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Report on the Ecology of the Saya de Malha Bank and Current Threats to Its Marine Biodiversity

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Abstract

DSCC provided this report to the attention of SIOFA in relation to INFO paper **MoP-08-INFO-08 Bottom Trawl Fisheries on the Saya de Malha Bank**.

Report on the Ecology of the Saya de Malha Bank and Current Threats to Its Marine Biodiversity

Prof. Alex David Rogers

Science Director, REV Ocean, Oksenøyveien 10, NO-1366 Lysaker, Norway

www.revocean.org

Email: Alex.Rogers@revocean.org

Seagrass meadows on the Saya de Malha Bank (Hibertz et al., 2002).

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Introduction

This report has been written in support of the Saya de Malha Bank Expedition currently in planning by Monaco Explorations (https://www.monacoexplorations.org/en/). The report represents a brief survey of the literature regarding the geology, oceanography and benthic ecology of the Saya de Malha Bank as well as current threats to its biodiversity. The report was undertaken by Prof. Alex David Rogers, an expert in deep-sea ecology with more than 30 years of experience in the field including 167 peer-reviewed papers, 27 book chapters, 4 books and edited volumes and 60 reports. This experience has included projects on deep-sea fisheries and their environmental impacts with FAO, the UN Division of Oceans and Law of the Sea and several non-governmental organisations. It has also included work specifically on the Indian Ocean especially seamounts and deep-sea hydrothermal vents. Alex Rogers is currently on the Advisory Committee for the Saya de Malha Bank Expedition for Monaco Explorations.

As will be seen from the report below this work has identified an immediate danger to the unique ecosystem of the Saya de Malha Bank posed by bottom trawling. This threat is analysed and recommendations for actions made. The report will be circulated to governmental and non-governmental bodies with responsibility or interests in the ecosystem-based management and conservation of the Saya de Malha Bank. Alex Rogers has received no financial reward for this report and all the findings have been made in the context of the expedition by Monaco Explorations.

Geological background

The Saya de Malha Bank (Figure 1) is a poorly mapped large topographic feature lying in the western Indian Ocean and forms part of the Mascarene Ridge also known as the Mascarene Plateau (Hibertz et al., 2002; Spencer et al., 2008). It is formed by a series of shallow banks and shoals, 20m-90m deep separated by deep passages (Spencer et al., 2008; Figure 1) extending for 2,000km from the Seychelles in the north to Reunion in the south (Vortsepneva, 2008). At its shallowest the ridge is 7m - 8m deep (latter is Poydenet Rock on the Saya de Malha Bank) but rapidly plunges to depths of more than 4,000 – 5,000m to the east and west (Spencer et al., 2008; Vortsepneva, 2008). From north to south the ridge includes the Seychelles Plateau (31,000km^2), Ritchie Bank (also known as the northern Saya de Malha Bank; 5,800km^2), the Saya de Malha Bank (40,000km^2), the Nazareth Bank (26,000km^2) and the Saint Brandon Bank or Cargados Carajos Shoals (10,000km^2; Spencer et al., 2008). Although it superficially appears as a single structure the ridge is comprised of elements of very different geological origin and age (Hibertz et al., 2002). The Seychelles Plateau comprises pre-cambrian granite about 650 MY old and the Seychelles islands, one of only two sets of granitic islands in the world, are a continental fragment left over from the break-up and drift of Gondwana (Hibertz et al., 2002). At the other end of the ridge Mauritius is only a few million years old and was formed by a crustal hotspot which now underlies the volcanically active island of Réunion. The Réunion hotspot has given rise to the Chagos, Maldives and Laccadives archipelagos and was also responsible for the formation of the Deccan lava traps in India more than 60 MY ago (Hibertz et al., 2002; Vortsepneva, 2008). 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 (Hibertz et al., 2002; Figure 1). This means that the geological origin of the northern and southern elements of the Saya de Malha Bank may be different (Hibertz et al., 2002). The Ocean Drilling Programme has drilled three boreholes around the Saya de Malha Bank (Sites 705, 706 and 707; Hibertz et al., 2002). 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 MY ago (Hibertz et al., 2002). Back tracking suggests that the Chagos Archipelago and the Saya de Malha Bank were originally a single feature but were divided and drifted apart as a result of the formation of the Central Indian Ridge (Hibertz et al., 2002; Figure 2).

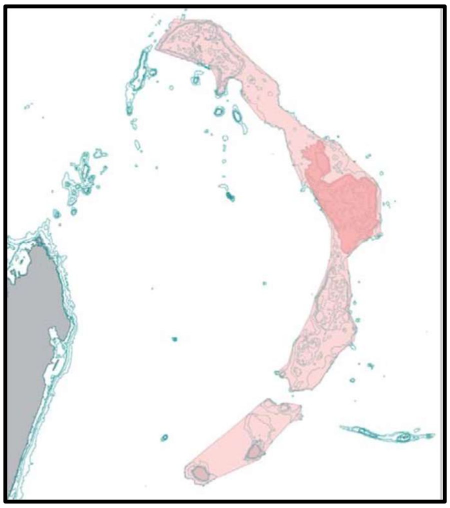

Figure 1. Mascarene Ridge showing Saya de Malha Bank in darker red/pink (Obura et al., 2012).

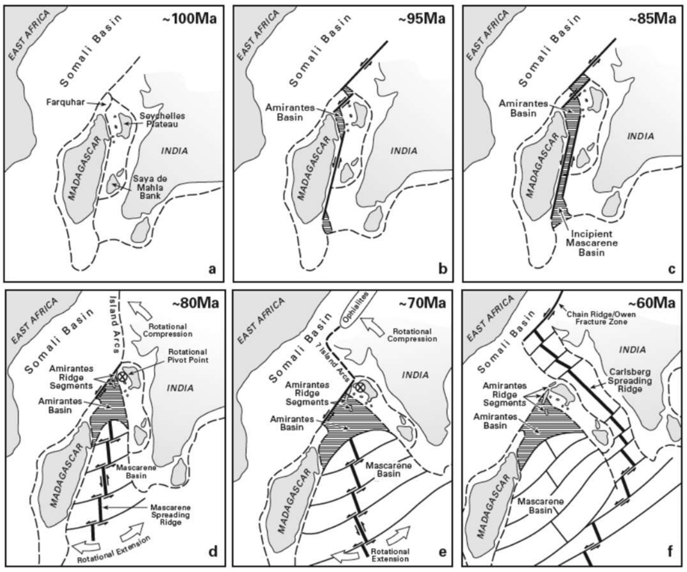

Figure 2. Palaeographic evolution of the Seychelles – Madagascar Rift and drift and the development of the Amarante Basin, Mascarene Basin and Amarante Ridge/ trough complex (Spencer et al., 2008).

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 (Hibertz et al., 2002). However, the Saya de Malha Bank forms a large area of flat horizontal terrain (Hibertz et al., 2002). This is found on some seamounts (e.g. Atlantis Bank, south west 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 (Hibertz et al., 2002). 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 (Hibertz et al., 2002). Instead, the carbonate accumulation which lays atop the basalt that form the feature appear to have been built up mainly by calcareous red algae, not coral as suggested in older literature (e.g. Davis and Francis, 1964) which tends to grow in waters too deep, too cold or too nutrient rich for corals (Hibertz et al., 2002). 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 of Bermuda; Tuvalu in the SW pacific; seamounts off Brazil). Rhodoliths are also often associated with areas subject to strong currents that prevent the accumulation of sand or fine sediments (Hibertz et al., 2002). Hibertz et al. (2002) drilled a shallow bore hole in the surface of the bank using SCUBA divers and found it to be formed by layers of calcium carbonate. Note that the findings of Hibertz et al. (2002), 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 70m in the north and 140m in the south (Vortsepneva, 2008). Two depressions on the bank are reported, one in the south at 980m depth and the other in the north at 455m depth (Vortsepneva, 2008). The slope to the east is reported as very steep with cavernous reef limestone from 20m-120m and rhythmically foliated limestone from 200m-400m depth (Vortsepneva, 2008). The south slope of the bank is reported to be formed of a number of narrow shoals and then a steep drop to 300m depth (Vortsepneva, 2008). Thickly foliated limestone gives away to thinly foliated limestone at 800-1,650m depth although it is unclear what this means (Vortsepneva, 2008). The west slope of the bank is described as steep and concave with an angle of 16^o in the upper part. The Nazareth Bank lies 20km to the south with a maximum depth of 1,100m between it and the Saya de Malha Bank (see New et al., 2007). This is covered in silt up to 700m thick and formed by lime silt in the upper layers and chalk with silica intrusions at greater depths below the seafloor (Vortsepneva, 2008).

Mineral Resources

The Mascarene Ridge has been subject to some exploration for oil deposits. Drilling by Texaco in the 1970s penetrated Palaeocene carbonates down to volcanic basalts (Kamen-Kaye & Mayerhoff, 1980). These rocks were considered to have a low potential for oil, however, it was pointed out that Mesozoic sedimentary rocks lying beneath the basalt layers may host oil (Kamen-Kaye & Meyerhoff, 1980). Later work has sampled Mesozoic rock layers in the vicinity of the Seychelles Islands which do suggest the presence of coal-bearing shales with the potential to host oil deposits (Plummer et al., 1998). Whether or not economically viable oil fields lie in the Mascarene Ridge area remains to be seen.

The Saya de Malha Bank

Oceanography

The Mascarene Ridge forms a barrier that modifies the predominantly westward flow of the South Equatorial Current (SEC; New et al., 2007; Ansorge & Attwood, 2009). As this current approaches the Mascarene Ridge it splits into a number of flows the largest of which is forced between the Nazareth and Saya de Malha Banks at 12^o-13^{o}S (about 50% of the water transport; New et al., 2007; Ansorge & Attwood, 2009; Figure 3). The remainder of the flow in approximately equal volumes passes around the northern edge of Saya de Malha Bank (8^o-9^o S) and between Mauritius and the Cargados-Carajos Bank (18^o-20^{o}S; Ansorge & Attwood, 2009; Figure 3.). Between Nazareth and the Saya de Malha Banks is mainly a sill of 400m – 500m depth although there is a deeper channel running to approximately 1,100m depth on the southern flank of the Saya de Malha Bank (New et al., 2007). Flow speeds of the largest branch of the SEC to the east of the Mascarene Ridge are in the order of up to 60-70cm sec^{-1} between 11^o-13^{o}S and to the east of the ridge the flow is typically 30-40cm sec^{-1} but up to 65cm sec^{-1} between 12^o-14^{o}S near surface (~ 27m, depth; New et al., 2007; Figure 3). Deeper (51m depth) flow can be up to 75cm sec^{-1} past the sill separating the Nazareth and Saya de Malha Banks (New et al., 2007). To the north of the Saya de Malha Bank the portion of the SEC flowing across the Mascarene Ridge may retroflect in the vicinity of the Seychelles Bank to join with the South Equatorial Counter Current (SECC; New et al., 2007). Overall, the Mascarene Ridge splits the SEC into two cores which flow westwards until they hit Madagascar where they may for the Northeast and Southeast Madagascar Currents (New et al., 2007).

In terms of water masses the upper waters of the SEC are made up of relatively low salinity water formed by the Tropical Surface Water (TSW). This water originates from the Pacific via the Indonesian Archipelago and from the excess of precipitation over evaporation in the NE Indian Ocean (New et al., 2007). Immediately below the TSW is water from the Indonesian Through Flow (ITF) with a core at 10°S and which flows to the western Indian Ocean via the SEC (New et al., 2007). The SEC acts as a barrier between water masses to the north and south. Subtropical Surface Water (STSW), Sub-Antarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) are present on the southern side of the SEC, whereas Arabian Sea High Salinity Water (ASHSW) and Red Sea Water (RSW) are found on its northern side (New et al., 2007). As they approach the Plateau, the STSW and SAMW are partially drawn northwards, and Tropical Surface Water (TSW) is drawn southwards, in order to flow across the sill near 12°–13°S (New et al., 2007). As they pass the sill between the Nazareth and Saya de Malha Banks there is considerable mixing of several of these water masses (the TSW, STSW, SAMW and RSW; New et al., 2007). At greater depths the North Indian Deep Water passes below the SEC on the western side of the Mascarene Ridge (New et al., 2007). Antarctic Bottom Water (AABW) is also present to the west of the Mascarene Ridge at depths below 4,000m spreading as far north as 10°S (New et al., 2007).

The dominant flow of the SEC in the region provides a route of connectivity for larval dispersal from the Indo-Pacific coral triangle, the Mascarene Ridge, Madagascar and other regions of the western Indian Ocean. This emphasises the potential importance of the Mascarene Ridge in terms of biogeography and dispersal with the region. Greater connectivity should be expected from east to west than from north to south bot as a result of the dominant east to west flow but also as a result of the SEC acting as a barrier between different water masses lying to the north and south of this current. Water masses will also strongly influence the biota present on the Saya de Malha Bank at different depths. Furthermore, the strong current flows around and across the Saya de Malha Bank are important in its ecology (e.g. areas of sediment-free seafloor and brining food and larvae to benthic communities).

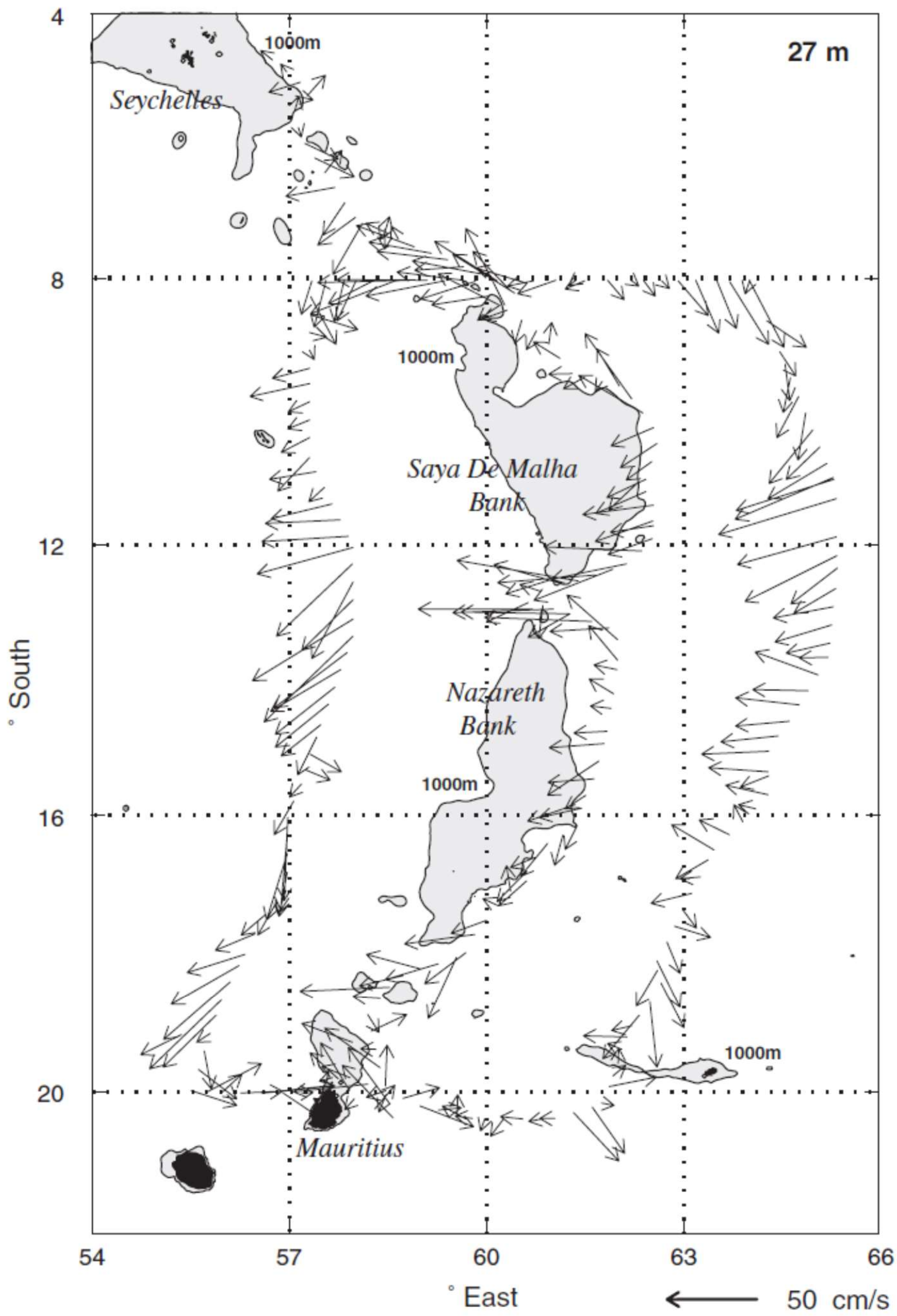

Figure 3. Acoustic Doppler Current Profiler currents (30km along track averages) at a depth of 27m. The length of the arrows indicates current speed and the direction of current is indicated by the direction of the arrows. The high current speeds at the core of the flow through the gap between the Saya de Malha Bank and the Nazareth Bank are clearly visible. Topography shallower than 1,000m depth is shaded (New et al., 2007).

Benthic communities of Saya de Malha Bank

Seagrasses

Obura et al. (2012) report that the Saya de Malha Bank hosts the largest contiguous seagrass beds in the world covering much of the estimated 40,000km^2 shallow area (Hibertz et al., 2002). *Thalassodendron ciliatum* (Forsskal) den Hartog is reported to be common on the Mascarene Ridge from shallow water to 50m depth (Milchakova et al., 2005; Figure 4,5). This seagrass species is reported to cover 80-90% of shallow surfaces from 30m-40m depth (Obura et al., 2012). It is also recorded from the islands of the Seychelles, Red Sea, eastern and western Indian Ocean (Milchakova et al., 2005). Other species of seagrass recorded from Saya de Malha Bank include *Halophila decipiens* Ostenfeld reported to occur from 20m - 40m depth and which is reported as widespread in the Indian Ocean (Milchakova et al., 2005). *Enhalus acaroides* (L.) Royle has also been sampled at 20m depth on the Saya de Malha Bank and sparsely elsewhere in the Indian Ocean although is reported to occur elsewhere in the Seychelles (Milchakova et al., 2005).

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 (Hibertz et al., 2002; Figure 4). 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 (Hibertz et al., 2002; Figure 8).

Algae

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* (Hibertz et al., 2002) although detailed work on the algae of the Saya de Malha Bank is very sparse and some very old (e.g. Foslie, 1907). The soft green alga *Microdictyon* sp. is also present on the bank as is the calcareous green alga *Halimeda opuntia* (Figure 4). Some of these algae are capable of growing to considerable depths and so it is likely that they grow well into the mesophotic zone (30 – 150m depth) and possibly into the rariphotic zone (150m - 300m depth). A significant effort on identification/description of algal taxa and their distribution on the bank should be a priority for investigation.

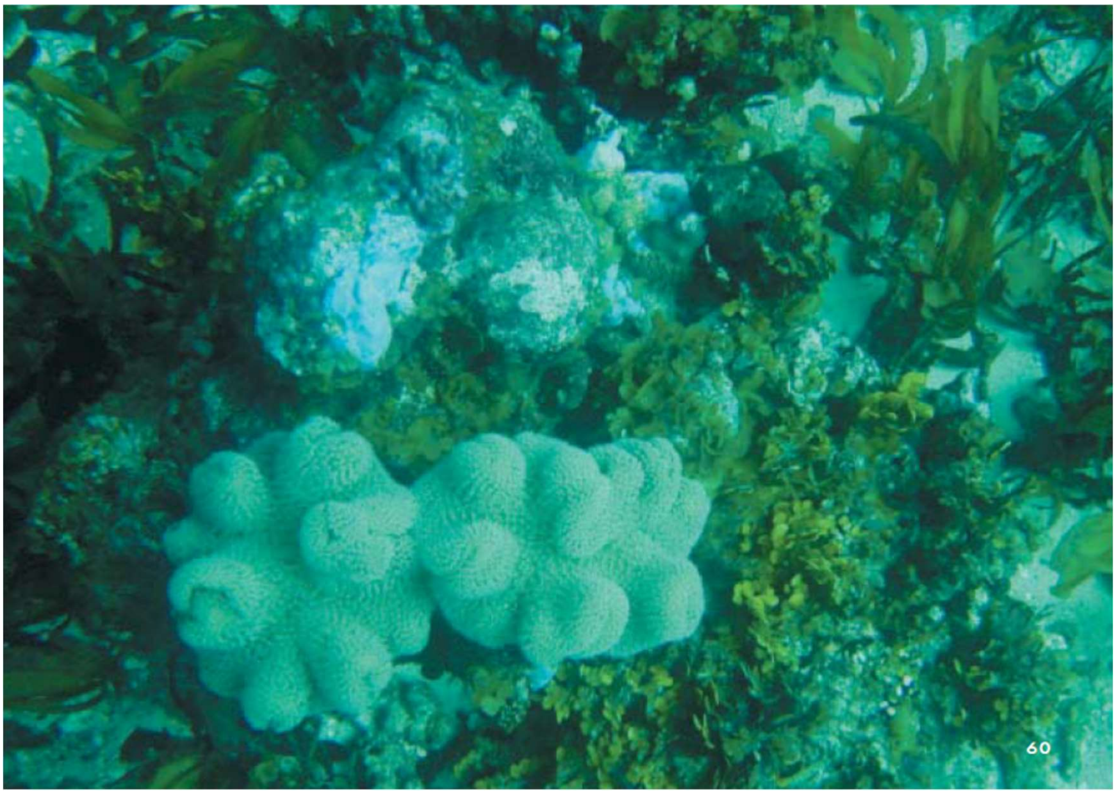

Figure 4 Photograph from Saya de Malha Bank showing mixed habitat with corals, calcareous algae and seagrass, likely Ritchie Bank (Hibertz et al., 2002).

Corals

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 seafloor or occur as scattered individuals or small clumps in seagrass (Hibertz et al., 2002; Figure 4,5). There are also observations of coral hills and ridges located in the flat on top of the bank (lagoon; Vortsepneva, 2008). Observations indicate that unlike other areas of the Indian Ocean coral communities were very mixed rather than being dominated by a few prevalent taxa (Hibertz et al., 2002). Diversity observed by SCUBA divers is high (Hibertz et al., 2002). Larger coral colonies reported in 2002 were *Porites* sp. as well as *Heliopora*, *Millepora* spp (Hibertz et al., 2002; see also Vortsepneva, 2008). Russian work indicates the presence of acroporids and *Montipora* (Vortsepneva, 2008). 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 (Hibertz et al., 2002). Vortsepneva (2008) also indicates that the steep eastern, current-exposed slopes are favourable for the growth of octocorals (Gorgonaria).

Figure 5. A scene from Saya de Malha Bank showing extensive seagrass beds with outcrops of corals (Hibertz et al., 2002).

Other invertebrates

The diversity of other benthic invertebrates has been reported to be low (e.g. soft corals, boring sponges and a few starfish; Hibertz et al., 2002) 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) identified sponges, bryozoans and tunicates as dominating slope habitats. Areas of flat sediment in the “lagoon” are reported to be populated with deposit feeders such as

Spatangus purpureus, *Priapulus* sp. which feed on plant and algal detritus and which can occur at a high density (14 individuals m^{-2}; Vortsepneva, 2008). *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 (Vortsepneva, 2008). Polychaetes reported include multiple species of *Prionospio* from finer sediments in flat areas of the reef and lagoon as well as *Spiophanes soderstromi* (Vortsepneva, 2008). A community characterised by *Anomia ephippium* (saddle oyster) is also described from the "lagoon entrance" where there is a course sediment of mollusc/algae sand (Vortsepneva, 2008). This is another species with a distribution focused in the NE Atlantic / Mediterranean with 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 which appears to be endemic (*Tridacna rosewateri*, Sirenko & Scarlatto, 1991). Vortsepneva (2008) reports 142 molluscs from the Saya de Malha Bank (including 89 Gastropoda, 7 Bivalvia). The majority of these species were found at 12-15m depth whilst 15 were found at 70m depth and only two at 200m (Vortsepneva, 2008). This paper also identifies 11 new species of molluscs have been described from the bank, all of which are endemic to Saya de Malha or the Mascarene Ridge (Vortsepneva, 2008). Molluscs described from the bank include: *Lyria doutei*, *L. surinamensis*, *Murex surinamensis* (Bouchet & Bail, 1991); *Conus primus* (Röckel & Korn, 1990 in Bouchet & Bail, 1991); *Haustellum danilai* (Houart, 1992); *Amalda danilai*, *Amalda trippneri* (Kilburn, 1996) and *Prionovolva melonis* (Rosenberg, 2010). Of these species only *Prionovolva melonis* is known outside of the Saya de Malha Bank (i.e. is not endemic). Bouchet & Bail (1991) 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 100m-400m and includes the octopus Scaeurgus (175m-250m depth) that is found on the top of the bank, the squid *Abralia* and *Enoploteuthis* which inhabit the slopes, near bottom squids including *Moroteuthis* (518m-1720m depth), *Ancistrocheirus* (518m-1720m depth), *Histiotheuthis* (518m-1720m depth), *Todaropsis* (170m-400m depth), *Nototodarus* (170m-400m depth), *Ornithoteuthis* (518m-1720m depth), the near bottom squids *Heteroteuthis* and *Alloposus* (960m-1650m depth) and the near-bottom octopuses *Opisthoteuthis*, *Grimpoteuthis* (960m-1650m depth) and *Benthoctopus* (960m-1650m depth; Vortsepneva, 2008). The second group are shallower water species associated with the reef habitat at up to 200m depth and include: *Sepia, Sepiola, Sepioteuthis, Loligo* and *Octopus* (Vortsepneva, 2008).

Crustaceans found on the bank include: *Puerulus carinatus* (George & Main, 1966); *Nephropsis malhaensis* (Borradaile, 1899 in Chan, 2010); and *Oreophorus holthuisi* (Huang, 2010). 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 western Indian Ocean or beyond (see below for fish).

Vortsepneva (2008) 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 lies 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).

Vortsepneva (2008) provides two maps reporting on the seabed physical composition and occurrence of some species in their publication (see Figures 6,7).

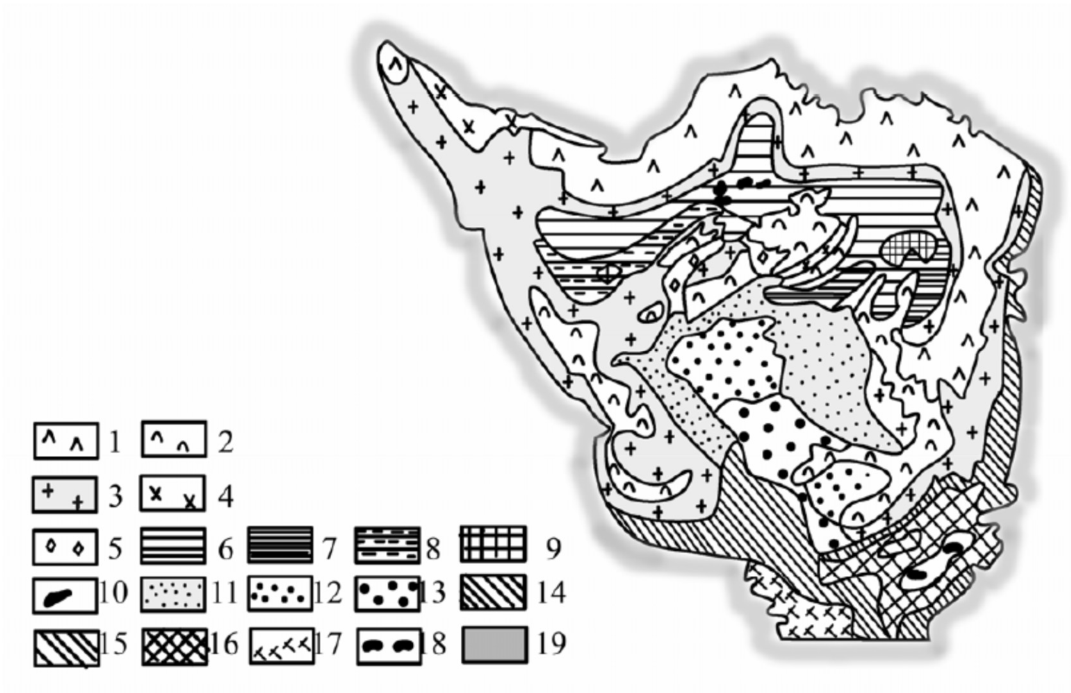

Figure 6. Landscape of Saya de Malha Bank. **Landscape of submerged circular reef.** 1. Upper terrace. Bottom consists of float stone – gravel – pebble. Dominants: macrophyte, madreporarian corals (Madreporaria), Spongia. 2. Low terrace. Bottom consists of sand – gravel foraminifera – algae ground. Dominants: calcareous algae, benthic foraminifera. 3. Slopes and foot of reef. Bottom consists of foraminifera – algae send. Dominants: *Spatangus purpureus* (Echinoidea), *Priapulus* sp. 4. Slopes of reef. Bottom consists of silt – send. Dominants: *Spiophanes soderstromi*. 5. Shallow gullies. Bottom consists of silt – send. Dominants: *Prionospio* sp. **Landscape of shallow coral lagoon.** 6. Bottom accumulative flat. Bottom consists of fine-dispersed silt. Dominants: *Brisaster* sp. (Echinoidea) and *Trochostoma* sp. 7. Bottom accumulative flat. Bottom consists of silt. Dominants: *Prionospio* sp. 8. Bottom accumulative flat. Bottom consists of sound – silt. Dominants: *Prionospio* sp. 9. Bottom accumulative flat. Bottom consists of sound – silt and fine-dispersed silt. Dominants: *Pelosina* sp. 10. Intralagoon coral mount and ridge. Bottom consists of coral – algae gravel and pebble. Dominants: acropores, tunicates, spongy, calcareous algae. **Landscape of deep coral lagoon.** 11. Bottom-dwelling accumulative flat. Bottom consists of silt – send. Dominants: *Prionospio* sp. 12. Bottom-dwelling abrasive flat. Bottom consists of foraminifera send. Dominants: collecting detritophage. 13. Bottom-dwelling abrasive flat. Bottom consists of mollusk-algae send. Dominants: *Anomia ephippium* (Bivalvia). **Landscape of the reef top.** 14. Limestone flat. Bottom consists of thin layer foraminifera send. Dominants: *Spiophanes soderstromi.* 15. Limestone flat. Bottom consists of gross calcareous – algae send. Dominants: *Spatangus purpureus* и *Priapulus* sp. 16. Limestone flat. Bottom consists of rock with thin layer algae – foraminifera send. Dominants: immovable seistonophage. 17. Limestone flat. Bottom consists of foraminifera send. Dominants: horny coral. 18. Intralagoon rises. Bottom consists of coral limestone with gravel – pebble algae ground. Dominants: calcareous algae and spongia. **Landscape of slopes.** 19. Slopes with steep steps. Bottom consists of send. Dominants: *Spiophanes soderstromi* (Vortsepneva, 2008).

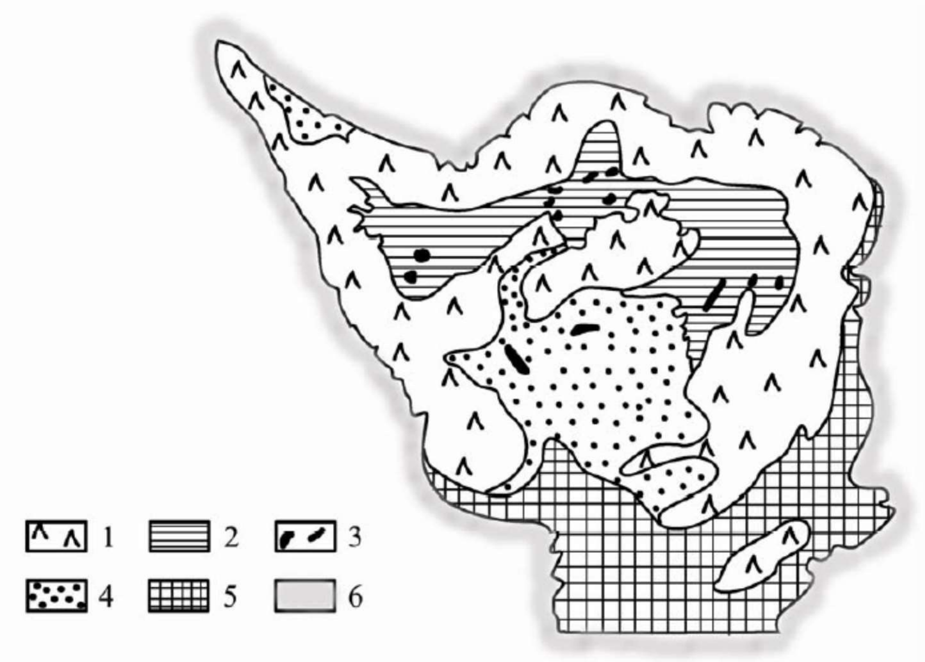

Figure 7. Zoning of Saya de Malha Bank by results of trawl. 1. coral reefs. 2. shallow lagoon 3. coral rises. 4. shallow lagoon and accumulative slopes. 5. limestone flat of the reef. 6. Slopes with steep steps (Vortsepneva, 2008)

Fishes

A high diversity of fish was observed on the Saya de Malha Bank with the greatest concentrations near the seafloor and close to coral reefs / clumps (Hibertz et al., 2002). 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* (40m-290m depth in the winter and 10-80m in the summer), *Decapterus kiliche* (shelf zone, 10m-280m 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 105m-250m); greeneyes (Chlorophthalmidae) including: *Chlorophthalmus* sp.; grenadiers (Macrouridae), including *Malacocephalus laevis* (500m-560m depth) and rabbitfish (Chimaeridae) including *Chimera monstrosa* (800m-1,300m depth; Vortsepneva, 2008). 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*, Fraser, 2000), dragonets (*Callionymus dragonae*, Nakabo, 1979); flatfish (*Tosarhombus nielseni*, Amaoka & Rivaton, 1991; *Engyprosopon hensleyi*, *Arnoglossus sayaensis*, *Parabothus malhensis*, Amaoka & Imamura, 1990; *Samariscus leopardus*, Voronina, 2009; *Brachirus sayaensis*, Voronina, 2019), goat fishes (*Parupeneus* procerigena, Kim & Amaoka, 2000); gurnards (*Lepidotrigla sayademalha*, Richards, 1992); lizard fish (*Saurida tweddlei*, Russell, 2015); sand lances (*Protammodytes* ventrolineatus, *Bleekeria profunda*, Randall & Ida, 2014); scorpion fish (*Ebosia saya*, Matsonuma & Motomura, 2014); serranids (*Odontanthias dorsomaculatus*, Katayama & Yamamato, 1986), shovelnose ray (*Rhinobatos nudidorsalis*, Last et al., 2004), sparids (*Polysteganus cerasinus*, Iwatsuki & Heemstra, 2015 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 to 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 western Indian Ocean or beyond. Further investigation of the levels of endemism associated with the bank are clearly very urgent given the damage to the feature by fishing. This is likely to have both impacted on some of these fish species directly (e.g. *Saurida tweddlei*) or their habitat (see below).

Charismatic megafauna

The 2002 Lighthouse expedition recorded frequent observations of green turtles likely feeding on seagrasses (Hibertz et al., 2002; Figure 8). Observations of schools of spotted dolphin, spinner dolphin, pilot whales, and beaked whales were also recorded, either over the bank or on the bank edges (Hibertz et al., 2002). Bird tracking in the western Indian Ocean has demonstrated that the Mascarene Ridge area to the south of the Seychelles is important for seabird foraging, especially for the wedge-tailed shearwater and for the white-tailed tropic bird (Le Corre et al., 2012).

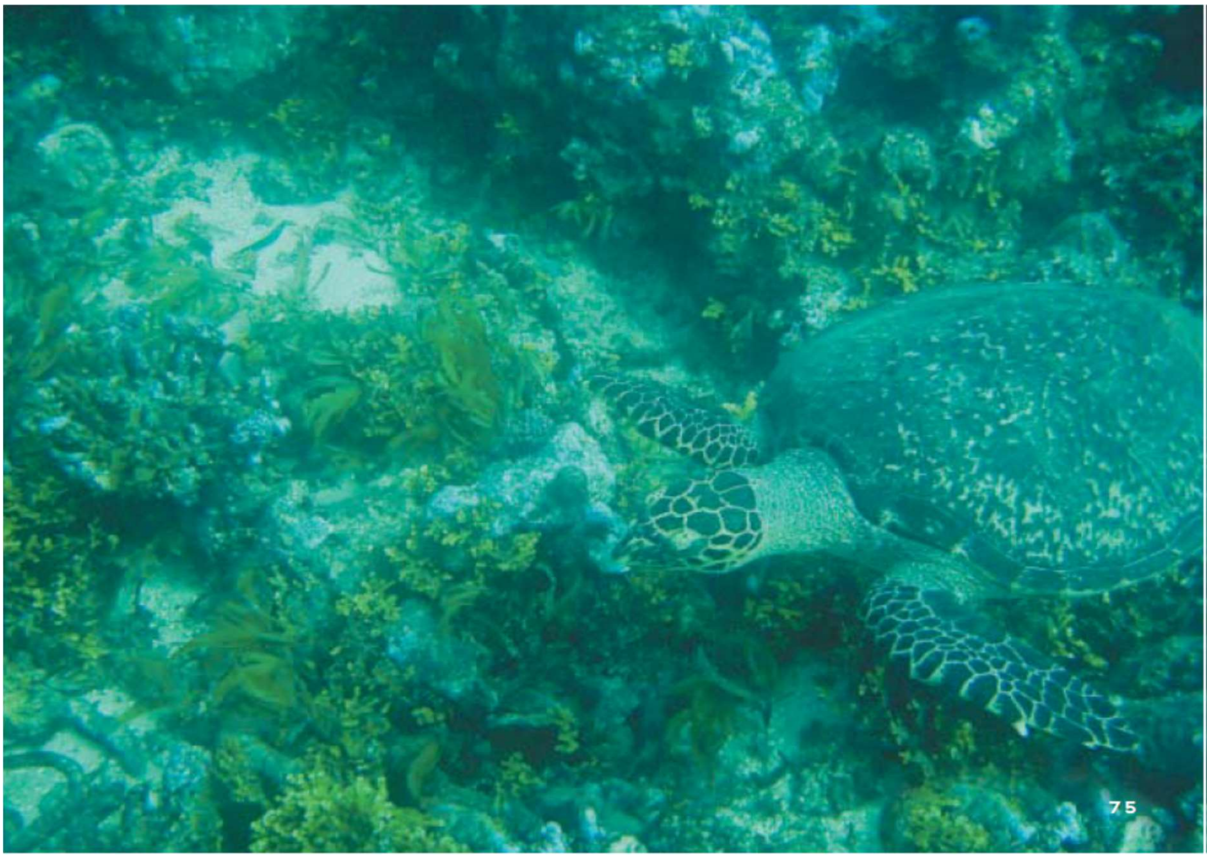

Figure 8. Green turtle browsing on the Saya de Malha Bank (Hibertz et al., 2002).

Threats

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 Banks but disease identified in corals may be driven or exacerbated by increasing water temperatures (Hibertz et al., 2002; see below). 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 southwestern Indian Ocean on seamounts (Woodall et al., 2015). Beyond doubt, however, fishing is by far the most significant threat to the benthic and pelagic ecosystems of the Saya de Malha Bank.

Fishing: a total failure of regulation

The hook and line fishery

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 (listed in Vortsepneva, 2008) and fisheries assessment cruises by FAO / UNDP and the EAF Nansen programme (Strømme et al., 2008; FAO, 2014), and China (van der Elst & Everett, 2015). Fishing began on the 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 (FAO, 2014). 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 (FAO, 2014). 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 (FAO, 2014). 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 lack of sufficient local active fishermen for fishing campaigns the number of Mauritian vessels began to decline again from 1994 (FAO, 2014). Local fishing companies began to reflag their vessels to avoid certification costs and hire fishers from other countries (e.g. Madagascar; FAO, 2014). In 2006 the Mauritian Government made further policy changes charging a "contributary fee" to foreign vessels and allocating catch quotas for foreign vessels (FAO, 2014).

It is important to note that throughout this period the predominant form of fishing on the Saya de Malha Bank was handlining (FAO, 2014). 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 (FAO, 2014). Mother ships are typically 35m – 55m in length and carry 15 to 22 dories (FAO, 2014). Bottom longlines, gillnets and traps have also been deployed on the bank, but these were found not to be effective (FAO, 2014). The hook and line fisheries tend to target areas of coral reef and seagrass between 18m – 60m depth (FAO, 2014) and the map of the fished area for hook and line (see Fig. 9) corresponds to reef areas identified in Vortsepneva (2008; see Fig. 6).

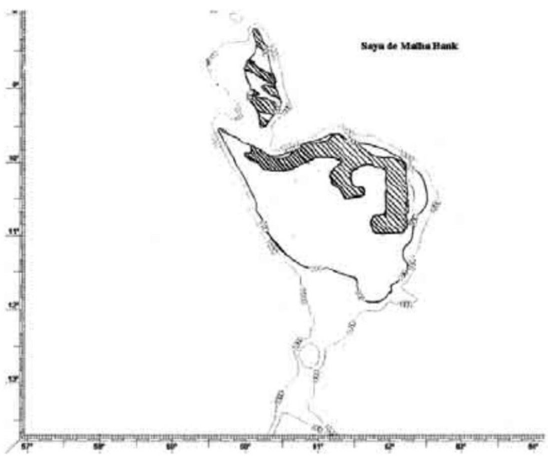

Figure 9. Fishing areas on the Saya de Malha Bank by the hook and line fishery in 2011 (FAO, 2014)

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*; FAO, 2014). 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 (FAO, 2014). The fishery has therefore been overexploited in the past and more recently moderately exploited (FAO, 2014). 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. There is also a bottom-line fishery in the area although details of this fishery are scant (FAO, 2014).

Management of areas beyond national jurisdiction including the Saya de Malha Bank by SIOFA

In 2012 the Southern Indian Ocean Fisheries Agreement (SIOFA) came into force in the south west and western Indian Ocean charged with managing non-tuna fisheries in areas beyond national jurisdiction, including on the Saya de Malha Bank (SIOFA, 2006). Mauritius and several other countries have now joined the agreement including Thailand and China. Much of the resources and time of the organisation has been concerned with putting into place the institutional framework, and only recently grappling 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 five areas closed to bottom trawling to protect vulnerable marine ecosystems (VMEs) 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 (SIOFA 2020a). Taxa (indicators for VMEs) listed for the SIOFA region include (SIOFA 2020a):

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)

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. These measures are triggered on levels of bycatch reaching threshold values (SIOFA, 2020a):

a. 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.

b. 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 (SIOFA, 2020a).

As described in past literature there are many issues with VME encounter protocols which render their effectiveness questionable (Auster et al., 2010; Rogers & Gianni, 2010). 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 within the region being managed. At present SIOFA are still mapping where potential VMEs may be distributed in the region and also an assessment of potential trawl impacts of the Saya de Malha Bank, both due to be delivered in 2022 (SIOFA, 2020b). The development of a framework for assessing and preventing significant adverse impacts on VMEs will be undertaken after these studies are competed and is due for delivery in 2023 (SIOFA, 2020b). SIOFA have also undertaken work on shark bycatch in the area of competence.

The Thai trawl fishery

In 2015 the Thai distant-water fishing fleet commenced an otter board trawl fishery on the Saya de Malha Bank (DOF Thailand, 2018; Marsac et al., 2020; Delegation of Thailand, 2021; Figure 10,11). Catches in the first year of fishing amounted to just over 22,729t and was 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; Delegation of Thailand, 2020). However, note that these figures vary in reports to the Scientific Committee of SIOFA in 2018 and 2021 (Delegation of Thailand, 2018, 2021).

Figure 10. Thai trawler (DOF Thailand, 2018).

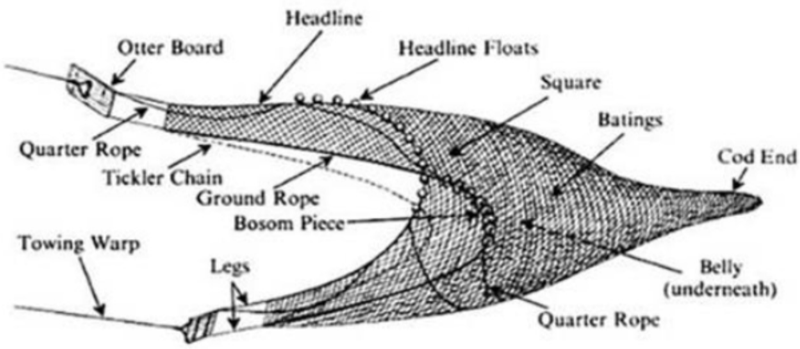

Figure 11. Otter trawl (DOF Thailand, 2018).

It was in 2017 when Thailand joined SIOFA and in February of this year the fleet was called on to return to port in Thailand and fishing rules amended to reflect regulations set by SIOFA (Delegation of Thailand, 2018). The main catch of the Thai trawl fleet during this period were reported as lizardfish (mainly *Saurida undosquamis*) and round scad (mainly *Decapterus russelli*; Delegation of Thailand, 2021). 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 (Delegation of Thailand, 2021). 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 are 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 (Marsac et al., 2020). The area in which historic trawling has taken place is illustrated in Figure 12 and where trawling is currently taking place is illustrated in Figure 13.

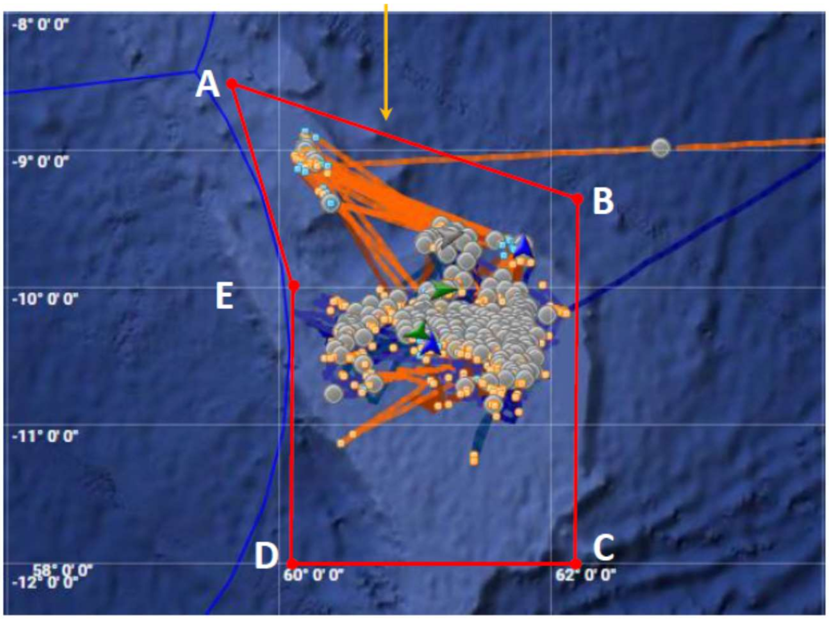

Figure 12. Fishing footprint of Thai trawlers on the Saya de Malha Bank (DOF Thailand, 2018).

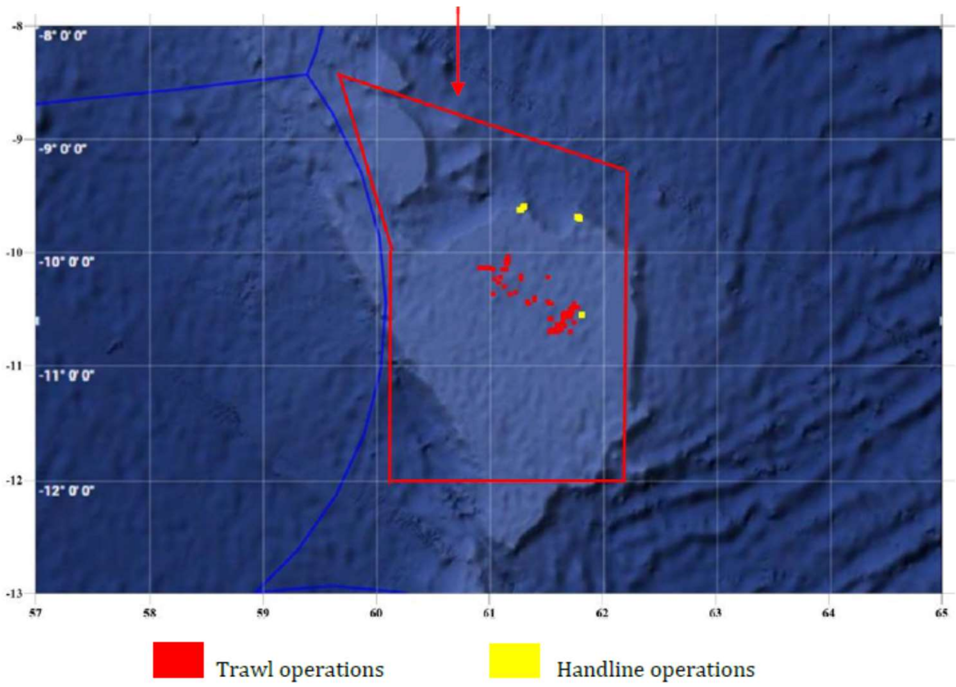

Figure 13. Fishing ground for the otter-trawl fleet in 2020 (Delegation of Thailand, 2020).

According to the habitat maps by Vortsepneva (2008; Figures 6,7) the trawl fishery has targeted what is termed coral reef, reef slope, limestone flat, low terrace and lagoon habitats. These habitats are known to host coral reef communities, seagrass meadows and algal communities (see above). 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 (Delegation of Thailand, 2021). The handline bycatch of corals over the same period was 27.5kg and 10kg (Delegation of Thailand, 2021). It is notable that seagrass is not a VME taxon in the SIOFA lists and so none are recorded on observations. It is also unknown as to whether seagrass would be retained by fishing gear or rather just torn up and left on the seafloor. It is also notable that 3 leatherback turtles, 560kg of hammerhead sharks, 1 Mobula ray and 5 guitarfish were also caught as bycatch in 2020 (Delegation of Thailand, 2021).

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 recognised by UNESCO as being a potential candidate Marine World Heritage site, classified as a site with "*Potential Outstanding Universal Value*" (Obura et al., 2012) because it is a bank in the high seas 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) 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 ecologically and biologically significant Area (EBSA) under the Convention for Biological Diversity is unclear. What is surprising is that the trawl fishery is continuing under SIOFA. At present, the Saya de Malha Bank is part of a Joint Management Area between Seychelles and Mauritius and the competence of SIOFA over the Bank has been discussed in the 2018 Meeting of the Parties (SIOFA, 2018). SIOFA's competence over the Bank has been questioned. (Marsac et al., 2020). It is unknown what Mauritius and Seychelles' position is on the destruction of biodiversity on the Saya del Malha Bank, but in any case the Convention on Biological Diversity (CBD) imposes obligations on States to take steps to protect biological diversity in-situ where possible (CBD Article 8), and States are obliged under UNCLOS to "protect and preserve the marine environment" (UNCLOS Article 192) as well as to take measures to protect rare or fragile ecosystems (UNCLOS Article 194(5)). Obligations to conserve the living resources of high seas include a State's responsibility to consider the effects of fishing on associated species, which could include sedentary species on the continental shelf. (UNCLOS Article 119(1)(b)).

Disease

Hibertz et al. (2002) observed two diseases effecting 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 (Hibertz et al., 2002). 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 (Hibertz et al., 2002). Whether a background occurrence of these diseases is normal or whether it is driven by climate change (e.g. rising sea temperatures) has not been investigated.

Summary

(1) The Saya de Malha Bank is a unique marine ecosystem the like of which is not found anywhere else in the ocean. Its uniqueness comes from the following features identified in the literature:
- The largest contiguous seagrass habitat in the global ocean
- An unusual combination of coral reef, calcareous algae and seagrass forming communities on an isolated topographic feature
- A high diversity of species which are potentially endemic to the Saya de Malha Bank

(2) The bank is also highly biologically diverse, of strong importance to oceanic megafauna (e.g. turtles, seabirds) and of great importance in terms of connectivity of coral and other ecosystems in the western Indian Ocean and, over longer timescales, the wider Indian Ocean and Indo-Pacific Coral Triangle. As a result of these features the Saya de Malha Bank has been identified as an EBSA under the CBD and also a candidate UNESCO high seas World Heritage Site.

(3) There is a lack of data on almost every aspect of the ecology of the Saya de Malha Bank including:
- High resolution bathymetric map
- High resolution habitat map
- Comprehensive inventory of biological diversity including potential marine genetic resources
- Use and importance of the Saya de Malha Bank by migratory fish species and oceanic megafauna (whales, turtles, sharks, seabirds)
- Importance of the bank as a blue carbon ecosystem (seagrasses and algae are important in carbon sequestration)
- Importance of the bank in connectivity of coral reef and other ecosystems in the western Indian Ocean
- Deep-sea ecosystems (200m+ depth)

(4) Hook and line fishing has taken place on the Saya de Malha Bank since the 1950s. At times this fishery has likely overexploited target fish stocks but its impact on the wider ecosystems of the Saya de Malha Bank are likely to have been relatively low compared to other forms of fishing.

(5) The commencement of a bottom trawl fishery by the Thai fishing fleet on the Saya de Malha Bank in 2015, which continues today, is likely to have caused catastrophic damage to fragile VMEs on the upper parts of the bank. This damage will have been particularly severe to the seagrass beds, coral reef and calcareous algal communities which are the main features of conservation importance of the bank and the reason it has been recognised globally as a feature of international importance.
(6) Damage to the Saya de Malha Bank may or may not be recoverable but it is imperative that the current bottom trawl activities cease to prevent further destruction of the benthic ecosystems of the bank including widely recognised VMEs. Immediate cessation of trawling will prevent further damage to VMEs and will allow scientific evaluation of the damage to the Saya de Malha Bank and likelihood of recovery (e.g. a scientific expedition is planned to the bank in 2022/2023 by Monaco Explorations). A management plan can then be developed which conserves the important and unique biodiversity of the bank for the future.
(7) Other forms of fishing will require assessment in terms of their sustainability and also damage to seafloor ecosystems (hook and line, trap, bottom line fisheries)
(8) It is important that the SIOFA list of VME Indicator species is reviewed and modified to reflect VMEs that occur in the Indian Ocean region that may be distinctive or even unique to the region. In short order seagrasses should be included in the list. Further taxa can be added as current VME mapping activities are completed.

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