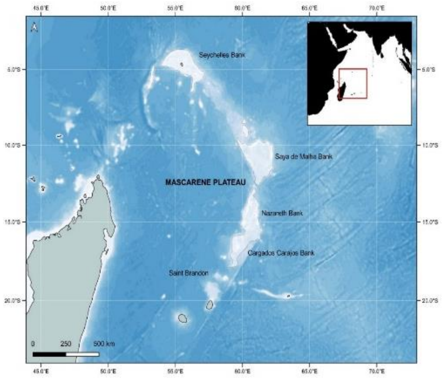

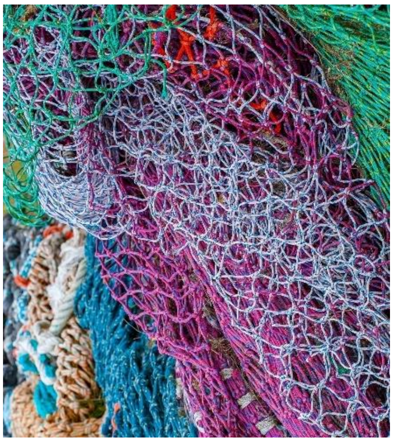

Impact Assessments of Bottom Trawl Fisheries on VME Indicator Species

Southern Indian Ocean Fisheries Agreement

SER2021-03

Final Report

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MRAG

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Acronyms

Acronym	Definition
ABNJ	Areas Beyond National Jurisdiction
CMMs	Conservation and Management Measures
EU	European Union
SAI	Severe Adverse Impact
SIOFA	Southern Indian Ocean Fisheries Agreement
ToR	Terms of Reference
VME	Vulnerable Marine Ecosystem

Executive Summary

The Saya de Malha Bank (hereafter "Saya de Malha") is the world's largest submerged ocean bank, covering an area of approximately 41,000 km^2. Saya de Malha is a highly productive ecosystem and is thought to contain among the most extensive seagrass areas in the world, interspersed coral reefs. As such, Saya de Malha is likely an important biodiversity hotspot which may be highly sensitive to the impacts of fishing. Saya de Malha falls within the Southern Indian Ocean Fisheries Agreement's (SIOFA's) area of competence whom, amongst other responsibilities, set out the management of bottom trawling activities under CMM 2020/01. This includes the development and provision of advice for encounters and associated thresholds for VME species.

This report aims to assess whether bottom trawl fisheries on Saya De Malha have severe adverse impact (SAI) on VME indicator species, using the information collected and collated under the Scoping Study on Saya de Malha Fisheries. VMEs are groups of species, communities or habitats that may be vulnerable to impacts from fishing activities. Several VME taxon have already been defined by SIOFA in CMM-2020-01 and these were assessed. Seagrass was also assessed given in prevalence on Saya de Malha. Assessing the potential for SAI on VMEs needs to consider 'impact' and 'risk' (the intensity, duration, spatial extent and cumulative effects of fishing activities), and define the dependency of these elements on spatial and temporal scales. 'Overall risk' can be defined as the risk remaining after monitoring, management and mitigation measures are accounted for.

At present the identification of VME species, their distribution and the impacts of bottom trawl fisheries on Saya de Malha is poorly understood. The first assessment of flora and fauna of Saya de Malha was completed 20 years ago. Recent studies on Saya de Malha and or the SIOFA area since have focused on physical oceanography, ocean productivity and pelagic and demersal resources. This study takes the first steps towards an informed assessment of bottom trawling impacts on VME species on Saya de Malha by inferring the potential distributions of VME species based on estimated depth ranges from closely related species, or the same species but from different regions, and considering their spatial overlap with the known spatial distribution of bottom trawl fisheries (based on AIS data from Global Fishing Watch, available for 2020 only) and semi-quantitative assessments of species tolerance to and recovery from trawling activities. The findings indicate that the highest-risk VME species are Euryalida (basket star), closely followed by Actiniaria (sea anemones), Alcyonacea (soft corals), Antipatharia (black coral), Crinoidea (crinoids), Pennatulacea (sea pens) and Stylasteridae (lace corals), all of which have low recovery potential from trawling impacts. Other groups of relative concern, particularly if trawling activities were to increase in the coming years, include Cidaroida (sea urchin), Sceleractina (stony/hard corals), Serpulidae (tube-building worms), and the extensive seagrass beds formed of *Cymodoceaceae spp*.

At present the level of trawling activity appears low with Thailand the only confirmed fishing nations operation only two and three vessels in 2019 and 2020, respectively. This low-effort serves to limit the spatial overlap between many VME species and trawling activities. However, if trawling were to increase toward levels seen in earlier years (i.e., 56 and 58 vessels in 2015 and 2016, respectively) the spatial overlap with, and thus the risk to, many VME species would likely increase substantially and may be a cause for major concern.

In order to better understand the bottom trawl fisheries interactions with VME species of Saya de Malha, SIOFA should prioritise efforts to more precisely document species and fisheries effort distributions both historically and in future. This would serve to improve confidence in the assessment of impacts from ongoing fisheries and allow for evidence-based management decision-making and the formulation and implementation of appropriate management actions if required.

1 Introduction

The Southern Indian Ocean Fisheries Agreement (SIOFA) is a legally binding agreement that was signed in Rome the 7th July 2006 and entered into force in June 2012 to ensure the long-term sustainability of non-tuna fishery resources in the Southern Indian Ocean through cooperation among the Contracting Parties, and to promote the sustainable development of fisheries in the Area (Figure 1).

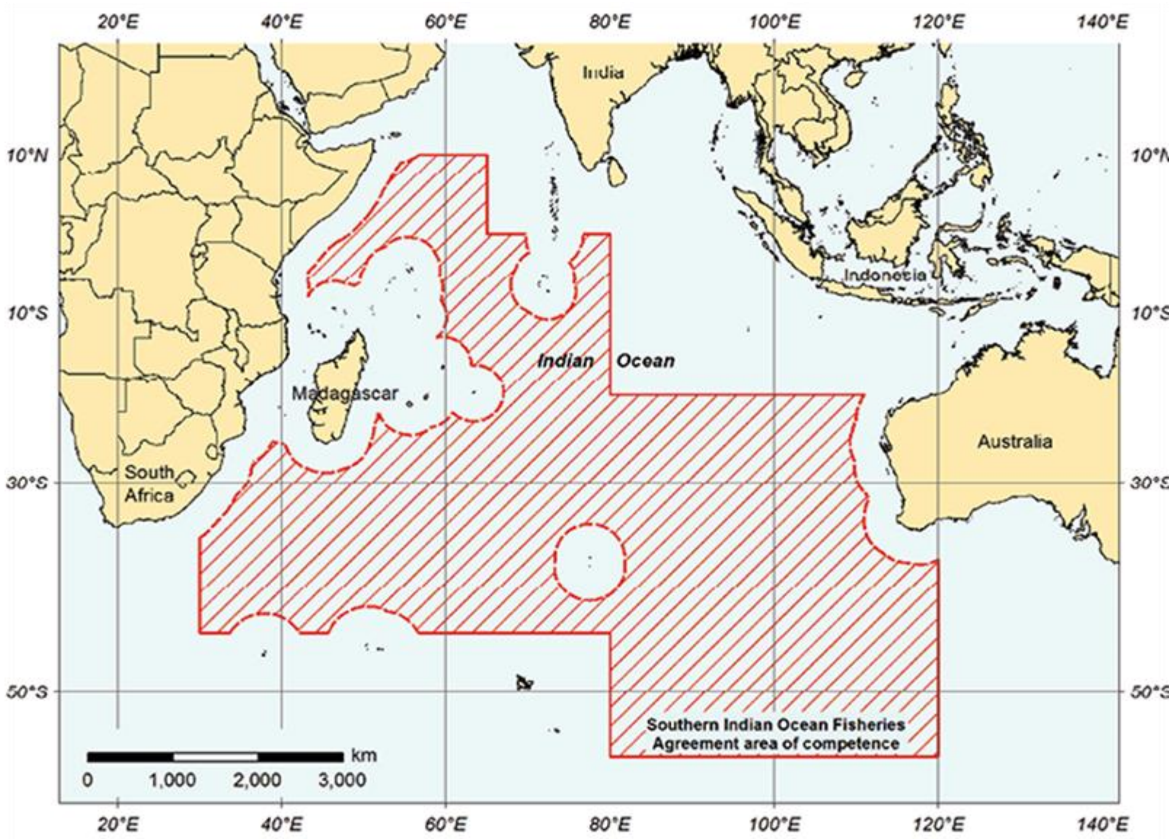

Figure 1. Southern Indian Ocean Fisheries Agreement Area (Source: Australian Government[1])

To date, SIOFA has ten Contracting Parties: Australia, China, the Cook Islands, the European Union, France on behalf of its Indian Ocean Territories, Japan, the Republic of Korea, Mauritius, the 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.

SIOFA manages a variety of fishery resources, excluding highly migratory species and sedentary species subject to the jurisdiction of coastal States, through the implementation of conservation and management measures[2] (CMMs), which make provision for control measures and area restrictions for species and ecosystem protection. Some of the main fish targeted in the SIOFA area include: *Saurida* spp. (*Synodontidae)*; scads (*Decapterus)*; Patagonian toothfish (*Dissostichus eleginoides)*; orange roughy *(Hoplostethus atlanticus)*; alfonsino *(Beryx splendens)* and oilfish (*Ruvettus pretiosus).*

The EU has agreed to a 2-year funding arrangement to enable SIOFA to commission a series of scientific studies to support the SIOFA/Scientific Committee's Work Plan (Report of the

[1] https://www.agriculture.gov.au/fisheries/international/siofa
[2] https://www.apsoi.org/cmm

Scientific Committee, SC6). As part of this agreement, Specific Objective 4 (under General Objective 1) relates to the assessment of key target stocks of the Saya de Malha Bank fisheries.

The Saya de Malha Bank (Figure 2), hereafter "Saya de Malha", is the largest submerged ocean bank in the world covering an area of approximately 41,000 km^2. Saya de Malha is comprised of two separate structures, the smaller North Bank and larger South Bank, which is recognised as a submerged atoll structure. The banks are covered with seagrass, thought to be among the most extensive seagrass areas in the world with a potential area of more than 4,000 km^2[2,3], interspersed with small coral reefs.

ToR 2 aims to assess whether bottom trawl fisheries on Saya De Malha have severe adverse impact (SAI) on VME indicator species, using the information collected and collated under ToR 1.

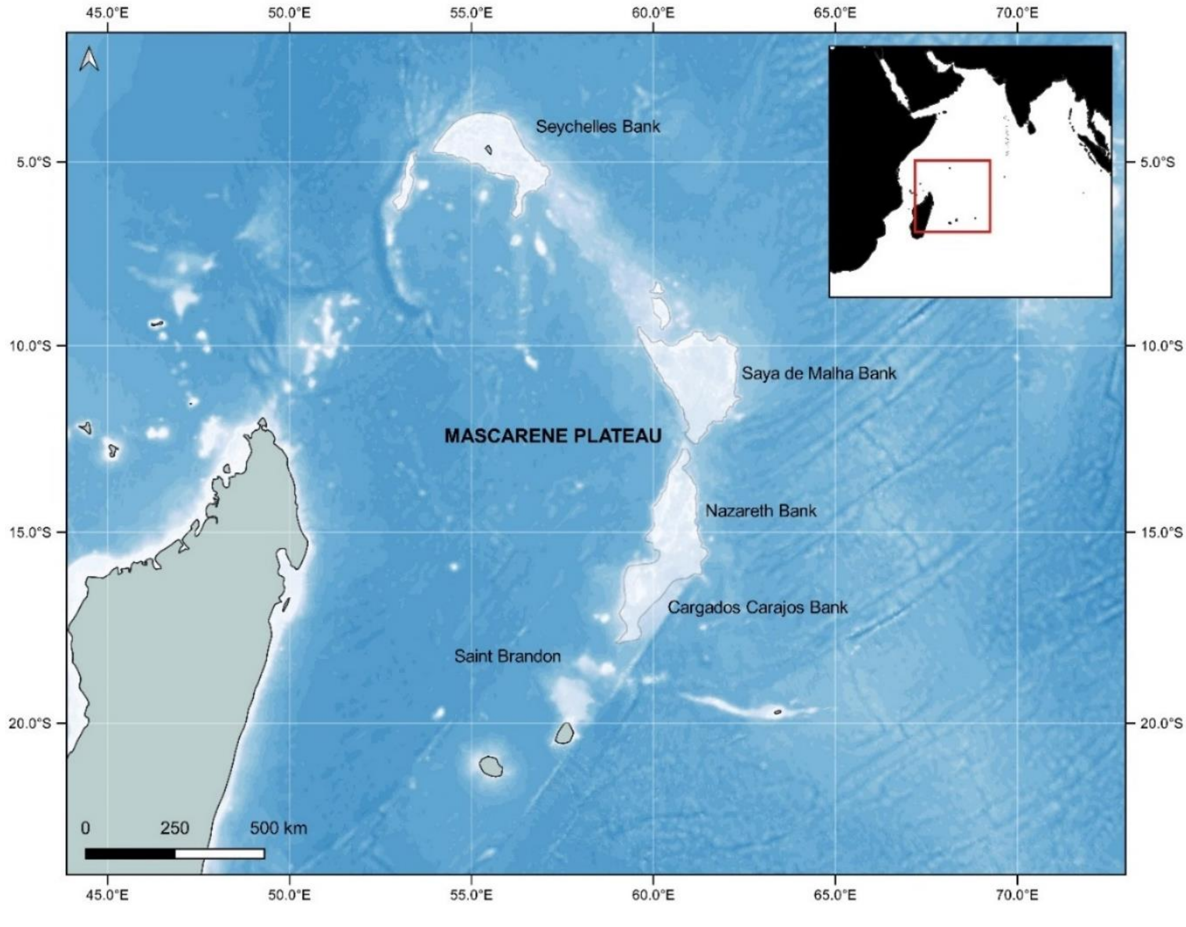

Figure 2. Mascarene Plateau; highlighting the Saya de Malha Bank

[3] http://www.wolfhilbertz.com/downloads/2002/saya_2002_rev1.pdf

2 Methodology

Assessing the potential for SAI on VMEs needs to consider 'impact' and 'risk' (the intensity, duration, spatial extent and cumulative effects of fishing activities), and define the dependency of these elements on spatial and temporal scales. 'Overall risk' can be defined as the risk remaining after monitoring, management and mitigation measures are accounted for. This requires several tasks including:

(1) defining VME indicator species for Saya de Malha;
(2) determining the distributions of VME indicator species;
(3) identifying bottom trawl fisheries operating on and around Saya de Malha;
(4) identifying the nature, extent and persistence of impacts from bottom trawl gears on different VME indicator species;
(5) assessing how the current management arrangements may affect the impact or risk of SAI on VME indicator species; and
(6) determining overall risk.

In order to identify the bottom trawl fisheries operating on and around Saya de Malha, spatial resources made available by Global Fishing Watch (GFW) were visualised using AIS data from vessels that GFW has identified as known or possible commercial fishing vessels. In order to identify fishing activities, GFW use two convolutional neutral networks (vessel characterization and fishing detection) – a cutting edge form of machine learning model – to classify fishing vessels and predict when they are fishing. Data points with values of less than 0.1 fishing hours were excluded from this assessment. It should be noted that while AIS provides a high-resolution way to monitor global commercial fishing activity, there are several important limitations and caveats e.g., sporadic fleet coverage; irregular AIS message detection and increases in AIS adoption[4] and therefore presented patterns should be looked at with an element of caution.

In order to assess the nature, extent and persistence of impacts from bottom trawl fisheries on the identified VME indicator species, given the known data limitations, a qualitative expert-based assessment was employed to determine the level of impact of each VME and fishery interaction, using the following criteria as per SIOFA Bottom Fishing Impact Assessment Standard: a) intensity, b) duration, c) spatial extent and d) cumulative impact. Criteria was scored on a qualitative basis (high, medium, low), as below, informed by a review of evidence related to each interaction, where high = 3, medium = 2, low = 1.

Qualitative scoring of interactions was informed through desk-based study utilising a combination of quantitative and qualitative data from various primary and secondary sources identified under the scoping study (ToR 1). Where data paucity exists the project team employed qualitative expert judgement using evidence from the literature.

Literature searches were conducted using Google Scholar, which has been shown to be useful for both peer-reviewed and grey literature[5]. Searches used Boolean logic to combine terms relating to the VME and fishery interaction in question. Additional search terms specifying geography e.g., Saya de Malha or Southern Indian Ocean were added to identify literature of specific relevance to the study area. Searches were restricted to articles published in the time

[4] https://globalfishingwatch.org/dataset-and-code-fishing-effort/

[5] Haddaway NR, et al. The role of Google Scholar in evidence reviews and its applicability to grey literature searching. PLoS ONE. 2015;10(9):e0138237.

period 2000-2020. Literature was saved in the open-source reference management software (Zotero).

2.1 Qualitative Scoring

1. **Intensity** – The intensity or severity of the impact at the specific site affected. This may be quantified by previous studies or an expert evaluation of the magnitude of the impact (Table 1).

Table 1. Intensity criteria

Impact	Description
None	No detectable impact.
Low	Some physical damage to some taxa/colonies.
Medium	Substantial damage to a small proportion of colonies/taxa, or small damage to a large number of taxa at the site, likely to modify biological and ecological processes e.g., reproduction.
High	Significant damage to a significant proportion, which environmental functions and processes are significantly altered such that they temporality or permanently cease.

2. **Duration** – how long the effects of the impact are likely to last (Table 2).

Table 2. Duration criteria

Duration	Description
None	No detectable impact.
Low	The effects of the impact are likely to be observed on a short-term basis and therefore temporary i.e., days.
Medium	The effects of the impact are likely to be observed on a medium-term basis i.e., months.
High	The effects of the impact are likely to be observed on a long-term basis or are permanent i.e., years or permanent.

3. **Spatial extent** – The spatial impact relative to the extent of the VMEs (e.g., will fishing impact 5 %, 30 % or 80 % of the VME distribution) and whether there may be offsite impacts (e.g., will reproduction be impacted at a broader spatial scale) (Table 3).

Table 3. Spatial extent criteria

Spatial extent	Description
None	No detectable impact.
Low	A small area of VME will be impacted in relation to their spatial extent i.e., 5 %.
Medium	A moderate area of VME will be impacted in relation to their spatial extent i.e., 30 %.
High	A large area of VME will be impacted in relation to their spatial extent i.e., 80 %.

4. **Cumulative impact** – The frequency of the impact will influence the risk, with activities occurring repeatedly at a site likely to have a greater risk. This will depend on the amount of fishing effort and will be considered in relation to the recovery of the VMEs/taxa (Table 4).

Table 4 Cumulative impact criteria

Cumulative impact	Description
None	No detectable impact.
Low	Fishing effort is at a low frequency of occurrence per year.
Medium	Fishing effort is at a moderate frequency of occurrence per year.
High	Fishing effort is at a high frequency of occurrence per year.

For each VME and fishery interaction identified, the key mitigation or management measures currently in place to mitigate the perceived impacts, where identified, were given a qualitative rating of adequacy (Strong = 1, Moderate = 2, Weak = 3) (Table 5). For example, one of the tools SIOFA implements to manage impacts on VMEs from fishing is the application of move-on rules when thresholds of VME indicators are reached[6].

Table 5. Management and mitigation measure criteria

Management	Description
Strong	The mitigation or measure in place would significantly reduce the likelihood of an impact occurring or the magnitude of that impact.
Moderate	The mitigation or measure in place would reduce the likelihood of an impact occurring or the magnitude of that impact.
Weak	The mitigation or measure in place would see minimal to no reduction in the likelihood of an impact occurring or the magnitude of that impact.

[6] Report of the Fourth Meeting of the SIOFA Scientific Committee.

3 Results

3.1 Defining VME indicator species for Saya de Malha

The VME concept emerged from discussions at the United Nations General Assembly (UNGA) and gained momentum after UNGA Resolution 61/105. VMEs are groups of species, communities or habitats that may be vulnerable to impacts from fishing activities. VMEs are now firmly embedded in regimes for the management of deep-sea fisheries in the areas beyond national jurisdiction (ABNJ). Several VME taxon have been defined by SIOFA in CMM-2020-01[7] (Table 6). Seagrass has been added to this list, under the specific request of SIOFA given in prevalence on Saya de Malha.

Table 6. Vulnerable Marine Ecosystem (VME) species considered in the scoping study, VME taxon are defined in CMM-2020-01, seagrass was added under specific request

VME Species	
• Actiniaria	• Gorgonacea
• Alcyonacea	• Hexactinellida
• Anthoathecatae	• Pennatulacea
• Antipatharia	• Porifera
• Ascidiacea	• Pterobranchia
• Bathylasmatidae	• Scleractinia
• Brachiopoda	• ***Seagrass***
• Bryozoans	• Serpulidae
• Chemosynthetic organisms	• Stalked crinoids
• Cidaroida	• Stylasteridae
• Cnidaria	• Xenophyophora
• Demospongiae	• Zoantharia
• Euryalida	

Of the VME taxon defined by SIOFA; 14 have been taken forward for the purpose of this risk assessment (Table 7). VME taxon were selected based on known records or descriptions of *genera* occurring within the South Western Indian Ocean region e.g., Mauritius, Reunion, Seychelles or Madagascar. A description of each VME taxon is given below.

Table 7. VME taxon to be considered for the purpose of this impact assessment

Phylum	Class	Order	Family	Common
Cnidaria	Anthozoa	Gorgonacea	-	Sea fans
Cnidaria	Hydrozoa	Anthoathecata		Athecate hydroids
Cnidaria	Hydrozoa	Anthoathecata	Stylasteridae	Lace corals
Cnidaria	Anthozoa	Sceleractina	-	Stony corals
Cnidaria	Anthozoa	Antipatharia	-	Black coral
Cnidaria	Anthozoa	Actiniaria	-	Sea anemones
Cnidaria	Anthozoa	Alcyonacea	-	Soft corals
Cnidaria	Anthozoa	Pennatulacea	-	Sea pens
Bryozoa	-	-	-	Bryozoans
Annelida	Polychaeta	Sabellida	Serpulidae	Tube-building worms

[7] https://www.apsoi.org/node/638

Phylum	Class	Order	Family	Common
Echinodermata	Crinoidea			Crinoid
Echinodermata	Ophiuroidea	Euryalida		Basket star
Echinodermata	Echinoidea	Cidaroida		Sea urchins
		Alismatales	Cymodoceaceae	Seagrass

3.1.1 Gorgonacea

Gorgonacea (sea fans, horny corals) are an order of sessile colonial Octocorals that are anchored to the benthos, usually rocky substrata, by a holdfast and have a tree-like shape supported by branching, central skeleton of horn-like organic or calcareous material. Like corals, many sea fans have zooxanthellae enabling them to photosynthesize, for which light in essential. Therefore, commonly sea fans are found within the littoral zone. They are integral components of the reef system and provide habitat for a diversity of other marine species. The order Gorgonacea has now been taxonomically revised into the order Alcyonacea (see 3.1.7 Alcyonacea).

3.1.2 Anthoathecata

Anthoathecata (athecate hydroids) are an order of hydrozoan within the phylum Cnidaria, often referred to as Athecate hydroids. Genera found in the South West Indian Ocean region include *Millepora*, also known as fire corals, and *Solanderia.* Fire corals often have a yellow-green-brown skeletal covering and grow on rocky outcrops and corals where tidal currents are strong. Fire coral has several common growth forms; these include branching, plate and encrusting.

3.1.3 Stylasteridae

Stylasteridae (lace corals) are a family of fragile, usually small, uniplanar to slightly arborescent colonial hydrozoans of the order of Anthoathecata. The species of lace coral *Crypthelia micropoma* can be found within the Western Indian Ocean region (Cairns 1985).

3.1.4 Scleractinia

Scleractinia (stony corals, hard corals) are reef forming marine animals belonging to the phylum Cnidaria. The individual animals, termed polyps, have a cylindrical body crowned by an oral disc in which a mouth is fringed with tentacles. The base of the polyp secretes calcium carbonate, forming the coral skeleton. These polyps reproduce asexually through a process termed budding. Genera found within the South West Indian Ocean region and Saya de Malha include *Acropora* and large colonies of *Porities* heads, of two to three meters in diameter; along with *Madrepora* (Hilbertz *et al.,* 2002).

3.1.5 Antipatharia

Antipatharia (black coral) is an order belonging to the phylum Cnidaria, with seven families, 44 genera and 280 species. Black corals are more abundant with depth, a pattern which has been hypothesized to avoid competition with photosynthetic fauna (Wagner *et al.,* 2012). Recent work has identified that shallow black coral species e.g., *Antipathes grandis* can be found spawning from the Indian to the Pacific Ocean (Gress *et al.*, 2020) Genera found in the western Indian ocean are *Antipathes* (Fassbender 2021), *Palythoa* and *Zoanthus* (Van der Land 1994).

3.1.6 Actiniaria

Actiniaria (sea anemones) typically consist of a single polyp that attached to a hard substrate by its base; however, some species live in soft sediments. The polyp has a columnar trunk topped by an oral disc with a ring of tentacles and a central mouth. Sea anemones are known for their symbiotic relationship with other marine animals e.g., *Amphiprion chrysogaster* (Mauritian anemonefish). Body sizes can vary between 2.5-10 cm in diameter, with few species reported to reach 1.8 m (Venkataraman and Raghunathan, 2015). Fassbender *et al.,* (2021) identified six distinct, but unidentified, species in waters surrounding Seychelles, in addition to species from the genus *Heteractis.*

3.1.7 Alcyonacea

Alcyonacea (soft corals) contain minute, spiny skeletal elements called sclerites. Sclerites provide support and a predator deterrent by way of their spiky, grainy texture. Soft corals thrive in nutrient-rich water. Almost all use symbiotic photosynthetic zooxanthellae as a major energy source. In addition, most feed on zooplankton in the water column. Evans *et al.,* (2011) report the occurrence of four families belonging to the order Alcyonacea in Antisaranana Bay, Madagascar. The most abundant genera of which include: *Sinularia, Sarcophytion* and *Rhytisma.* Further, Taylor and Rodgers (2017) report *Narella* on South West Indian Ocean seamounts.

3.1.8 Pennatulacea

Pennatulacea (sea pens) are colonial marine cnidarians with multiple polyps, each with eight tentacles, that occupy sandy and or muddy substrates using a muscular peduncle; however, some are able to anchor to rocky (Williams 2011). The exposed portion of sea pens may extend up to two meters from the benthos. Genera reported in the South West Indian Ocean region, specifically eastern Africa/Mozambique channel include; *Amphiacme, Amphiacnme, Anthoptilum, Cavernulina, Distichoptilum, Funicilina, Gyrophyllum, Halipteris, Kophobelemnon, Pennatula, Scleroptilum, Scytaliopsis*, *Ubellula* and *Virgularia* (Williams 2011).

3.1.9 Bryozoa

Bryozoa (bryozoans) are colonial animals made up of zooids. Most of which are sessile residing on hard substrates such as rocks, sand or shells. Bryozoans have erect and non-erect colony growth forms. Most species filter feed, mainly phytoplankton, from the water column. Zooids are simultaneous hermaphrodites that undergo internal and external fertilisation, depending on the species, producing ciliated larvae that are free-swimming (Decker at al 2020). Deep-sea general found by Hayward (1981) between Seychelles and Sri Lanka includes: *Euoplozoum, Camptoplites, Columnella, Cornucopia* and *Himantozoum* between depths ranging from the intertidal zone to 5,900 m (Gordon 1989; Hayward 1981).

3.1.10 Serpulidae

Serpulidae (tube-building worms) are a family of sessile, tube-building worms in the class Polychaeta. They are benthic, epifaunal suspension feeders with an operculum that blocks the end of their tube when retracted. Serpuilds secrete tubes made of calcium carbonate; making them one of the most important bio mineralisers among annelids. In addition to the genera *Anisomelus, Crucigera, Ditrupa, Hydroides, Serpula and Spirobis, c*ommonly seen species of Serpuilds include *Spirobranchus giganteus* (Christmas tree worm) found throughout tropical oceans.

3.1.11 Crinoidea

Crinoidea (crinoids) are one of the classes of the phylum Echinodermata. Crinoids, in their adult form, which are attached to the benthos by a stalk are commonly termed stalked crinoids or sea lilies. The basic body form of a crinoid is comprised of a stem and a crown; consisting of a cup-like central body known as the theca, and a set of five rays or arms, usually branched and feather-like. Stalked crinoids are passive suspension feeders, filtering plankton and small particles of detritus within the water column. They are commonly found in sandy and muddy habitats; but also attached to hard substrates by a holdfast. Genera occurring in the South West Indian Ocean region include; *Cenometra, Comanthus. Oligometra, Stephanometra* and *Tropiometra.*

3.1.12 Euryalida

Euryalida (basket star) are a sub-order within the phylum Echinodermata. Basket starts are a taxon of brittle stars; many of them having characteristically repeatedly branched arms. Generally, Euryalida occupy deep-sea habitats. Like other echinoderms, basket stars lack blood and achieve gas exchange via their water vascular system. Genera recorded in the South Western Indian Ocean include *Asterogegus, Astroboa* and *Euryale.*

3.1.13 Cidaroida

Cidaroida (sea urchin) is an order of primitive sea urchins, the only living order of the subclass Perischoechinoidea. Typified by exhibiting primary spines far less densely packed than compared with other urchins, they can act as habitat for other marine organisms. The majority exhibit simple ambulacral plating, short but think spines, and a singular large tubercle over each interambulacral plate**.** Three species of Cidaroida have been found in the Seychelles by Fassbender *et al.,* (2021) at a minimum depth of 111 m and a maximum depth of 351 m. Only one was identified to genus level: *Acanthocidaris.*

3.1.14 Cymodoceaceae

Cymodoceaceae (seagrass) is a family of flowering plants, encompassing five genera including only marine species. Hilbertz (2002) reports seagrass lawns of Saya de Malha exclusively comprised of *Thalassodendron ciliatum*. *Thalassodendron ciliatum* has an upper depth limit of 0 m and a lower depth limit of 33 m, although Milchakova (2005) reports specimens being found at depths up to 50 m. Reported to be slow to colonise new areas, it is hence slow to recover from areas it has been removed from. Recovery rates range from leaf growth rates of 25.5 g DW (dry weight) m^{-2} on rocky habitats to 9.5 g DW m^{-2} (Bandeira 2002).

3.2 Determining the distributions of VME indicator species

The first assessment of flora and fauna of Saya de Malha was completed in March 2002 (Hilbertz *et al.,* 2002). Underwater surveys reported that of the area surveyed, seagrass bed (*Thalassodendron ciliatum*) covered roughly 80-90 % of the bottom, with corals covering around 10-20 %, and sandy areas being less than 5 %. Studies on Saya de Malha and or SIOFA area since have focused on physical oceanography, ocean productivity and pelagic and demersal resources (Groeneveld and Koranteng 2017). It is noted that the benthic ecosystem and therefore distribution of VME indicator species is not explicitly mapped for Saya de Malha.

The FAO guidelines[8] for VME mapping note that '*where site-specific information is lacking, other information that is relevant to inferring the likely presence of vulnerable populations,*

[8] **FAO**. 2009. International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, 73p.

communities and habitats should be used'. Therefore, in order to identify where VME indicator species could potentially occur on Saya de Malha, depth distribution ranges evidenced from the literature, will be used as ancillary predictors of areas potentially supporting VMEs on Saya de Malha. Table 8 describes the depth distributions of selected VME species, which are displayed in Figure 3 using GEBCO depth contours.

Table 8. Depth distribution range for selected VME taxon

VME species group	Common name	Depth distribution (m)	Reference(s)
Gorgonacea	Sea fans	0-50 m	
Anthoathecata	Athecate hydroids	0-50 m	Fassbender, 2021
Stylasteridae	Lace corals	0-630 m	Cairns (1985[9]) – WoRMS
Sceleractina	Stony corals	0-50 m	OBIS, 2015 SeaLifeBase[10]
Antipatharia	Black coral	50-8,600 m	Wagner *et al.*, 2012
Actiniaria	Sea anemones	0-250 m	Fassbender et al. 2021
Alcyonacea	Soft corals	0-870 m	Taylor and Rodgers 2017
Pennatulacea	Sea pens	Intertidal-6,100 m	Williams 2011
Bryozoa	Bryozoans	Intertidal-5,900 m	Gordon 1989; Hayward 1981
Serpulidae	Tube-building worms	Intertidal-abyssal	WoRMS[11]
Crinoidea	Crinoid	Littoral-91 m	SeaLifeBase[12]
Euryalida	Basket star	0-290 m	Rowe & Gates 1995; Lane et al. 2000
Cidaroida	Sea urchins	111-351 m	Fassbender *et al.*, (2021)
Cymodoceaceae	Seagrass	0-50 m	Hilbertz *et al.*, 2002; Milachakova 2005

[9] https://www.marinespecies.org/aphia.php?p=taxdetails&id=285789#distributions
[10] https://www.sealifebase.se/summary/Acropora-valida.html
[11] https://www.marinespecies.org/aphia.php?p=taxdetails&id=117246
[12] https://www.sealifebase.ca/summary/Oligometra-serripinna.html

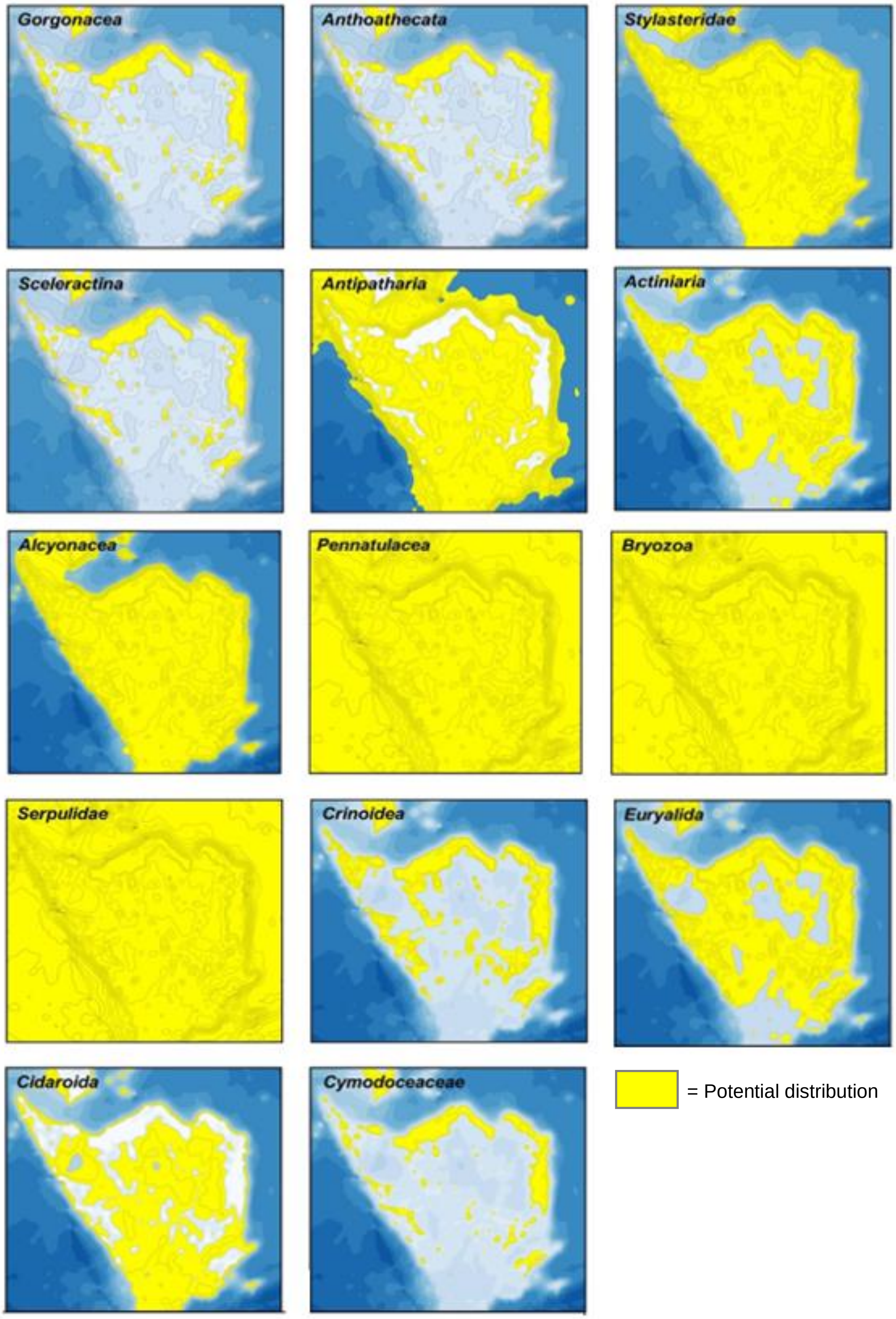

Figure 3 Depth distribution ranges of selected VME taxon, as cited in reviewed literature

3.3 Identifying bottom trawl fisheries operating on and around Saya de Malha

Known and reported bottom trawl fisheries operating on and around Saya de Malha include Thai fishing vessels only. Thai bottom trawling activity is reported to occur between 2015-2020; with the exception of 2018. However, spatial data indicating the spatial footprint of the Thai bottom trawling fleet and fishing intensities is only available for 2020; upon which this assessment is based.

Bottom trawling may also occur by Chinese vessels, on the basis of known fishing activity over the banks but not designated to a specific gear type (Global Fishing Watch 2021), but is not confirmed and is therefore not included within this assessment.

3.3.1 Thailand

During the period 2015-2020, there were a total 60 authorised Thai vessels with active fishing operations in the western Indian Ocean (SC-03-06.2), employing a mixture of bottom trawling gear types namely; otter board trawls (OTB) and pair trawl (PTB) (Table 9).

The pair trawler head rope length is 62-76 m, and ground rope length is 65-82 m long. Otter-board trawler's head rope lengths are reported to be between 20-43 m, with a ground rope length of 22-46 m. The several bobbins on the ground rope, each have a diameter of between 70-140 mm. Most nets are two-seam with a mesh size of 60-240 mm in the wings and a cod-end of 50 mm. The otter boards are made of rectangular wood with the size approximately 1.5 x 3 m.

Table 9. Thai bottom trawl fisheries

Country	Type of fishery	# Vessels	Operation period	Gear type	Species exploited
Thailand	Commercial	56	2015	OTB	Round scad (*Decapterus spp*.), lizard fish (*Saurida spp*.), threadfin bream (*Nemipterus spp*.), goat fish (*Parupeneus spp*.), bigeye scad (*Selar spp*.) and Indian mackerel (*Rastrelliger spp*.).
Thailand	Commercial	58	2016	OTB	
Thailand	Commercial	11	2017	OTB	
Thailand	Commercial	2	2019	OTB	
Thailand	Commercial	3	2020	OTB	
Thailand	Commercial	1	2016	PTB	
Thailand	Commercial	1	2017	PTB	

Figure 4 highlights the spatial footprint and apparent fishing effort (hours/1,000 km^2) of the Thai bottom trawling fleet in 2020 as indicated by vessel AIS data collected by Global Fishing Watch. Thai bottom trawling vessels predominately operate on Saya de Malha, between latitude 10-11 °S and longitude 60-62 °E at depths of approximately 20-80 m. The fishing area of Thai fleet is around 33,336 km^2, mostly on continental shelf area which covers 7.15 % of trawlable area or 0.12 % of total SIOFA area (SC-03-06.2). Fishing trips are reported to last up to three months.

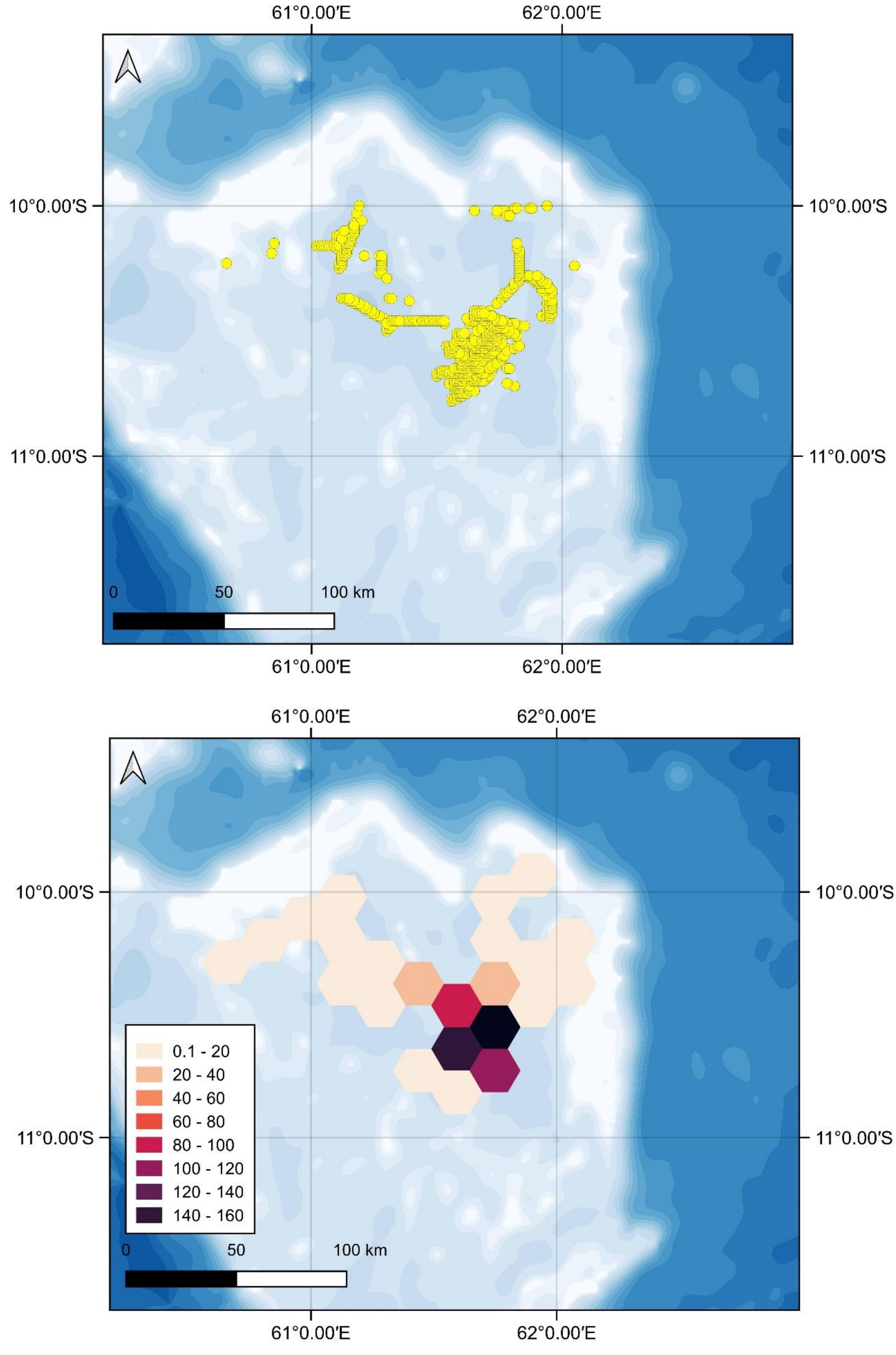

Figure 4. Spatial footprint and apparent fishing effort (hours/1,000 km^2) of the Thai bottom trawling fleet in 2020 as indicated by AIS data (Source: Global Fishing Watch).

3.4 Identification of the nature, extent and persistence of impacts from bottom trawl gears on different VME indicator species

Trawling directly and indirectly impacts benthic habitats and their associated species in areas where the bottom trawl gear makes physical contact with the seafloor. The trawl doors and ground-gear drag across the seafloor during tows, penetrating the substrate (Eigaard *et al.,* 2017; Hiddink *et al.,* 2017). In areas dominated by hard substrate, trawl gear can also dislodge, remove and or damage substrata, as well as biogenic substrates (e.g., corals), which can reduce benthic habitat complexity (Althaus *et al.,* 2009). In addition, other major issues associated with bottom trawling when considering benthic organisms include removal alteration of sedimentation pattern, changes in predation rate and transformed population structures (Meenakumaris *et al.,* 2008).

The following sections provide a qualitative assessment to determine the potential level of impact on each VME from Thai bottom trawling, using the criteria as per SIOFA Bottom Fishing Impact Assessment Standard: a) intensity, b) duration. c) spatial extent and d) cumulative impact. Where data paucity on the impacts of trawling on VME species in the South Western Indian Ocean has been identified, studies from other geographies with similar ecological requirements and sensitives to the species groups in question have been used to provide evidence. It should be noted that the assessment below is reflective of Thai bottom trawling activity in 2020 only.

3.4.1 Gorgonacea

Table 10. Qualitative assessment of potential bottom trawl impact on Gorgonacea

	Score	Evidence
Intensity	Medium	Benthic trawling can result in the crushing, sheering or dislodgement of *Gorgoncea* species, particularly larger erect forms that protrude into the water column, which are prone to snagging (Althaus *et al.,* 2009). As a result, reducing the three-dimensional structure of the reef epibenthos. Investigating the impacts of bottom trawling on deep-coral ecosystems of seamounts off Tasmania, Althaus *et al.,* (2009) reported that the densities of snapped-off bases and detached specimens of large colonies of gorgonians were statistically significantly higher in areas subject to active trawling, in comparison to areas never trawled or where trawling has ceased.
Duration	High	It is acknowledged in the literature that Gorgoncea species are slow growing and long lived (Cúrdia et al., 2013), suggesting that the effects of the impact are likely to be observed on a long-term basis with recovery taking decades, if not longer (Althaus *et al.,* 2009).
Spatial extent	None	The depth distribution of Gorgoncea species is reported up to 50 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2.11 km^2, equating to < 1 % of the assessed area Gorgoncea species could occur.
Cumulative impact	None	In 2020, the Thai bottom trawling fleet reported 5.55 hours of fishing within the depth range that Gorgoncea species could occur.

3.4.2 Anthoathecata

Table 11. Qualitative assessment of potential bottom trawl impact on Anthoathecata

	Score	**Evidence**
Intensity	High	The two Genera of Anthoathecata reported in the South West Indian Ocean include; *Millepora*, also known as fire corals, and *Solanderia.* Characterised by a fragile exoskeleton often formed as extensive outcrops projecting into the water column, where tidal currents are strong, athecate hydroids are particularly vulnerable to being broken or crushed by trawling activity.
Duration	Medium	It is recognised in the literature that hydroids are thought to be relatively fast-growing early colonisers in disturbed habitats (Althaus *et al.,* 2009), suggesting that the effects of the impact are likely to be observed on a medium-term basis with recovery taking months.
Spatial extent	None	The depth distribution of Anthoathecata species is reported up to 50 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2.11 km^2, equating to < 1 % of the assessed area Anthoathecata species could occur.
Cumulative impact	None	In 2020, the Thai bottom trawling fleet reported 5.55 hours of fishing within the depth range that Anthoathecata species could occur.

3.4.3 Stylasteridae

Table 12. Qualitative assessment of potential bottom trawl impact on Stylasteridae

	Score	Evidence
Intensity	High	The potential impacts of bottom trawling on Stylasteridae are not well reported within the literature. In a global review of the diversity of Stylasteridae*,* Cairns (2011) describes lace corals as often small and fragile, which could suggest upon direct contact with trawl gear Stylasteridae are vulnerable to damage and or dislodgement. Althuas *et al.,* (2009) reports that the small hydrocoral *Stylaster spp*. Contributed most to the overall dissimilarity between never-trawled and activity trawled seamounts, being consistently less abundant at activity trawled.
Duration	Medium	Recognised a relatively fast growers, a study assessing the effect of deep-water trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand, found *Stylasteridae* more frequently in samples from fished seamounts (Clark and Rowden 2009). This suggesting reliance and fast colonisation response post disturbance.
Spatial extent	Low	The depth distribution of Stylasteridae species is reported up to 630 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,649 km^2, equating to 3.75 % of the assessed area Stylasteridae species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 952 hours of fishing within the depth range that Stylasteridae species could occur.

3.4.4 Scleractinia

Table 13. Qualitative assessment of potential bottom trawl impact on Scleractinia

	Score	**Evidence**
Intensity	High	The rigid, hard matrix of Scleractinia corals is likely to be severely damaged by heavy trawl doors or tangled in associated ropes and nets (Clark and Koslow 2007; Clark and Rowden 2009). As a consequence, leaving rubble or bare rock substrata behind; reducing the three-dimensional structure of reefs that many marine organisms depend on. Investigating the impacts of bottom trawling on deep-coral ecosystems of seamounts off Tazmania, Althaus *et al.,* (2009) reports higher densities of snapped off bases and detached specimens of Scleractinia corals on trawled seamounts than on undisturbed seamounts by two orders of magnitude.
Duration	High	*Porites spp.* grows its skeleton about the central axis by approximately 3.67 mm/year, calcifies at approximately 0.55 g/cm^2/year, and increases density in this region of the body at approximately 1.69 g/cm^3/year (Rendon *et al.,* 2010), therefore suggesting the effects of the impacts of bottom trawling are likely to be observed on a long-term basis.
Spatial extent	None	The depth distribution of Scleractinia species is reported up to 50 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2.11 km^2, equating to < 1 % of the assessed area Scleractinia species could occur.
Cumulative impact	None	In 2020, the Thai bottom trawling fleet reported 5.55 hours of fishing within the depth range that *Scleractinia* species could occur.

3.4.5 Antipatharia

Table 14. Qualitative assessment of potential bottom trawl impact on Antipatharia

	Score	Evidence
Intensity	Medium	Benthic trawling can result in the sheering or dislodgement of Antipatharia species, particularly larger erect forms that protrude into the water column, which are prone to snagging (Althaus *et al.,* 2009). As a result, reducing the three-dimensional structure of the reef epibenthos. However, due to their flexible skeletons, Antipatharia may be more resilient than Scleractinia corals. Investigating the impacts of bottom trawling on deep-coral ecosystems of seamounts off Tasmania, Althaus *et al.,* (2009) reported, based on the intensive and broad-scale video surveys of 25 seamounts, corals (including all Antipatharians) were markedly reduced on seamounts that had been trawled.
Duration	High	Althaus *et al.,* (2009) reported that, on those seamounts where trawling had been reduced to < 5 % a decade ago and ceased completely five years ago, there was no clear signal of recovery of the mega benthos; communities remained impoverished comprising fewer species at reduced densities of Antipatharians. Due to the slow life cycle and deep-water habitats of black coral, little is known about their life cycle and reproduction.
Spatial extent	Low	The depth distribution of Antipatharia species is reported from 50-8,600 m. The spatial footprint of bottom trawling by Thai vessels in

	Score	Evidence
		2020 within that depth range is 2,647 km^2, equating to 4.18 % of the assessed area Antipatharia species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 946 hours of fishing within the depth range that Antipatharia species could occur.

3.4.6 Actiniaria

Table 15. Qualitative assessment of potential bottom trawl impact on Actiniaria

	Score	Evidence
Intensity	High	Due to their soft-bodied nature, Actiniaria can be easily torn and uprooted from the benthos by trawl gear, ending up as bycatch in nets (McConnaughey *et al.,* 2000; Steinberg *et al.,* 2020). Anemones have varying degrees of structural complexity and provide important structural habitat for many species (Steinberg *et al.,* 2020). The damage or removal of sea anemones through trawling can result habitat loss for associated macro-symbionts including *Dascyllus spp*. damselfishes, anemone shrimps, and anemone crabs (Steinberg *et al.,* 2020). Further, disturbance to the seafloor can damage anemones through smothering, reducing their photosynthetic ability. The lack of skeletal structure means initial loss as a result of trawling can be difficult to quantify because anemones leave no obvious traces of population declines or extirpations (Steinberg *et al.,* 2020).
Duration	High	Anemones generally do not form calcium carbonate skeletons, and therefore do not contribute to the building of long-term reef structures. As such, soft-bodied habitat-forming organisms can often recruit and grow faster than hard-bodied organisms. The literature reports varying recovery times in damaged Actiniaria colonies. In the North West Atlantic, Goode *et al.,* (2020) reports anemones to have colonies artificial substrate within four years following disturbance. Whereas, on Australian seamounts, dense aggregations of anemones have been observed where fishing ceased three years prior; suggesting early colonisation (Goode *et al.,* 2020), but long-term impacts.
Spatial extent	Low	The depth distribution of Actiniaria species found in the South Western Indian Ocean, specifically Seychelles, is reported up to 250 m. The spatial footprint of bottom trawling by Thai vessels within that depth range is 1,403 km^2, equating to 3.09 % of the assessed area Actiniaria species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 527 hours of fishing within the depth range that *Actiniaria* species could occur.

3.4.7 Alcyonacea

Table 16. Qualitative assessment of potential bottom trawl impact on Alcyonacea

	Score	Evidence
Intensity	Medium	Benthic trawling can result in the crushing, sheering or dislodgement of Alcyonacea species, particularly larger erect forms that protrude into the water column, which are prone to snagging (Althaus *et al.,* 2009). As a result, reducing the three-dimensional structure of the reef epibenthos. However, Eno *et al.* (2001) described a resistance to direct impact of fishing gears by various species of sea fan that are able to flex under the pressure of fishing gear. For example, the *Chrysogorgia* corals observed in greater abundance on the actively

	Score	Evidence
		trawled seamounts were similarly small in size and flexible, possibly allowing them to pass relatively unharmed under the trawl gear.
Duration	High	It is acknowledged in the literature that *Alcyonacea* species are slow growing and long lived (Rogers *et al.,* 2007; Kaiser *et al.,* 2018), suggesting that the effects of the impact are likely to be observed on a long-term basis with recovery taking decades, if not longer (Althaus *et al.,* 2009). This is further supported by Goode *et al.,* (2020) which used a metanalysis to categorise taxa into four post-fishing response groups (no recovery; low recovery; intermediate/high recovery and early colonisation) placing Alcyonacea in the 'no recovery' category due to their slow growth and being primarily brooders.
Spatial extent	Low	The depth distribution of Alcyonacea species is reported up to 870 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,649 km^2, equating to 3.75 % of the assessed area Alcyonacea species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 952 hours of fishing within the depth range that Alcyonacea species could occur.

3.4.8 Pennatulacea

Table 17. Qualitative assessment of potential bottom trawl impact on Pennatulacea

	Score	Evidence
Intensity	Medium	The vertical structure of Pennatulacea and the varying ability to completely retract within the sediment (Malecha and Stone 2009) makes them vulnerable to damage by trawl gear through interaction with trawl doors and or nets. For example, a single trawl pass dislodged 55% of the Genus *Halipteris* in Alaska (Malecha and Stone 2009). If species of *Pennatulacea* are only dislodged by trawl gear, they are able to re-bury their peduncle. However, damage caused during dislodgement may lead to mortality e.g., Malecha and Stone (2009) reported the survival of only one *Halipteris* species 372 days after disturbance.
Duration	High	Categorised by Goode *et al.,* (2020) using a metanalysis, Pennatulacea were placed in the low recovery post-fishing response group.
Spatial extent	Low	The depth distribution of Pennatulacea species is reported from intertidal-6,100 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,649 km^2, equating to 3.75 % of the assessed area Pennatulacea species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 952 hours of fishing within the depth range that Pennatulacea species could occur.

3.4.9 Bryozoa

Table 18. Qualitative assessment of potential bottom trawl impact on Bryozoa

	Score	Evidence
Intensity	Low	Bryozoa, which are sessile, small encrusting colonies; residing on hard substrates measuring only several centimetres are more resilient to surviving the impacts of trawling than erect colonies.
Duration	Low	Goode *et al.,* (2020) reports that in both shelf and deep-sea environments, Bryozoa have been found to be early recolonises after

	Score	Evidence
		disturbances associated with fishing. Suggesting that the impacts from trawling are seen on only a short-term basis.
Spatial extent	Low	The depth distribution of Bryozoa species is reported from intertidal-6,100 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,649 km^2, equating to 3.75 % of the assessed area Bryozoa species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet 952 hours of fishing within the depth range that Bryozoa species could occur.

3.4.10 Serpulidae

Table 19. Qualitative assessment of potential bottom trawl impact on Serpulidae

	Score	Evidence
Intensity	Low	Serpuilds secrete tubes made of calcium carbonate; making them particularity venerable to damage in contact with bottom trawled gear. However, are not present in large colonies. In a study comparing observed impacts to the seabed and benthos in areas of varying fishing intensity; Serpulidae were found to have a negative correlation between fishing intensity and density within the Barents Sea (Buhl-Mortensen et al. 2015).
Duration	High	Categorised by Goode *et al.,* (2020) using a metanalysis, Serpulidae were placed in the low recovery post-fishing response group.
Spatial extent	Low	The depth distribution of Serpulidae species is reported from intertidal to abyssal. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,649 km^2, equating to 3.75 % of the assessed area Serpulidae species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet 952 hours of fishing within the depth range that Serpulidae species could occur

3.4.11 Crinoidea

Table 20. Qualitative assessment of potential bottom trawl impact on Crinoidea

	Score	Evidence
Intensity	High	The protruding nature of Crinoidea makes them vulnerable to damage by trawl gear through interaction with trawl doors and or nets. For example, in a study investigating the vulnerability of mega benthic species to trawling, Crinoidea were classified as having large mean body size and heigh above the sediments, and consequently with 'high risk' of being caught by a trawl (Jørgensen *et al.,* 2015). The study further reports fragmentation of sea lilies while being sieved through the meshes of the trawl, with only parts of the body available for weighing.
Duration	High	Categorised by Goode *et al.,* (2020) using a metanalysis, Crinoidea were placed in the low recovery post-fishing response group.
Spatial extent	Low	The depth distribution of Crinoidea species reported in the South Western Indian Ocean region is reported up to 91 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 272 km^2, equating to 1.04 % of the assessed area *Crinoidea* species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 316 hours of fishing within the depth range that Crinoidea species could occur.

3.4.12 Euryalida

Table 21. Qualitative assessment of potential bottom trawl impact on Euryalida

	Score	Evidence
Intensity	High	The protruding nature of Euryalida makes them vulnerable to damage by trawl gear through interaction with trawl doors and or nets. For example, in a study investigating the vulnerability of mega benthic species to trawling, basket stars were classified as having large mean body size and heigh above the sediments, and consequently with 'high risk' of being caught by a trawl (Jørgensen *et al.,* 2015).
Duration	High	There is no publicly available information describing the recovery rates of Euryalida. In the absence of peer-reviewed evidence this has been scored as high risk.
Spatial extent	Low	The depth distribution of Euryalida species reported in the South Western Indian Ocean region is reported up to 290 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,612 km^2, equating to 4 % of the assessed area Euryalida species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 947 hours of fishing within the depth range that Euryalida species could occur

3.4.13 Cidaroida

Table 22. Qualitative assessment of potential bottom trawl impact on Cidaroida

	Score	Evidence
Intensity	High	The potential impacts of bottom trawling on Cidaroida are not well reported within the literature. In the absence of peer-reviewed evidence this has been scored as high risk.
Duration	Medium	The literature presents contradictory information regarding the length of time impacts from trawling can be seen amongst Cidaroida. In a study testing the recovery of three seamount habitats, using repeated towed camera surveys, Williams *et al.,* (2010) suggested a high resilience against trawling amongst Cidaroida species, due to their ability to seek natural refuge in areas inaccessible to trawling. However, Goode *et al.,* (2020) categorised Echinoids within the no recovery post-fishing response group.
Spatial extent	Medium	The depth distribution of Cidaroida species reported in the South Western Indian Ocean region is reported up to between 111-351 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2,431 km^2, equating to 5.17 % of the assessed area Cidaroida species could occur.
Cumulative impact	Low	In 2020, the Thai bottom trawling fleet reported 872 hours of fishing within the depth range that Cidaroida species could occur.

3.4.14 Seagrass (Cymodoceaceae)

Table 23. Qualitative assessment of potential bottom trawl impact on Cymodoceaceae

	Score	Evidence
Intensity	High	Underwater surveys reported that of the area surveyed, seagrass bed (*Thalassodendron ciliatum*) covered roughly 80-90 % of the bottom (Hilbertz *et al.,* 2002). Trawling is reported to have major direct and indirect impacts on seagrass beds (Moore and Jennings

	Score	Evidence
		2000); substrate is lost or destabilised, seagrasses are uprooted and damaged (Tudela 2004) and sediment resuspension reduces light necessary for seagrass photosynthesis.
Duration	High	Rates may be slow where adjacent seed sources and viable grass beds are present, but can be between 60-100 years where the removal of rhizomes has occurred.
Spatial extent	None	The depth distribution of Cymodoceaceae species is reported up to 50 m. The spatial footprint of bottom trawling by Thai vessels in 2020 within that depth range is 2.11 km^2, equating to < 1 % of the assessed area Cymodoceaceae species could occur.
Cumulative impact	None	In 2020, the Thai bottom trawling fleet reported 5.55 hours of fishing within the depth range that Cymodoceaceae species could occur.

3.5 Assess how the current management arrangements may affect the impact or risk of SAI on VME indicator species

Weak	The management of bottom trawling activities is set out in CMM 2020/01. The agreed measure required that by 2020, and upon any major changes in the fisheries thereafter, the Scientific Committee develop and provide advice on definitions for encounters and associated threshold levels for VMEs. The measure sets out a threshold of 60 kg of coral or 300 kg of sponges in a given tow above which remedial action must be taken through the relocation of fishing activity away from the area. Encounters with VMEs must be reported to the SIOFA Secretariat. The current measure only makes provision for the relocation of fishing activity by vessels which encounter the thresholds of the above-mentioned species groups and does not prevent other vessels from exploiting the same area. Further, it does not make provision for long-term preventative measures e.g., closed and or restricted zones.

3.6 Determine overall risk

As per the SIOFA Bottom Fishing Impact Assessment Standard, overall risk scores are defined as follows:

- **Low:** The impact will have a negligible influence on the environment and no active management or mitigation is required. This has been allocated to impacts of low intensity and duration, but could be allocated to impacts of any intensity, if they occur at a local scale and are of temporary duration.
- **Medium:** The impact could have an influence on the environment, which will require active modification of the management approach and/or mitigation. This would be allocated to short or medium-term impacts of moderate intensity, locally to regionally, with a possibility of cumulative impact.
- **High:** The impact could have a significant negative impact on the environment, such that the activity(ies) causing the impact should not be permitted to proceed without active management and mitigation to reduce risks and impacts to acceptable levels. This would be allocated to impacts of high intensity that are local, but last for longer than 5-20 years, and/or impacts which extend regionally and beyond, with high likelihood of cumulative impact.

Overall risk scores (Table 24) are based on a cumulative total of intensity, duration, spatial extent, cumulative impact and management scores where None = 0, Low = 1, Medium = 2, and High = 3. Overall risk is scored as None = 0-3, Low = 4-7, Medium = 8-11, and High = 12-15.

Table 24. Overall risk scores for VME interactions with bottom trawl fishing on the Saya de Malha Bank

VME species group	Intensity	Duration	Spatial extent	Cumulative impact	Management	Overall risk
Gorgonacea						Low (8)
Anthoathecata						Low (8)
Stylasteridae						Medium (10)
Sceleractina						Medium (9)
Antipatharia						Medium (10)
Actiniaria						Medium (11)
Alcyonacea						Medium (10)
Pennatulacea						Medium (10)
Bryozoa						Low (7)
Serpulidae						Medium (9)
Crinoidea						Medium (11)
Euryalida						Medium (11)
Cidaroida						Medium (11)
Seagrass						Medium (9)

0-5 None; 6-8 Low; 9-11 Medium; 12-15 High

4 Conclusions

Saya de Malha is the largest submerged ocean bank in the world covering an area of approximately 41,000 km^2. The banks represent a highly productive ecosystem. They are thought to contain among the most extensive seagrass areas in the world and are interspersed with small coral reefs. As such, Saya de Malha is likely an important biodiversity hotspot which may be highly sensitive to the impacts of fishing. Conversely, if fished in a sustainable manner the area could be a valuable source of seafood and resultant food, nutritional, and economic security for fishers and consumers.

Saya de Malha sits within the remit of SIOFA whom, amongst other responsibilities, set out the management of bottom trawling activities under CMM 2020/01. This includes the development and provision of advice for encounters and associated thresholds for VME species. VMEs are groups of species, communities or habitats that may be vulnerable to impacts from fishing activities. Several VME taxon have been defined by SIOFA in CMM-2020-01[13], with the addition to seagrass given in prevalence on Saya de Malha.

At present the identification of VME species, their distribution and the impacts of bottom trawl fisheries on Saya de Malha is poorly understood. The first assessment of flora and fauna of Saya de Malha was completed 20 years ago. Recent studies on Saya de Malha and or the SIOFA area since have focused on physical oceanography, ocean productivity and pelagic and demersal resources. This study takes the first steps towards an informed assessment of bottom trawling impacts on VME species on Saya de Malha by inferring the potential distributions of VME species based on estimated depth ranges from closely related species, or the same species but from different regions, and considering their spatial overlap with the known spatial distribution of bottom trawl fisheries (based on AIS data from Global Fishing Watch, available for 2020 only) and semi-quantitative assessments of species tolerance to and recovery from trawling activities. The findings indicate that the highest-risk VME species are Euryalida (basket star), closely followed by Actiniaria (sea anemones), Alcyonacea (soft corals), Antipatharia (black coral), Crinoidea (crinoids), Pennatulacea (sea pens) and Stylasteridae (lace corals), all of which have low recovery potential from trawling impacts. Other groups of relative concern, particularly if trawling activities were to increase in the coming years, include Cidaroida (sea urchin), Sceleractina (stony/hard corals), Serpulidae (tube-building worms), and the extensive seagrass beds formed of *Cymodoceaceae spp*.

At present the level of trawling activity appears low with Thailand the only confirmed fishing nations operation only two and three vessels in 2019 and 2020, respectively. This low-effort serves to limit the spatial overlap between many VME species and trawling activities. However, if trawling were to increase toward levels seen in earlier years (i.e., 58 and 58 vessels in 2015 and 2016, respectively) the spatial overlap with, and thus the risk to, many VME species would likely increase substantially and may be a cause for major concern.

In order to better understand the bottom trawl fisheries interactions with VME species of Saya de Malha, SIOFA should prioritise efforts to more precisely document species and fisheries effort distributions both historically and in future. This would serve to improve confidence in the assessment of impacts from ongoing fisheries and allow for evidence-based management decision-making and the formulation and implementation of appropriate management actions if required.

[13] https://www.apsoi.org/node/638

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