their populations are greatly reduced through fishing mortality. In the WIO the bull shark or Zambezi shark (*Carcharhinus leucas*) is most strongly implicated in attacks on people, at both mainland and island sites, fuelling the general fear of sharks and low commitment to their conservation in most countries in the region. In austral winter in Mayotte, manta rays (*Manta alfredi*) and scalloped hammerhead sharks (*Sphyrna lewini*) are particularly abundant near steep reef slopes. Geyser Bank may constitute a nursery area for tawny nurse sharks (*Nebrius ferrugineus*) and Zélée Bank could be a nursery ground for grey reef sharks (*C. amblyrhynchos*). At Tofo in southern Mozambique, there is a major manta ray (*M. alfredi*) aggregation that has been investigated for several years. Annual population size estimates range from 150 to 450 individuals and the super-population estimate was 800 individuals. Guitarfish are known from the region, though exploited and highly depleted.

Reducing excess mortality of sharks is a fisheries issue requiring action on gear types and their operation, and preventing the most destructive markets, especially for shark fins. These actions need to be taken at regional and global levels. An additional solution is the creation of marine protected areas focused on key locations and habitats of importance to sharks, and some of the remaining high-density populations of sharks. Because of their importance in fisheries and as charismatic species, sharks have been mentioned in multiple global legal instruments, which can support actions at multiple levels[4].

## 5.1.5. MARINE TURTLES

Green turtle, *Chelonia mydas* © Seychelles Island Foundation

Threats facing marine turtles in the WIO include: exploitation for food (meat and eggs), oil, leather and ornamentation; mortality associated with incidental capture in fisheries; marine and land-based pollution; and disruption of essential nesting and feeding sites. Some of these threats have been going on for centuries as turtles have long been a resource of economic and cultural significance to people living in the region. Turtle meat and eggs provided protein to coastal residents, and the calipee (dried cartilage used to make turtle soup) and meat from green turtles and shell from hawksbills were exported to foreign markets in Europe and Asia. In some locations (for example, South Africa, Kenya, Seychelles, Mayotte and Madagascar) turtles also generate income as a tourism attraction. Until the mid-to-late 1900s direct take of turtles and their eggs posed the greatest danger to their long-term survival. While this remains an enormous problem in many areas, indirect threats are growing in importance, particularly incidental bycatch in artisanal and commercial fishing gear, and loss of nesting and foraging habitats due to coastal development, pollution, and erosion resulting from poor coastal management and sea-level rise. Marine ecosystems are disrupted by over-exploitation, mechanical damage, pollution of all kinds and land-based runoff as well as by temperature rise associated with global warming and climate change.

Two regional instruments relevant to sea turtle conservation in the WIO include the Sodwana Declaration[202], which provides a comprehensive "shopping list" of priority actions and strategies in various domains, but does not hold Governments and other partners accountable for actions, and the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of

the Indian Ocean and Southeast Asia (IOSEA)[203], adopted in 2001 under the auspices of the CMS. However, this too, is non-binding, but undertakes a suite of activities coordinated from a secretariat co-located with UNEP in Bangkok, Thailand. Under these programmes, several meetings have been hosted in the WIO over the last two decades, all calling for regional cooperation among countries to manage marine turtles as a shared stock, though WIO countries are still conducting turtle conservation and management largely in isolation. The World Heritage Convention offers a particularly powerful complement to this suite of regional instruments[4]. According to the Sodwana Declaration, "only a few of the discrete populations in the region are stable or growing; three of the populations are becoming extinct; most populations are either in decline or have not yet begun to recover from centuries of irrational use". Sea turtle conservation and management provide numerous challenges. Saving marine turtles requires the protection of these ecosystems on which we all depend on both small and large scales. Moreover, marine turtles are highly migratory, and individual animals may travel tens of thousands of kilometres in their lifetimes, spending various lengths of time in the open sea, and in territorial waters of multiple states. Conserving marine turtles thus also requires that people cooperate internationally and regionally. Also, although such threats are fairly well recognized they are not as well documented, and spatial and temporal overviews of threats generated from specific data sources are lacking. Today international agreements, most importantly CITES, prohibit international trade in marine turtles.

### 5.1.6. SEABIRDS

Sacred ibis, *Threskiornis bernieri* © Seychelles Island Foundation

The main threat to both resident and migrant birds in the WIO is habitat degradation, affecting breeding and nesting sites. Other threats are disturbance by fishers and tourists, egg collecting, and predators such as rats, cats, dogs and potentially oil spills. Invasive species such as rats and cats can decimate breeding bird populations on remote islands. Fisheries impact seabirds in various ways, the main impacts include direct mortality by fishing gear (bycatch) and competition when fisheries and seabirds target the same prey. Climate change is an increasing and more insidious threat to coastal birds. Rising sea-levels may swamp low-lying nesting colonies or lead to loss of shoreline feeding habitat. Warming and acidification of waters damage coral reefs and may affect the distribution and abundance of key food species for some coastal and seabirds.

Few species breeding in the WIO region are globally threatened because most seabirds have very wide distributions. However, dependence on remote islands for breeding makes individual populations highly vulnerable to changes and threats. The Roseate tern (*Sterna dougallii*) is of particular concern in the WIO as populations have undergone major declines, as have the status of the Réunion Petrel (*Pseudobulweria aterrima*) (Critically Endangered) and Barau's Petrel (*Pterodroma barau*i) (Endangered) on Réunion.

Some of the large nesting seabird colonies and key roosting and feeding sites for coastal migrants lie within MPAs. For example, Seychelles has a particularly large number of important breeding sites which are now protected, such as Aldabra, Cousin Island, and Aride. Another mechanism for the protection of bird populations is through the designation of Ramsar sites under the Convention on Wetlands (Ramsar). For designation, a site must meet one of two criteria of importance to waterbirds: Criterion 5 for sites that regularly support at least 20,000 waterbirds; and Criterion 6 for sites that regularly support 1% or more of a waterbird species biogeographic population. Many of the key sites for bird species are now recognized internationally as Important Bird Areas (IBAs), under a scheme initiated by BirdLife International, and several of these are included either within or overlap with MPAs. The distribution of IBAs in the WIO reflects many of the most important breeding sites mentioned above, but further protection measures are necessary in many of them. BirdLife's Global Seabird Programme, which started in 1997, focuses on specific objectives for seabirds, with a focus on fishery interventions and regional and global scale issues affecting seabirds. In 2004 the GSP launched a marine IBA programme, and work towards identifying marine IBAs in the WIO region is well underway[4].

#### 5.1.6.1. MARINE MAMMALS

Humpback Whale, *Megaptera novaeangliae*, and calf © Christopher Jones

The near-shore zone throughout the WIO is highly productive and subject to high levels of artisanal exploitation and development, especially in nearshore habitats such as seagrass and coral reefs. Dugongs are entirely dependent on such seagrass and reef habitats. An increase in large mesh gill netting from the 1970s onwards, along with a lack of law enforcement, seine netting, commercial trawl operations, palisade fish traps, habitat destruction of seagrass beds and increased anthropogenic disturbance all contribute as threats to dugong populations in Mozambique, and in the WIO.

The greatest threats known to whales and dolphins (similar to the dugong) include fishing net entanglement either directly (whaling) or indirectly causing death through drowning. Chemical pollution (heavy metals, pesticides and other toxins) can cause direct harm to the animals by accumulation in their tissue, via ingestion of contaminated prey. Deep water beaked

whales and delphinids are known to be sensitive to acoustic disturbance in areas with rapidly expanding exploration for offshore petroleum (including seismic surveys and bathymetric mapping, implicated in disturbance and strandings in other regions). A key area is Northwest Madagascar where there are active offshore petroleum concessions, high species diversity including deep water species, and a recent mass stranding of melon headed whales (*Peponocephala electra*) that was coincident with petroleum exploration activities. There was also a mass stranding of common bottlenose dolphins (*Tursiops truncatus*) off Bazaruto in October 2007, coincident with offshore seismic surveys.

The Bazaruto Archipelago is an existing MPA and has the largest and possibly last viable dugong population in the Eastern African region. The survival of the dugong ultimately depends on the maintenance of adequate habitat, notably the seagrass beds. Amongst the efforts of the International Whaling Commission (IWC) to facilitate the recovery of the great whales was the establishment of the Indian Ocean Sanctuary (IOS) in 1979. This Sanctuary consists of those waters of the Northern Hemisphere from the coast of Africa to 100°E (including the Red and Arabian Seas and the Gulf of Oman) and those waters of the Southern Hemisphere between 20°E and 130°E from the equator to 55°S. The Sanctuary offers protection from commercial whaling to the great whales. The IOS is generally established for limited time periods, and has been extended continuously to date, in 1989, 1992 and most recently in 2002.

There is a critical need to investigate the status of dolphin populations and threats to them in the countries bordering the Indian Ocean. More research emphasis should in future be placed on investigating by-catch and the possible overfishing of delphinid prey stocks, and on the abundance and distribution particularly for offshore cetacean species. Within South Africa and Mozambique, there is limited evidence that the IOS has played a role in stimulating research on cetaceans to date. In Zanzibar, research on dolphins based on mortality as fisheries bycatch has revealed information on diet and population structure. Whale and dolphin watching, if developed carefully, could bring much needed income to developing countries. This has recently been developed in several countries including South Africa, Kenya, Seychelles and Mauritius[4].



# 5.2. THREATS FROM ACTIVITIES IN THE SAYA DE MALHA BANK

Despite its remoteness, the Saya de Malha Bank is subject to a number of global and local threats. Global threats include the effects of climate change such as increasing ocean temperature, ocean acidification and changes in oxygen saturation. There have been no specific studies of these effects on the Saya de Malha Bank, but disease identified in corals may be driven or exacerbated by increasing water temperatures[10]. Plastic pollution is another global threat which undoubtedly also contaminates the Saya de Malha Bank and has been described from the deep sea of the Southwest Indian Ocean on seamounts[204]. Beyond doubt, however, fishing is by far the most significant threat to the benthic and pelagic ecosystems of the Saya de Malha Bank[9].

## 5.2.1. FISHERIES

**The hook and line fishery[9]**

There is a decades-old history of experimental and commercial fishing on the Saya de Malha Bank. This includes at least 20 expeditions undertaken by Russian vessels[39] and fisheries assessment cruises by FAO / UNDP and the EAF Nansen programme[8] [205], and China[206]. Fishing began on the Saint Brandon Islands to the south of Nazareth Bank in 1927 with fishing on Nazareth Bank for *Letherinus mahsena* (known locally as "dame berry") commencing in the 1950s. Fisheries on the offshore banks, including Saya de Malha increased through the 1960s and 1970s with a peak in frozen fish production in 1974 at 3,279 t but declining to 1,232 t by 1980. This decline seems to have resulted from issues with the management of fishing vessels and labour problems leading to a decline in local fishing vessels and chartering of South Korean vessels for fishing between 1977 and 1984[311]. The Mauritian Government attempted to reverse this situation by providing incentives for local Mauritian fishers to fish the banks, however, because of the expenses for maintenance and certification of fishing vessels and the lack of sufficient local active fishermen for fishing campaigns the number of Mauritian vessels began to decline again from 1994. Local fishing companies began to reflag their vessels to avoid certification costs and hire fishers from other countries. In 2006 the Mauritian Government made further policy changes charging a "contributory fee" to foreign vessels and allocating catch quotas for foreign vessels[311].

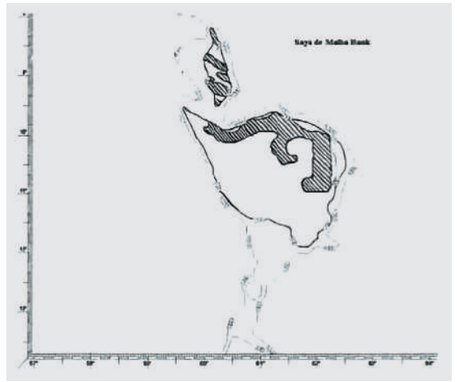
It is important to note that throughout this period the predominant form of fishing on the Saya de Malha Bank was handlining. This type of fishery is executed by 6-7m dories generally taken to the bank by a mother ship where they are deployed with three fishermen on board. Mother ships are typically 35m – 55m in length and carry 15 to 22 dories. Bottom longlines, gillnets and traps have also been deployed on the bank, but these were found not to be effective. The hook and line fisheries tend to target areas of coral reef and seagrass between 18m – 60m depth and the map of the fished area for hook and line corresponds to reef areas identified in Vortsepneva (2008)[39].

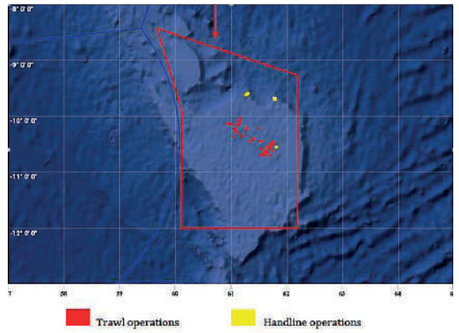
*Lethrinus mahsena* made up approximately 90% of the catch in this fishery with other species being caught including serranids, lutjanids and other lethrinids (e.g., *Plectropomus maculatus*, *Aprion virescens*, *Variola louti*, *V. albimarginata*, *Lethrinus rubrioperculatus*, *L. elongatus*. Over time the estimated maximum sustainable yield of the *Lethrinus mahsena* stock on the Saya de Malha Bank has varied from 2,887t to 2,350t and levels of exploitation varied from up to 3,173t in the mid-1990s to between 771t and 1,845t from 2006 – 2010. The fishery has therefore been overexploited in the past and more recently moderately exploited. Some damage to corals occurred as a result of the hook and line fisheries but this is likely to be moderate compared to fishing with active gears or gill nets[311].

**The Thai trawl fishery[9]**

In 2015 the Thai distant-water fishing fleet commenced an otter board trawl fishery on the Saya de Malha Bank[207] [208]. Catches in the first year of fishing amounted to just over 22,729t and were prosecuted by 56 trawling vessels, including one pair trawler with an unknown number of tows on the seamount. In 2016 these catches declined to just over 8,435t (58 trawlers and one set of pair trawlers) and then 1,617t by 2017 (11 trawlers and one set of pair trawlers). However, note that these figures vary in reports to the Scientific Committee of SIOFA in 2018 and 2021[209] [319]. In 2017, Thailand joined SIOFA. In February of this year the Thai fleet was called on to return to port in Thailand and Thai fishing rules amended to reflect regulations set by SIOFA. The main catch of the Thai trawl fleet during this period were reported as lizardfish (mainly *Saurida undosquamis*) and round scad (mainly *Decapterus russelli*). The number of trawl tows was not recorded in 2015 but in 2016 was 3,971 hauls for otter trawls and 544 pair trawl hauls. This fell to 719 otter trawls in 2017 and 75 pair trawl hauls. All trawling ceased in 2018 but otter trawling recommenced in 2019 and continued in 2020 with 176 and 464 tows in these consecutive years. One trap-fishing vessel seems to have operated in 2015-2017 and handline fishing by Thai vessels commenced in 2019.

Whilst it is not possible to ascertain the state of the stocks of target species for the trawl fishery by Thailand, the precipitous decline in catches is likely to represent significant overexploitation of lizardfish and scad populations from 2015 - 2017. However, the impact of the trawl fishery on seabed ecosystems is likely to have been catastrophic[318].



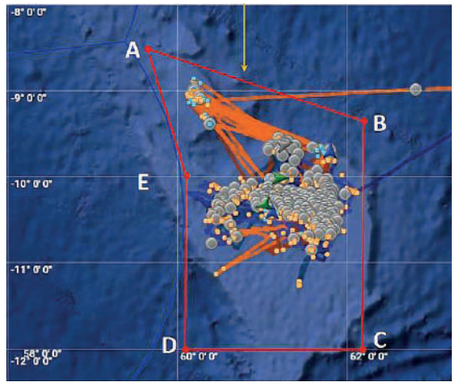




Figure 31: Fishing footprint in the Saya de Malha Bank area

- 1 Fishing areas on the Saya de Malha Bank[311]
- 2 Fishing footprint of Thai trawlers in SIOFA area in 2016[210]
- 3 Fishing ground of Thai otter board trawlers in the Saya de Malha Bank in 2018[214]

According to the habitat maps by Vortsepneva (2008)[24] the trawl fishery appears to be targeting what is termed as shallow lagoon and coral reef habitat. The report to the Scientific Committee of SIOFA indicates VME bycatch of 590kg and 308kg of sponge in 2019 and 2020 respectively and 6.5kg and 0.02kg of corals over the same period. The handline bycatch of corals over the same period was 27.5kg and 10kg. It is notable that seagrass is not a VME taxon in the SIOFA lists and so none are recorded on observations. It is also debatable as to whether seagrass would be retained by fishing gear or rather just torn up and left on the sea floor. It is also notable that three leatherback turtles, 560kg of hammerhead sharks, one *Mobula* ray and five guitarfish were also caught as bycatch in 2020[319].

It seems remarkable that the Thai Government permitted its fishing fleet to commence trawl fishing on the Saya de Malha Bank which has previously been recognized by UNESCO as being a potential candidate Marine World Heritage site, classified as a site with "*Potential Outstanding Universal Value*" because it is a bank in ABNJ hosting the largest contiguous seagrass bed in the world and as such is unique. Even a cursory glance of the scientific literature prior to 2015 would have indicated the unique nature of the bank and furthermore Vortsepneva (2008)[39] pointed out that should a trawl fishery commence on this feature it "*may irreversibly destroy seagrass and coral biotopes and cause depletion of particular species*". Whether this was a case of complete negligence in terms of managing the trawling fleet, or there was a deliberate policy to trawl the bank prior to joining SIOFA, or as a result of it being nominated as an EBSA under the Convention for Biological Diversity, is unclear. What is astonishing is that the trawl fishery is continuing under SIOFA. At present, the Saya de Malha Bank is a JMA between Seychelles and Mauritius and they have stated that SIOFA cannot undertake any projects on the bank. However, under UNCLOS sovereign rights under the extended continental shelf do not apply to marine living resources other than sedentary ones. Even sedentary species which are commercially valuable for fisheries fall within the scope of SIOFA[318].

Finally, IUU fisheries is a significant threat for this area. Several programmes are active in identifying and fighting IUU fisheries such as the Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels ***- an international tool, developed by FAO, to fight IUU fishing***[211], FISH-i Africa, an FAO regional initiative to build compliance and enforcement capacity[212], the Southwest Indian Ocean Regional Plan for Fisheries Surveillance of the Indian Ocean Commission, and the work of the Fisheries Transparency Initiative[275] (a global initiative), as well as the information provided by Global Fishing Watch[213].

### 5.2.2. THREATS FROM SHIPPING AND CRUISE TOURISM

A major sea route goes through Mauritius EEZ connecting the Cape of Good Hope to Sri Lanka and Asia (see in 5.1.1 about shipwreck in Mauritius). It is used by cargo vessels and also pleasure craft. As shown in a recent Bloomberg article and map[214], there are no specific risks for the Saya de Malha Bank and the southern banks, including Saint Brandon since the shipping routes are not located within that area. However, since the most important shipping route is passing east of Saint Brandon and a secondary shipping route is passing between Saya de Malha Bank and Nazareth Bank, there is a risk of collisions or groundings, with important possible consequences for the environment and ecosystems.

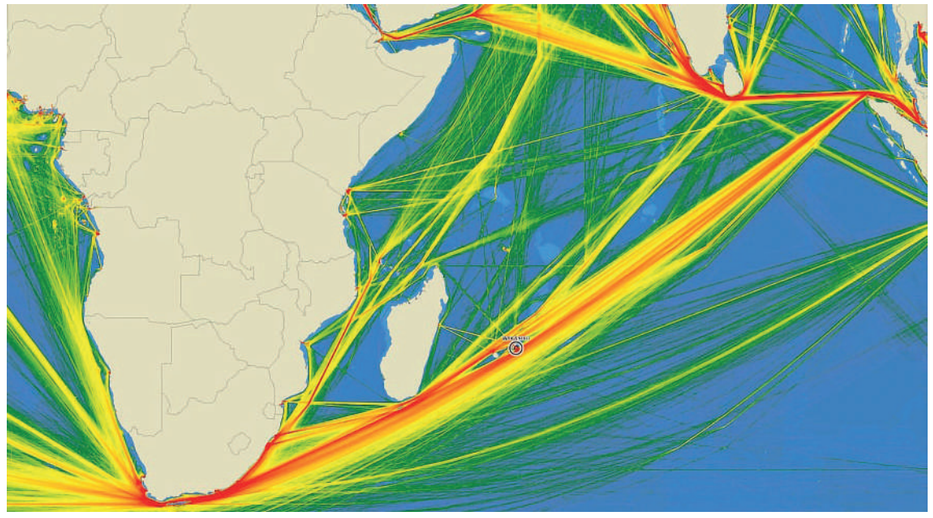


Figure 32: Maritime routes in the Indian Ocean[334]

### 5.2.3. RISKS FROM OIL AND GAS, AND SEABED MINING EXPLORATION

Legacy geophysical and geological data suggest that the oceanic crust is pervasive throughout the WIO, forming the Comoros Islands, the Glorioso Islands, Mauritius and much of the submarine Mascarene Ridge. This legacy information includes regional gravity and magnetics data, refraction and 2D reflection seismic, deep sea drilling project (DSDP) data and ocean drilling programme (ODP) wells, and geological field studies. However, based on several recent studies, there is overwhelming evidence for the existence of slivers of continental crust in the WIO which were previously thought to be purely of intra-oceanic magmatic origin[215].

Regional geological and local geophysical studies led to the drilling of two wildcat wells during 1975 - the SM-1 (Saya de Malha) and the NB-1 (Nazareth Bank)[216].

The total depths are 3,264 and 1,716 m, respectively. The sedimentary section, upper Paleocene-Quaternary, consists of neritic to shallow-water carbonate rocks which are 2,432 m thick in the SM-1. The carbonates overlie a section of basaltic rocks 832 m thick. The results of the two wells do not offer much encouragement for the petroleum prospects on the Mascarene Ridge.

In October 2021, the Mauritian Prime Minister signed the Offshore Petroleum Bill (n°XIV of 2021)[217]. The object of this Bill is to repeal the Petroleum Act, legislation which dates back to the year 1970, and replace it with a new and more appropriate regulatory regime for the conduct of petroleum activities in the seabed and subsoil areas of the maritime zones of Mauritius, such as the prospecting, exploration, retention and production of petroleum. The Department for Continental Shelf, Maritime Zones Administration and Exploration of the Prime Minister's Office shall, amongst its other functions, be the regulatory body for petroleum activities in the maritime zones of Mauritius and shall, inter alia:

- (a) regulate, monitor and oversee petroleum activities;
- (b) be responsible for the issue of prospecting permits, exploration licences, retention licences and production licences;
- (c) negotiate, on behalf of the Government, prospecting agreements and petroleum agreements; (d) facilitate the conduct of petroleum activities;
- (e) develop strategies and policies to minimize and manage the impacts of petroleum activities on the marine environment;
- (f) advise the Minister in the formulation, planning and management of policies in relation to petroleum activities; and
- (g) do such other things as may be necessary for the proper conduct of petroleum activities.

In addition, all sovereign rights to petroleum contained in the seabed and subsoil areas of the maritime zones shall vest, and shall always be deemed to have been vested, in the State of Mauritius.

Shaama Sandooeya, a young scientist and environmental activist, highlights, in *Le Mauricien*[218], the risks that are brought by this Bill which was backed up by the Ministry of Environment, Solid Waste Management and Climate Change, despite the consequences of the oil spill caused by MV *Wakashio* in 2020 and the climate crisis.

Manisha Deena, in *L'Express*[219], also addresses the issue of the threats coming from the *Offshore Petroleum Bill* and from the *Seabed Minerals Bill* which is under preparation by the Government of Mauritius.

Regarding seabed minerals, the distribution of manganese nodules in the Exclusive Economic Zone of Mauritius was delineated during cruise SK-35 of O. R. V Sagar Kanya in 1987. The areas surveyed included Saya de Malha and Nazareth Banks, the Cargados Carajos shoals, Rodriguez Ridge, and the Soudan Bank of the Mascarene Plateau and Mascarene Basin. Of the 57 locations sampled, manganese nodules were recovered at 11 sampling stations. The nodules were confined to a small area of approximately 11,900 km2 in the Mascarene Basin off Tromelin Island. Nodule density varied from 1.23 to 10 kg/m2, and they were predominantly spheroidal to sub-spheroidal, a majority of them falling in the 2- to 4-cm-diameter size class. Surface textures were mostly smooth, except at one station where botryoidal nodules with rough surface texture were recovered. Further surveys are necessary to arrive at a proper estimate of the deposits[220].

### 5.2.4. RISKS FROM GOVERNANCE GAPS

As a general governance risk, not unique to the WIO, regional governance fragmentation is an issue, as well as the lack of coordination and harmonization across instruments and institutions.

The JMA is a unique governance arrangement under UNCLOS. There is no other example of joint management of the continental shelf. The fact that the JMA is an area of extended continental shelf implies that the bottom of the sea is under the governance of both Seychelles and Mauritius, but the water column is in the high sea since it is located beyond the Seychelles and Mauritius EEZ. Therefore, there is a risk that the decision-making process be complicated and a robust cooperation between Seychelles and Mauritius will be necessary for the arrangement to work.

Future management of the Saya de Malha Bank will depend on joint arrangements by Seychelles and Mauritius, and agreement on national priorities such as in fisheries. Management, surveillance, and enforcement of a distant marine zone with no emergent land to host a management base will be challenging, but increasingly possible with the advent of remote sensing surveillance technologies, and existing operationalization of them in, for example, fisheries management and vessel surveillance. National legislation to enable the management of this type of distant marine site would be necessary[4].

### 5.2.5. RISKS FROM CLIMATE CHANGE AND CO2 EMISSION

Climate change is resulting in a suite of harmful changes in ocean physics and chemistry which in turn are having an impact on biodiversity and the ecosystem services provided by the ocean. The main changes are in the pH leading to ocean acidification and temperature leading to increased frequency and intensity of stratification, intensification of deoxygenation, changes in the capacity for storage of blue carbon, increased release of seafloor greenhouse gases such as methane and nitrous oxide and more frequent and intense heatwaves.

The Indian Ocean has experienced the most rapid basin-wide increase in sea surface temperature with an average rise of 0.15°C decade-1 since 1951 resulting in an overall temperature increase of around 1.0°C which is much higher than the global average of 0.7°C. Model projections indicate a continuing strong warming trend in the Northwest Indian Ocean of up to 2.8°C increase (RCP 8.5) between 2017 and 2100[221]. The rapid warming of the surface layers has led to enhanced ocean stratification resulting in suppression of nutrient mixing from deeper layers and an alarming decrease in phytoplankton[222]. Associated with this increase in ocean temperature, marine heatwaves are also becoming much more frequent and intense. Such events have increased in frequency 4-fold in the WIO and up to 3-fold in the northern Bay of Bengal. Such heatwaves not only are having an effect on biodiversity, but they are also affecting monsoon winds leading to severe dry spells on the Indian sub-continent.

The rising seawater temperature has also already had a major effect on coral reef bleaching events – the reefs in Madagascar, Comoro Islands and Mascarene islands are all now classified Critically Endangered. The implications of coral reef collapse include loss of coastal protection, especially of low-lying coastal areas, tourism and fisheries.

Long-term observational records of sea levels are scarce in the Indian Ocean. Climate-model simulations have revealed that the sea level has decreased substantially in the southern Tropical Indian Ocean but has increased elsewhere. The sea level around Seychelles has been decreasing, whereas around Reunion and Mauritius it has been rising rapidly and these areas are likely to experience significantly greater sea-level rise than the global mean in the future[223].

There remains a scarcity of data on ocean acidification in the WIO. WIOMSA, in partnership with various other organizations, is currently implementing ocean acidification monitoring projects in the region.

Also associated with increasing ocean temperature is ocean deoxygenation. Warmer water holds less oxygen and is more buoyant than cooler water leading to reduced mixing of the surface oxygenated water with the deeper layers. At the same time organisms living in warmer water have higher metabolic rates and consequently elevated oxygen demand.

Overall, there is a general lack of long-term, high-frequency data on all aspects of climate change in the WIO that constrains what can be reported.

### 5.2.6. RISKS AND THREATS FROM POLLUTION (PLASTIC, CHEMICAL, NOISE, ETC.)

The concentrations and distribution of plastics (both macro and micro) in the Indian Ocean are poorly understood largely due to under-sampling, particularly in comparison to other ocean basins. It is estimated that 15% of all coastal plastic and 20% of all riverine plastic enters the Indian Ocean and that it represents the second largest plastic loading after the North Pacific Ocean[224]. As well as plastic pollution derived from the surrounding land it also enters from various ocean-based sources such as fishing, shipping and offshore platforms. The monsoon winds drive the circulation patterns of the floating plastic resulting in the greatest accumulations of beached plastic found on the east African coast and the west coast of India. The smaller island nations are not immune to this impact. For example, around 513 tonnes of plastic waste were washed up on the shores of Aldabra in one year, including an estimated 360,000 flip-flops[225]. Plastic bags, smaller plastic fragments and pellets

are also known to be ingested by animals but there is no information as to the scale of the impact this has. The other major impact of plastic is the ghost fishing of lost or discarded fishing gear on sharks and rays, cetaceans, pinnipeds, sea turtles and birds but again there is a lack of data to allow accurate estimates of the scale of the impact. The likely scale of impact is considerable. For example, in one-year volunteers in the Maldives removed over 100 ghost nets and recorded 140 trapped turtles, four reef mantas, three sharks, a sperm whale and numerous fish[226].

The hydrocarbons discharged into the Indian Ocean from all sources are estimated to be between 3 – 5x106 T.yr-1, which is equivalent to 40% of the global total discharges. The potential for major pollution events also exists from shipping accidents and during exploration and production activities. There is recognized potential for future offshore oil exploration and production in the waters around the Comoro Islands as well as Seychelles. Such activities come with a wide range of potential impacts, including oil pollution, the introduction of non-native species and noise pollution. To date there has been little research into noise pollution levels in the Indian Ocean which has the potential to come from several sources including military sonar, oil exploration, shipping and underwater construction[227].

Seychelles Islands © Shutterstock

# CONCLUSION

The WIO is quite well studied in general, with some areas having received focused attention. However, some parts of its open seas, such as the Saya de Malha Bank and the Mascarenes Plateau, are still to be explored in detail.

The Saya de Malha Bank was named by Portuguese explorers 500 years ago, who encountered the bank on the voyage between the Cape of Good Hope and India. After traversing miles of deep blue Indian Ocean, they found themselves sailing above a shallow area of the bank, covered with swaying green seagrass.

The first scientific survey of the bank was undertaken by Captain Robert Moresby of the Royal Navy in 1838. Moresby previously surveyed the Laccadives, the Red Sea, the Maldives, and the Chagos Banks.

The first documented visit to the bank was The Percy Sladen Trust Expedition organized by John Stanley Gardiner on-board the sail-steam RV Sealark in 1905. The geographical focus of the expedition was in the insular areas of the WIO, particularly in the areas of the Chagos Archipelago, Seychelles, Amirante and Farquhar Islands, Cargados-Carajos Islands, the islands of St. Pierre and Mauritius. Although the emphasis was on the shallow water and onshore biota, this expedition was the first to explore the insular slopes of the WIO islands. The scientific results of the expedition were published in the Transactions of the Linnean Society of London between 1907 and 1936[39].

In the early 1960s when a new generation of freezer trawlers came into being, the USSR Ministry of Fisheries considered the WIO as an area of tremendous potential resources which had been previously only slightly exploited by coastal artisan fisheries and long-lining but never by bottom trawling. The mid-1960s to the early 1990s was the time of the greatest Soviet fisheries expansion in the Indian Ocean. At that time, prior to the introduction of Exclusive Economic Zones under UNCLOS, a total of 26 cruises[39], as reconnaissance cruises in the then *mare liberum* of the Indian Ocean, were organized by Russian research institutes.

Later, Wolf Hilbertz and Thomas J. Goreau undertook two expeditions to the Bank in 1997 and 2002[10], with the support of the Lighthouse Foundation[228], and with the intention to create an artificial reef. These scientists planned to use the "seacrete" or "biorock" technology that they developed by utilizing electricity to accrete the minerals in seawater onto a metal structure. They attempted to create an island around a steel structure that had been anchored to the North Bank seabed at a depth of 11 m (36 ft) but they failed dismally. Some sources say that the island would have been named *Autopia* or *Autopia Saya* and declared a "micronation".

This was not the first intent of creating a new territory on the Saya de Malha Bank. The French adventurer Pierre Metzger had declared the Bank as a principality in January 1989[229 230]. From 4 May to 3 June 2018, a survey by RV *Dr. Fridtjof Nansen* on the Mascarene Bank took place to contribute primarily to the Theme 'Habitat mapping' of the EAF-Nansen Programme[231]. Oceanographic and habitat mapping work on the Saya de Malha Bank was carried out based on a proposal entitled "Characterizing the Marine Ecosystem and Morphology of the Saya de Malha Bank".

The main study objectives included: geomorphology, benthic habitats and benthos, fish and crustacean resources, and physical and chemical oceanography, including ocean current measurements. The survey was successfully completed, and a wide range of samples and data were collected, including samples of benthos and sediments, photographic material collected using the video assisted multi-sampler (VAMS), as well as oceanographic samples and data.

In 2019 (September to November), 38 scientists from nine different institutes and five countries (German-led Project MASCARA) participated in the RV *Sonne* research cruise SO270 on the Mascarene Plateau and the Saya de Malha Bank with the objective of amending models of carbonate sequence stratigraphy and developing a sedimentological model for a carbonate platform under the influence of internal waves[232], and to extend knowledge about controlling factors on carbonate deposition which is relevant for both a better understanding of how carbonate platforms may evolve in a changing world and for the interpretation of carbonate platform successions in the geological record[233].

Recently, Greenpeace organized an expedition with the *Arctic Sunrise* in 2021. This expedition focused mainly on observing birds, cetaceans, and turtles.

The 2022 expedition, organized by Monaco Explorations, raises expectations in terms of the generation of new knowledge about the Mascarene Plateau, including the Saya de Malha Bank and secondary targeted sites such as Aldabra Atoll and Saint Brandon. Saint Brandon seems to be an area for which there is limited scientific knowledge, as has been stated during the Indian Ocean EBSA process.

The Baseline study revealed gaps in knowledge that the Expedition will have to fill. These gaps include the following topics:

- Interactions between currents and marine organisms in the context of complex regionally and topographically controlled oceanographic processes, including the influence of the powerful currents on both pelagic and benthic ecology and vertical migration.
- Habitats around the bank, in shallow and deeper areas, and the actual proportion and coverage of different habitats.
- Species diversity and level of endemism on the bank (using an eDNA and genomic approach).
- Predator populations and trophic structures.
- Biological and ecological connectivity across the region (from genetic connectivity to megafauna connectivity).
- Precise mapping of the bank, including localization of wrecks (using AUVs (Autonomous Underwater Vehicles) and/or ASVs (Autonomous Surface Vehicles) as well as drones for aerial mapping).
- "Soundscapes" in coral reef areas: understanding the sounds in the sea from quantitative and qualitative perspectives.
- Blue carbon of the bank.
- Plankton survey to understand the area's productivity.
- Plastic pollution and litter threats.
- Impacts of fisheries, tourism and other human activities placing pressure on the area's ecological and social values.
- Socio-economics: looking at benefits that people get from the area.

Additionally, the Expedition will identify gaps in management and governance in the region (overlap of management regimes, conservation of marine biodiversity of areas beyond national jurisdiction, etc.), including the needs for future research and monitoring.

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François SIMARD
**Secretary**
formerly at IUCN



# LIST OF ACRONYMS

| | |
|---|---|
| **AABW** | Antarctic Bottom Water |
| **AAMA** | Association of African Maritime Administrations |
| **ABNJ** | Areas Beyond National Jurisdictions |
| **ACP-EU** | European economic partnership agreement with African, Caribbean, and Pacific countries |
| **AEWA** | African-Eurasian Waterbird Agreement |
| **AIMS** | Africa Integrated Maritime Strategy |
| **AMCEN** | African Ministerial Conference on Environment |
| **ASCLME** | Agulhas and Somali Current Large Marine Ecosystem project |
| **ASV** | Autonomous Surface Vehicles |
| **AU** | African Union |
| **AUV** | Autonomous Underwater Vehicle |
| **BBNJ** | Biodiversity Beyond National Jurisdictions |
| **BIOT** | British Indian Ocean Territory |
| **BMU** | Beach Management Unit |
| **CBD** | Convention on Biological Diversity |
| **CCAMLR** | Convention for Conservation of Antarctic Marine Living Resources |
| **CDW** | Circumpolar Deep Water |
| **CEMZA** | Combined Exclusive Maritime Zone of Africa |

| | |
|---|---|
| **CITES** | Convention on International Trade in Endangered Species of Wild Flora and Fauna |
| **CLC** | Civil Liability for Oil Pollution Damage |
| **CLD** | Coralline Algae Lethal Disease |
| **CLCS** | United Nations Commission on the Limits of the Continental Shelf |
| **CLIVAR** | Climate and Ocean: Variability, Predictability and Change (Projet) |
| **CLOD** | Coralline Lethal Orange Disease |
| **CMS** | Convention on the Conservation of Migratory Species of Wild Animals |
| **COI-IOC** | Commission de l'Océan Indien - Indian Ocean Commission |
| **COMESA** | Common Market for Eastern and Southern Africa |
| **COP** | Conference of the Parties |
| **CORDIO** | Coastal Oceans Research and Development in the Indian Ocean |
| **COVID** | Coronavirus Disease |
| **DBS** | Development Bank of Seychelles |
| **DiDEM** | Dialogue Sciences-Décideurs |
| **DOE** | Department of Environment (Mauritius) |
| **DOWA** | Deep Ocean Water Applications |
| **DRDM** | Department of Risks and Disaster Management |
| **DSM** | Deep Sea Mining |
| **EAC** | East Africa Community |
| **EAF** | Ecosystem Approach to Fisheries |
| **ECS** | Extended Continental Shelf |
| **eDNA** | Environmental DNA |
| **EEZ** | Exclusive Economic Zone |
| **EIA** | Environment Impact Assessment |
| **ENSO** | El Niño Southern Oscillation |
| **EPA** | Environment Protection Act |
| **EPCO** | Environmental Protection and Conservation Organization |
| **ESA** | Environmentally Sensitive Areas |
| **EU** | European Union |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FAR-WIO** | Forum of Heads of Academic/Research Institutions in the Western Indian Ocean |
| **FFEM** | Fond français pour l'environnement mondial - French Facility for Global Environment |
| **FiTI** | The Fisheries Transparency Initiative |
| **GATT** | General Agreement on Tariffs and Trade |
| **GDP** | Gross Domestic Product |
| **GEBCO** | The General Bathymetric Chart of the Oceans |
| **GEF** | Global Environment Facility |
| **GOOS** | Global Ocean Observation System |
| **HSH** | His Sovereign Highness |
| **ICM** | Integrated Coastal Management |
| **ICS** | Island Conservation Society |
| **ICZM** | Integrated Coastal Zone Management |
| **IDC** | Island Development Company |
| **IGC** | Intergovernmental Conference (BBNJ) |
| **IGO** | Intergovernmental Organization |
| **IHO** | International Hydrographic Organization |

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|---|---|
| **IIEO** | International Indian Ocean Expedition |
| **ILBI** | international legally binding instrument (BBNJ) |
| **IMBeR** | Integrated Marine Biosphere Research |
| **IMO** | International Maritime Organization |
| **IndOOS** | Indian Ocean Observing System |
| **INT** | IHO International Charts |
| **IOC** | Intergovernmental Oceanographic Commission (UNESCO) |
| **IOCAFRICA** | IOC Sub-Commission for Africa and the Adjacent Island States |
| **IOCEA** | IOC Regional Committee for the Central and Eastern Atlantic |
| **IOCINCWIO** | IOC Committee for the Cooperative Investigations in the North and Central Western Indian Ocean |
| **IOCWIO** | IOC Regional Committee for the Western Indian Ocean |
| **IOD** | Indian Ocean Dipole |
| **IOGOOS** | Global Ocean Observing System in the Indian Ocean |
| **IOMU PSC** | Indian Ocean Memorandum of Understanding on Port State Control |
| **IORA** | Indian Ocean Rim Association |
| **IOTC** | Indian Ocean Fisheries Commission |
| **IOTO** | Indian Ocean Tourism Organization |
| **IOTOA** | Indian Ocean Tuna Operators Association |
| **IRD** | Institut de Recherche pour le Développement |
| **ISA** | International Seabed Authority |
| **IUCN** | International Union for Conservation of Nature |
| **JMA** | Joint Management Area |
| **K-T** | Cretaceous-Tertiary |
| **LBSA** | Land-Based Sources and Activities |
| **LME** | Large Marine Ecosystem |
| **LTFO** | Lake Tanganyika Fisheries Organization |
| **LVFO** | Lake Victoria Fisheries Organization |
| **MARPOL** | Convention on the prevention of pollution from Ships |
| **MARXAN** | MARine, and SPEXAN, itself an acronym for SPatially EXplicit ANnealing |
| **MEA** | Multilateral Environmental Agreement |
| **MEDA** | Marine Ecosystem Diagnostic Analysis |
| **MMCO** | Marine Megafauna Conservation Organization |
| **MMCS** | Mauritius Marine Conservation Society |
| **MOI** | Mauritius Oceanography Institute |
| **MPA** | Marine Protected Areas |
| **MSP** | Marine Spatial Planning |
| **MT-IOSEA** | The Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and Southeast Asia |
| **MWF** | Mauritian Wildlife Foundation |
| **mya** | million years ago |
| **NADW** | North Atlantic Deep Water |
| **NEOC** | National Emergency Operations Centre |
| **NEPAD** | New Economic Partnership for Africa's Development |
| **NGO** | Non-Governmental Organisation |
| **NIDW** | North Indian Deep Water |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NOSCP** | National Oil Spill Contingency Planning |

| | |
|---|---|
| **PBT** | Pentabromotoluene |
| **PDO** | Pacific Decadal Oscillation |
| **PHC** | Petroleum Hydrocarbons |
| **PMAESA** | Port Management Association of Eastern and Southern Africa |
| **POP** | Persistent Organic Pollutant |
| **PROT-CLC** | Protocol of 1976 to amend the CLC |
| **RAMP-COI** | Réseau des Aires Marines Protégées – Commission de l'Océan Indien |
| **RCP** | Representative Concentration Pathway |
| **RFMO** | Regional Fisheries Management Organisation |
| **RHC** | Regional Hydrographic Commission |
| **ROPME** | Regional Organization for the Protection of the Marine Environment |
| **RSNC** | Royal Society for Nature Conservation |
| **SAIIA** | South African Institute of International Affairs |
| **SAP** | Strategic Action Plan |
| **SAPPHIRE** | Strategic Action Programme Policy Harmonisation and Institutional Reforms (Project) |
| **SBSTTA** | Subsidiary Body on Scientific, Technical and Technological Advice (CBD) |
| **SCOR** | Scientific Committee on Ocean Research (IOC) |
| **SEC** | South Equatorial Current |
| **SECC** | South Equatorial Counter Current |
| **SeyCCAT** | The Seychelles Conservation and Climate Adaptation Trust |
| **SFA** | Seychelles Fishing Authority |
| **SIBER** | Sustained Indian Ocean Biogeochemistry and Ecosystem Research (Project) |
| **SIF** | Seychelles Islands Foundation |
| **SIOFA** | South Indian Ocean Fisheries Agreement |
| **SOLAS** | Convention for the Safety of Life at Sea |
| **SPGA** | Seychelles Parks and Gardens Authority |
| **Sv** | Sverdrup: 1 Sv equal to 1 million cubic metres per second |
| **SWIOFC** | Southwest Indian Ocean Fisheries Commission |
| **SWIOFish** | Southwest Indian Ocean Fisheries Governance and Shared Growth Project |
| **TDA** | Transboundary Diagnostic Analysis |
| **UNCLOS** | United Nations Convention on the Law of the Sea |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNGA** | United Nations General Assembly |
| **UNODC** | United Nations Office on Drugs and Crime |
| **UNWTO** | United Nations World Tourism Organisation |
| **VAMS** | video assisted multi-sampler |
| **VME** | Vulnerable Marine Ecosystem |
| **WIO** | Western Indian Ocean |
| **WIOMER** | Western Indian Ocean. Marine Ecoregion (Project) |
| **WIOMSA** | Western Indian Ocean Marine Science Association |
| **WOMESA** | Association for Women in the Maritime Sector in Eastern and Southern Africa |
| **WTO** | World Trade Organisation |
| **WWF** | World Wide Fund for Nature |

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