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Southern Indian Ocean Fisheries Agreement
Accord relatif aux Pêches dans le Sud de l'Océan Indien

Project PAE2022-MPA1: Protocols to designate and evaluate MPAs in the SIOFA Area

Authors

Rubén Roa-Ureta
Yu-Jia Lin
Rodrigo Wiff
Andrés Flores
Consultants in Statistical Modelling, Marine Ecology and Fisheries

Funded by
the European Union

July 31, 2024

Project PAE2022-MPA1 Final Report: Protocols to designate and evaluate MPAs in the SIOFA Area

Acknowledgements. This work was conducted under contract with SIOFA, project PAE2022 MPA1 funded through the European Union project Support for Ecosystem Approaches to fisheries conservation and management in SIOFA (SIOFA-SEAs, EU Grant n. 101078892).

1 Executive Summary PAE2022-MPA1

The main goal of this project was to provide options for a protocol of designation and monitoring of currently existing as well as new marine protected areas (MPAs) under SIOFA's jurisdiction. Five tasks were completed: (1) reviewing SIOFA's and other regional management organization reports and the general scientific literature, (2) reviewing SIOFA historical databases, (3) implementing spatial statistical methods for evaluating and monitoring MPAs, (4) developing options to optimise the acquisition of new relevant data, and (5) developing options for protocols for designating new MPAs.

Two SIOFA reports, from 2017 and 2019, deal with principles and protocols for MPAs, and these largely agree with those of other regional organizations and with findings in the exponentially growing scientific literature on MPAs.

Two SIOFA databases relevant to designate and monitor MPAs (catch-effort and observers) revealed that there are sufficient data to conduct advanced spatial analysis with statistical models for both, designation and monitoring of MPAs. These databases need further editing and curating to correct wrong records and the addition of variables: (a) a fishing haul identifier to cross-reference catch-effort and observers databases and (b) environmental variables of (i) particular fishing hauls (depth, water temperature, weather) and (ii) open-access databases (sea surface temperature, chlorophyll-a).

For designation and monitoring of MPAs we demonstrated two statistical methodologies applied to catch-effort and observers databases: the Species Archetype Model (SAM) and Spatial Generalized Linear Models (SGLM). SAM conducts simultaneous analysis of all species and their connection with environmental covariates while SGLM involve first selecting a group of species of interest and then building the spatial distribution. Both methods yielded consistent results, indicating the existence of two hot spots of diversity south of Madagascar.

We reviewed protocols for the designation of MPAs from the IUCN, USA, European Union and Australia, finding that IUCN protocol is the *de facto* standard, and it offers flexibility in the degree of protection. Current SIOFA protocol for the designation of MPAs follows similar principles as the IUCN protocol.

We advise continued use of SIOFA's MPAs protocol, reinforced with the statistical methodologies SAM and SGLM, for quantitative delimitation of boundaries of new MPAs and continued monitoring of currently existing MPAs.

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2 General introduction

The overarching goal of SIOFA project PAE2022-MPA1 is to provide options for a standard protocol of future protected areas designation in the SIOFA Area and for evaluating and monitoring currently existing protected areas, for consideration by the SIOFA Scientific Committee. Five tasks were completed to meet this overall objective: (1) reviewing SIOFA reports and publications, reports from other regional marine management organizations, the general scientific literature, and other relevant information sources; (2) reviewing data about the fisheries, research, and any other data held by SIOFA to develop an understanding of benthic organism diversity and the fish catch composition in the area under SIOFA jurisdiction; (3) developing options for evaluating and monitoring protected areas based on statistical models that are apt to apply to existing and growing SIOFA databases; (4) developing options to optimize the acquisition of new data useful to the designation and monitoring of protected areas; and (5) developing options for protocols for designating new protected areas using the body of knowledge in open access governmental and international institutions' protocols.

2.1 General concept of marine protected area

The ocean contains unique biodiversity, provides food security to people, and is a major sink for carb (Sala et al. 2021). Yet human activities have impacts on marine ecosystems, some of them negative, such as modification or loss of habitats, marine pollution, truncation of marine food webs, depletion of fishing stocks, and massive wastage of bycatch (Vitousel et al. 1997). In the 18th and 19th centuries it was widely believed (e.g. by Jean Baptiste Lamarck and Thomas Huxley) that marine organisms are immune to extinction because of their ability to reproduce *en masse* and the inefficiency of exploitation gears. However, due to a mixture of factors including natural catastrophes, the introduction of alien species, fishing over-exploitation, and habitat alteration and destruction, a substantial number of extinctions was observed and so it has been suggested that marine organisms are at a far greater risk of extinction than previously assumed (Roberts and Hawkins 1999).

Effective use of strategic management tools, both area-based and non-area-based, can protect and restore ocean health while balancing human and ecological needs. Marine protected areas (MPAs) are common, well-studied area-based tools that can contribute to com- prehensive ocean management and governance (Sullivan-Stack et al. 2022), the protection of marine organisms from extinctions, and ensuring their long-term sustainable uses (Agardy et al. 2003, Worm et al. 2006, Sala and Giakoumi 2018, Jefferson et al. 2021, Kriegl et al 2021)

The concept of marine protected area has a long history, having been applied and practiced widely around the world. The use of the term "marine protected area" can be traced to the first World Congress on National Parks in 1962 after which a modern global movement promoting the concept of MPA begins (Humphreys and Clark 2020). But the idea of establishing areas in which marine life is specially managed, particularly when this is a key food source, has a long history and has been practiced over a wide range of regions, such as the protected parks established in Australia, South Africa, and the US in the mid-and the late 1800s, and the sea area closed to exploitation set by indigenous in the Pacific islands (Wells et al. 2016).

The most recent and commonly used definition of MPA internationally is that provided by International Union for Conservation of Nature (IUCN): a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Day et al. 2019) . This definition was given in the 2008 Guideline (Dudley 2008) in response to requests from members. Compared to the previous guideline (Kelleher and Kenchington 1992), the current definition gives greater emphasis to nature conservation and protection over the long term as well as management effectiveness (Dudley et al. 2010) . The area of the Southern Indian Ocean Fisheries Agreement (SIOFA) covers the open ocean/high seas between eastern Africa and Western Australia. Therefore, MPAs studies in the open ocean/high seas are directly relevant to this report.

Under pressure from increasing resource exploitation, pollution, and maritime traffic, the open ocean is one of the least protected ecosystems on Earth. The open ocean environment represents the largest realm on Earth (Angel 1993) and plays a key role in our economy with more than half of the fish consumed by humans coming from open ocean fisheries (http://www.greenfacts.org/en). Juridically encompassing both national exclusive economic zones (EEZ) and high seas, i.e. not part of any country's EEZ, beyond 200 nautical miles from any nation's territory, open ocean regions present difficulties in their spatial management and enforcement (Ardron et al. 2018). Yet of the more than 18,000 MPAs that protect 7.65% of the ocean recent research has suggested that the majority of MPAs, potentially 70% or more, fall short of their conservation goals (Bohorquez JJ, Dvarskas A, Jacquet J, Sumaila UR, Nye J and Pikitch EK (2022) A New Tool to Evaluate, Improve, and Sustain Marine Protected Area Financing Built on a Comprehensive Review of Finance Sources and Instruments. Front. Mar. Sci. 8:742846. doi: 10.3389/fmars.2021.742846)

The difficulties and challenges in the design of MPAs in the pelagic realm of the open ocean/high seas can be classified into physical challenges and governance challenges (Game et al. 2009). The physical environment is governed by processes that are highly dynamic in space and time, and therefore, pelagic MPAs will require different design responses depending on the physical features they are targeting for protection. The open ocean is also generally data-poor compared with terrestrial or coastal systems (Game et al. 2009). At the scale of thousands of kilometers, Longhurst (2010) described the world oceans' bio-geographical provinces according to abiotic and biotic pelagic factors. Then, De Broyer et al. (2014) used a bioregionalization multivariate procedure to delineate regions according to sea surface temperature, depth, and sea ice. Della Penna et al. (2017) applied Lagrangian methods to multi-satellite data as a support tool for an MPA proposal. They found that Lagrangian methods can be a valuable tool for tracking in time and space dynamical ecological key regions, mapping their inter-annual variability, and exploring possible trends associated with climate variability. The governance of pelagic environments is, moreover, complicated by the pelagic ocean including waters both within national jurisdiction (near shore and exclusive economic zones; EEZs) and outside (the high seas). The absence of a multilateral legal framework, which provides a clear legal basis for the designation of MPAs on the high seas, also limited the implementation of integrated spatial ecosystem management (Scott 2012) . Despite these challenges, there are also enormous opportunities for implementing MPAs in the open ocean: weak private property rights, limited habitat transformation, and potentially lower costs of protected area management (Game et al. 2009).

In addition to the studies focusing mostly on the pelagic marine ecosystem, the benthic habitats, on the other hand, also play important roles in the marine ecosystem in the open ocean/high seas. Howell (2010) suggests using a hierarchical classification system based on four surrogates that are useful at progressively finer spatial scales: biogeography, depth, substrate, and biological assemblages to classify the deep-sea fauna and provide scientific evidence for MPA designation. The unique underwater feature can be also used to guide the design of MPAs. The discovery of the Rainbow, a hydrothermal vent field located in the Portuguese continental shelf beyond 200 nautical miles, has led to the establishment of the first national MPA in the high seas (Ribeiro 2010)

One of the first international commitments to a global system of MPAs, including on the high seas, was the resolution adopted at the IUCN General Assembly in 1988. Then there are commitments to establish representative networks of MPAs at the World Summit on Sustainable Development in 2002, and subsequent United Nations General Assembly resolutions and Convention on Biological Diversity decisions (Gjerde and Kelleher 2005). In response to a need identified by the CBD Protected Areas Working Group, several international meetings and a consolidated set of criteria for identifying ecologically and biologically significant areas, and for evaluating representative networks of MPAs, were developed in Ardron et al. (2008):

1. identifying ecologically and biologically significant areas;
2. developing bio-geographic classification systems; and
3. identifying representative networks of MPAs.

It is essential to identify key ecological areas (i.e., criteria 1 and 2) within a preferred spatial resolution in the design of MPAs in the open ocean/ high seas (Della Penna et al. 2017) .

Nowadays, Target 3 of the Kunming-Montreal Global Biodiversity Framework (GBF) aims to effectively conserve 30% of terrestrial, inland water, coastal, and marine areas through protected areas and other effective area-based conservation measures by 2030. https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf

In this study we will be concerned with protocols to designate new and evaluate current MPAs in the seabed (or demersal) realm of SIOFA Area. This is because SIOFA data on species composition are available from demersal and seabed fishing gears. Our approach will be quantitative, data-based. From the available data, and assuming that new data will have a similar composition, we propose methodological protocols based on techniques of spatial statistics, in particular, geostatistics and species archetype modelling (SAM).

3 Task 1. Literature Review

3.1 SIOFA reports

Effective management of MPA requires continuous feedback of information to achieve objectives. The management process involves planning, design, implementation, monitoring, evaluations, communication, and adaptation (Day et al. 2019, Pomeroy et al. 2004). We have downloaded available full-text SIOFA reports relevant to the monitoring protected areas from the SIOFA website (https://siofa.org/) and searched for the keywords of monitor and protected area in the downloaded reports to obtain SIOFA advice. Particular attention was given to the following works and projects of the SIOFA Scientific Committee: "Saya de Malha Bank Fisheries-SER2021-03", "Bioregionalisation and Management of Vulnerable Marine Ecosystems (VMEs)-PAE2021-01", "Bottom Fishing Impact Assessment Trawl and Longline- PAE 2020-01" and "SIOFA Vulnerable marine ecosystems mapping- PAE2020-02".

SIOFA (2017a,b) proposed a standard protocol for future protected areas designation, which was listed in details in Annex H. Then SIOFA (2019) refined this protocol and provided an example of designating Atlantis Bank as a protected area (Annex L in SIOFA, 2019). This protocol included the criteria as the objectives (Table 1), principles for protected area designation (Table 2), considerations for determining boundaries of protected areas, and guidance for scientific committee recommendations to the meeting of the parties.

Table 1. SIOFA criteria for the designation of protected area

Criteria	**Remark**
VMEs are known to occur and/or triggering of VME indicator thresholds reported	• Closure may be warranted if there are known or consistent triggering of VME indicator thresholds of Contracting Parties, indicating potential VME
Bioregional representation	• Area is known to contain unique, rare or distinct,

	habitats or ecosystems that fishing operations will disturb. • Area with a comparatively higher degree of naturalness due to zero or a low level of human-induced disturbance or degradation from, for example, historical fishing activity.
Geographic and/or geomorphological representation	• The area provides for important or desirable geographic representation within the SIOFA area • The area proposed is known to contain unique or unusual geomorphological features that fishing operations may damage.
Biodiversity representation	• The area is known to contain unique or rare (occurring in only a few locations) species, populations or communities. • The area is known to contain a high diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity. • The area is known to contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.
Scientific interest	• The area has scientific research interest associated with understanding ecosystem, biological, geological and biodiversity processes in the SIOFA region.
Areas of special significance for threatened or important species or ecosystem properties	• There is evidence that the area is of special importance for life history stages of species and/or threatened species. • There is evidence that the area contains habitat for the survival and recovery of endangered, threatened, declining species or is an area with significant assemblages of such species.

Table 2. SIOFA (2019)'s principles for the designation of protected area.

Principles	**Remark**
Use best available information	• Recommendations must be informed by the available information. Best available information

	should include ecological, environmental, social, cultural and economic aspects of the marine environment that is available without unreasonable cost, effort or loss of timeliness. • Data derived from international reference databases should be analyzed and provided such as biophysical parameters and spatial indices, such as chlorophyll concentration, bottom temperature, currents velocity, salinity, dissolved oxygen concentration, depth, slope, rugosity, seamounts connectivity and bathomes representativity. A spatial analysis and description of the environmental context obtained from the clustering of the statistical layers may be provided. • Recommendations to implement spatial management measures should not be postpone because of a lack of full scientific certainty, especially where significant or irreversible damage to ecosystems could occur or indigenous species are at risk of extinction.
Evaluate adverse impacts	• Where there is a choice of several sites, which if protected would add a similar ecosystem or habitat to the closure network, and only one, or some of the sites are to be closed, the site(s) recommended should minimize adverse impacts on existing users. Where there is a choice to be made among minimum impact sites, selection may also be guided by: ease of management and enforcement; and i. if there are other benefits such as education or eco-tourism.
Consistent and transparent rationales for spatial management recommendation	
Evaluation of existing closures	• An enumeration of spatial management measures should be prepared to assess progress towards achieving the policies.

SIOFA (2019) proposed the following considerations for determining boundaries of protected areas:

- The recommended area should, as far as practicable, include continuous and contiguous depth;

- Area designation should be based on seafloor features such as geomorphic features;
- Size and shape should be orientated to account for inclusion of connectivity corridors and biological dispersal patterns within and across closures. Where this is unavailable, protected area proposal and designation may consider linkages with adjacent protected areas, or research from other oceans to inform inferences on biological dispersal patterns.
- Boundary lines should be simple, as much as possible following straight latitudinal/ longitudinal lines and, where possible, coinciding with existing regulatory boundaries;
- The size and shape of each area should be set to minimize socio-economic costs.

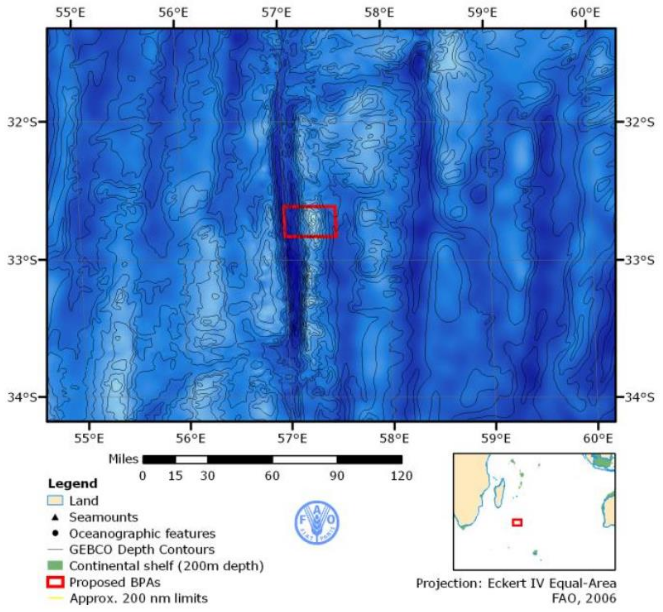
SIOFA (2019) proposed the following guidance for scientific committee recommendations to the meeting of the parties:

- The scientific committee should make a recommendation to the meeting of the parties based on how the proposal satisfies one or more of the criteria of the protocol.
- If the scientific evidence to support protecting area using the protocol is uncertain or insufficient,
- more data may be required.
- If the proposal documents the necessary data and scientific information to support a protected area using protocol, different measures could be applied, such as management measures, technical measures, closures.
- In case of an area becoming protected, a management and research plan shall be associated to it on the year to come. It will include:
    - The measures in place in the protected area;
    - The time of review of the protected area;
    - If needed, the research that should be undertaken in the area. To this end, the parties should consider to ask for international funds.

SIOFA (2019) provided an example of designate Atlantic Bank to be a protected area. Table 3 summarizes the designation process.

Table 3. The proposal and designation for Atlantic Bank as a SIOFA protected area.

Name	Atlantic Bank
Location	Coordinates: 32º00’S - 57 º00’W; 32º50’S - 58º00’E

Map	
Bathymetry	> 99 % of area deeper than 1500 m
Objectives	• Maintenance of the value • Integrity of the area's biodiversity • Special scientific interest
Criteria that the protected area meets	• Biodiversity representation – The area is known to contain high diversity of ecosystems, habitats, communities or species, or has higher genetic diversity; • Scientific interest – The area has scientific research interest associated with understanding ecosystem, biological, geological and biodiversity processes in the SIOFA region.
Social, cultural and economic interests	The area is located at a productive fishery area. It is possible that designation could have adverse social, cultural or economic impacts in terms of forgone opportunity for fishing.
Management measures	In accordance with CMM 2018/01, CCPs shall • prohibit all vessels flying their flag from engaging in bottom fishing, excluding line and trap methods; • For all other gears, CCPs shall ensure each vessel flying their flag has a scientific observer onboard at all times while fishing inside those areas.
Review periods	At least every 10 years. Could be more frequently if new information becomes available that enhances or degrades the justification.
Monitoring and research needed	• A desk-top compilation of publications from research undertaken within this area. • Non-destructive monitoring methods within protected area

The SIOFA advice to monitor protected areas can be summarized by the following practices: (1) Vessel Monitoring System (VMS) to track the location of the fishing vessel (SIOFA 2019a, 2022), (2) log-book systems to record the presence of organisms in the monitoring program, and (3) on-board observer programs to record organisms in the monitoring program from the fisheries catch and collect other required information.

The SIOFA Protected Areas and Ecosystems Working Group (PAEWG) provided the Scientific Committee with detailed advice on the protected area. Following the first meeting (PAEWG1) (SIOFA 2019a), the SIOFA meeting of parties adopted five protected areas in the Southern Indian Ocean for the protection of benthic ecosystems based mainly on their bioregional and biodiversity representation value. The PAEWG also suggested considering whether research monitoring is needed in these areas, and if so, how this monitoring could be undertaken. In Annex J of the same report, it suggested monitoring the catch of Vulnerable Marine Ecosystem (VME) indicator organisms in each segment of the long-line fisheries.

Rules and procedures are developed in SIOFA (2019b) for the monitoring, control, and surveillance of fishing activities in the SIOFA Area to ensure compliance with conservation and management measures. These procedures can be summarized by two requirements: (1) maintaining either an electronic fishing logbook or a bound fishing logbook and (2) implementing the Vessel Monitoring System (VMS) to maintain a record of all vessel position information in a required time interval.

It is also advised to monitor the bycatch from the fisheries operating in the SIOFA Area as one of the VME management measures (SIOFA 2020a, 2022a). This monitoring may be done using electronic monitoring equipment that is capable of generating, storing, and transmitting data to competent authorities in place of, or in conjunction with, a human observer or human observers on board a fishing vessel (SIOFA 2020b).

Fishing entities in SIOFA have been advised to monitor the fisheries by different practices, which could be also relevant to the monitoring of protected areas. The European Union suggested to monitor the catch of specific organisms, such as the proportion of deep-sea sharks in the catch in weight (SIOFA 2022b), and regulations are made to avoid high bycatch rates. Australia suggested to apply improved logbook recording of vessel position to permit fine-scale and consistent mapping of fishing effort distribution and a higher level of observer coverage to reduce data uncertainty (Williams 2011). Furthermore, Australia requires its fleets to implement the VMS for the purpose of monitoring fishing vessel activities in the SIOFA Area (SIOFA 2020c). France (SIOFA 2018) also suggested monitoring the impact of fisheries on VME using VMS, logbooks, and observer programs, which are also practiced for Japan bottom trawl and long-line fleets (SIOFA 2017a, 2017b).

3.2 Reports from other international organizations

In addition to SIOFA, we collected and summarised reports about MPA from other non-governmental (IUCN), and inter-governmental organizations (OSPAR, FAO, NAFO, and SEAFO).

Non-governmental organizations

There are good numbers of documents in the International Union for Conservation of Nature (IUCN) about monitoring protected areas. Pomeroy et al. (2004) proposed three types of monitoring indicators to address various aspects of management effectiveness: (1) biophysical, (2) socio-economic, and (3) governance indicators. These indicators measure the outputs and outcomes of MPA management, which also represent tangible benefits associated with MPA. Pomeroy et al. (2004) also provided guidelines on how to select MPA indicators for monitoring. Then, Otero et al. (2018) suggested to develop a monitoring and evaluation protocol for the MPA network. Considering the fact that there are many monitoring techniques, tools, and new technologies available, the great range and diversity of climate change impacts, and the usually limited resources available to the management authorities, Otero et al. (2013) proposed a suite of key indicators that can facilitate monitoring with five selecting criterion: (1) simple and easy to monitor and survey, (2) focusing and relevant to MPA management, (3) able to be measured at multiple sites, (4) able to incorporate different vulnerabilities of species, communities, and habitats across MPA frameworks, and (5) able to be represented in temporal trends or time series thus allowing temporal comparisons.

Remote sensing approaches are powerful tools for monitoring protected areas and they are also suggested in the most recent version of the IUCN Guideline for marine protected areas (Day et al. 2009) . The Secretariat of the Convention on Biological Diversity suggested that there are clear opportunities presented by existing and emerging remote sensing capabilities to support monitoring of the Earth's environments (Secades et al. 2014) . The use of remotely sensed Earth observation data is often constrained by access to data and processing capacity and therefore, Secades et al. (2014) recommended to put priorities on end users' needs for future development of remote sensing products and create a dialogue between data providers and users to promote the use of remotely sensed data.

Inter-governmental organizations

The Food and Agriculture Organization of the United Nations (FAO 2016) proposed a protocol for the observer program to collect data for the Vulnerable Marine Ecosystem, which could be considered as candidate protected areas. The observers are required to (1) monitor any set for evidence of the presence of VMEs and identify coral, sponges, or other organisms; (2) record on data sheets the following information for identification of VMEs (3) collect, if required, representative samples from the entire catch, and (4) provide samples to the scientific authority of a Contracting Party at the end of the fishing trip.

The Convention for the Protection of the Marine Environment of the North-East Atlantic, or OSPAR Convention (OSPAR 2018) suggested four key management actions in relation to OSPAR MPAs in Areas Beyond National Jurisdiction. Up to this date these involve the following types of activities: (1) Awareness raising, meaning sharing information to relevant authorities; (2) information building, facilitating the collection and sharing of information on the protected features; (3) marine science, promoting the application of best practice in terms of scientific research, and (4) new developments, ensuring the implementation of new activities in an OSPAR MPA. It is also suggested to establish and maintain long-term monitoring programs to evaluate the effectiveness of management measures to enable evidence-based assessments of feature conditions and support greater confidence in the assessment of management status, which is also relevant to the second item, information building (OSPAR 2018).

Northwest Atlantic Fisheries Organization (NAFO) applied two concepts to design areas similar to MPA: areas where specific organisms at critical life-history stage reside (i.e., nursery grounds where the juvenile fish reside, Godø and Haug 1987, Walsh, 1992; Anderson 1993, Walsh et al 2001) and VME area (Fuller et al. 2008, Muñoz et al. 2008, Kenchington et al. 2019, NAFO 2024). NAFO conducts regular surveys to identify distribution of commercially important species, such as cod (*Gadus morhua*), Greenland halibut (*Reinhardtius Hippoglossoides*), and yellowtail flounder (*Limanda ferruginea*) by life history stages. As the juvenile stage is considered to be critical for the adult abundance (review by Dahlgren et al. 2006), areas with high juvenile abundance are identified and defined in the context of establishing a Marine Protected Area (e.g. Walsh 1992, Walsh et al. 2001).

NAFO noticed the importance of VME and the impacts from the deep-sea fisheries. A case study of methodology for the identification of VME was conducted (Muñoz et al. 2008) in order to advise on conservation measures such as MPA. NAFO has identified 27 areas (NAFO 2024) as being vulnerable to bottom contact gears (e.g. Fuller et al. 2008, Muñoz et al. 2008, Kenchington et al. 2019) and subsequently closed these areas to bottom fishing (Article 17 in NAFO 2020). NAFO has also delineated existing bottom fishing areas to regulate bottom fisheries that cause a significant adverse impact on VME. The VME closed areas are divided into two categories, the blue areas in the map below represent the seamount closures, and the red areas represent the sponge, coral, and sea pen closures. No vessel shall engage in bottom fishing activities in any of these areas (NAFO 2020).

South East Atlantic Fisheries Organization (SEAFO) set MPAs in SEAFO Convention Area also under the framework of VME (SEAFO 2015). In response to UNGA Resolution 61/105 (UNGA 2007), SEAFO has defined its fishing footprint, closed 11 areas to bottom contact gears, implemented exploratory and encounter fishing protocols to protect seamounts and vulnerable marine habitats in SEAFO regions from significant adverse impacts caused by fishing. Mapping of bottom trawling activity is also given high priority by SEAFO. Existing bottom fishing areas within the SEAFO Convention Area for bottom fishing activities was mapped for the period from 1987 to 2011. The map and coordinates of existing bottom fishing areas and new fishing areas is revised by the SEAFO Commission on an annual basis (SEAFO 2023).

SEAFO Scientific Committee proposed a provisional list of benthic invertebrate VME indicator species/groups in 2009 (SEAFO 2023) and a coral and sponge taxa guide (Ramos et al., 2009) was developed for the scientific observers to monitor the collection of VME organisms for fishing fleets operating in the SEAFO Convention Area. SEAFO defined gear-specific threshold for the presence of VME taxa. All encounters of VME taxa above these threshold levels are reported to Executive Secretary and vessels are required to cease fishing and move 2 nm. An interim closure or 2 nm radius is also implemented in new fishing areas (SEAFO, 2015).

3.3 Publications in scientific journals

We have searched the Web of Science Database (Clarivate ©) in which more than 33,000 journals, books, proceedings, and reports are included. We used the following keyword in the search: "marine protected areas" OR "essential fish habitat" and this yielded 6,210 records. We included studies that are listed in the Science Citation Index Expanded (SCI-EAPANDED), Social Sciences Citation Index (SSCI), or Conference Proceedings Citation Index -Science (CPCI-S), which constitute more than 99 % of the 6,210 search records. Only studies in SCI-index or SSCI-index are included in this semantic analysis.

3.3.1 Summary of the literature related to MPA

A total of 7 studies related to MPA is included in the Web of Science Database in 1995. It increases steadily afterward and becomes 565 studies in 2021 and 473 in 2022 (Fig. 1) The majority of these MPA-related studies are conducted in USA region (2273 studies, 37%), followed by Australia (1215 studies, 20 %) and England, United Kingdom. (876 studies, 14 %) (Fig. 2). For SIOFA Parties and participants (https://siofa.org/about-siofa/parties-participants), the European Union has the largest contribution (2784 studies, 45 %), followed by Australia and New Zealand (183 studies, 3 %).

Environmental Sciences Ecology is the research area with the most studies (3452 studies, 56 %), followed by Marine Freshwater Biology (2137 studies, 34 %), and Oceanography (1233 studies, 20 %). In addition to science topics, the research area of International Relations also ranks 9th place in terms of the number of studies (497 studies, 8 %) (Fig. 3). Marine biology is the major meso-citing topic with the highest citation (4784 citations, 78 %), followed by Zoology and Animal Ecology (445 citations, 7 %) and Forestry (221 citations, 4 %) (Fig. 4). In terms of micro-citing topics, Fisheries is the most cited micro-citing topic (3233 citations, 52 %), followed by coral reefs (866 citations, 14 %) and common bottlenose dolphin *Tursiops Truncatus* (4784 citations, 78 %) (Fig. 5). Details in the meso and micro citing topics refer to this link:

https://incites.help.clarivate.com/Content/Research-Areas/citation-topics.htm

3.3.2 Semantic analysis

Because of a huge number of available pdf papers (Fig. 1) the text-mining was conducted over the period from 2017 to 2023. We also applied a sampling scheme that we sampled at least top 25 % of the most relevant papers using above-mentioned keywords with relevance as the sorting factor. For example, there are 452 papers in the Web of Science Database, and we downloaded the top 120 relevant papers shown in the search result in 2022. The text in the downloaded pdf papers were extracted using the package *pdftools* (Ooms 2023) in *R* (R Core Team 2023).

We successfully machine-read a total of 819 papers in pdf and extracted the texts. From this text, we explored the proportion that these keywords appeared: "success", "fail", "de- sign", "monitor", and "evaluate". The keyword "design", including design and designation, had the highest proportion of appearance (> 90 %), the keyword "success" and "monitor" appeared with similar frequencies (about 90 %), and the keyword "fail", fail or failure, ap- peared the least often (40 to 50 %). Generally, the keywords did not show a clear trend, except for "fail" with a slight declining trend (Fig. 6).

3.3.3 Review of relevant literatures

Monitoring

Monitoring is the gathering of data and information on the ecosystems of interest on a regular basis, preferably for an extended period of time (Wilkinson et al., 2003). Monitoring plays a critical role in managing these MPAs that provides the essential information about the achievement of MPA objectives (Pomeroy et al., 2005), which is required to make management decisions (Wilkinson et al., 2003). Therefore, being able to monitor a given MPA using scientifically sound criteria and protocols is key in demonstrating MPA effectiveness (Fenberg et al., 2012).

Wilkinson et al. (2003) proposed to classified the monitoring into two types: ecological monitoring and socio-economic monitoring. Ecological monitoring includes both physical and biological (biophysical) monitoring and aims to assess the status and trends of the marine ecosystems of interest. Physical parameters provide a general overview of the marine environment, while biological parameters measure the status and trends in the resident organisms. Socio-economic monitoring aims to understand how people use, understand and interact with the protected areas. Socio-economic data can help mangers determine what stakeholder and community attributes can provide the basis for successful management. (Table 4, Wilkinson et al., 2003).

Table 4. Descriptions of monitoring types, parameters, and examples

Monitoring type	**Parameters**	**Examples**
Ecological	Physical	Depth, bathymetry features, seabed profiles, currents, temperature, water quality, visibility, and salinity
	Biological	Percentage cover of corals, sponges, algae and non-living material; species composition, abundance, size structure, and health indicators of resident and target organisms, presence of predators, competitors, or invasive species.
Socio-economic		Number of fishermen, types of the fishing methods, prices of the catches, decision-making structures and mechanisms, community perceptions of management authorities, tourist perceptions of the value of MPAs and willingness to pay for management

A great number of scientific studies focus on how to design a monitoring program for protected areas. Hayes et al. (2019) recommended to design monitoring programs for marine protected areas within an Evidence-Based Decision Making Paradigm. An evidence hierarchy was proposed, with five types of evidence with increasing strength: (1) expert opinions, (2) uncontrolled time series and studies, (3) cohort, case-control, and cross-sectional studies, (4) non-randomized studies, and (5) randomized and controlled trials and time series. It is also suggested to use this strength of evidence hierarchy to assess the adequacy of different design strategies and other sources of information, improve the evidence base for addressing the objectives of marine protected areas, and motivate long-term monitoring programs (Hayes et al. 2019). Dunham et al. (2020) proposed a conceptual diagram linking four categories of MPA monitoring: (1) human pressure monitoring, (2) ecological performance monitoring, (3) reference monitoring, and (4) ambient condition monitoring. Human pressure monitoring is required to track compliance with enforced prohibitions and regulations. The results of ecological monitoring can be attributed to MPA effects and used to measure MPA performances. In addition, this MPA can be used as a reference area to support knowledge and data acquisition for ecosystem-based management. Information about human pressure and ambient conditions can be useful in excluding potential confounding effects Dunham et al. (2020).

Designation

Ware and Downie (2020) recommended to use a systematic, evidence-based approach for MPA designation and monitoring including (1) flexibility in feature classifications to allow additional features to be designated as required, (2) communication of limitations in the evidence bases to enable informed use in adaptive management decisions, (3) use of innovative technologies to more accurately map habitat features and (4) development of monitoring programs with a wider spatial scale which align with an ecosystem-based approach to the ongoing assessment of marine biodiversity.

It is essential to consider the age and size of MPA and the protection levels when designing MPA, as they are important factors affecting the efficiency of protecting marine organisms (Claudet et al. 2008, Friedlander et al. 2017, Sève et al. 2023). Claudet et al. (2008) reviewed 58 datasets from 19 European marine reserves and found that increase in the size of the no-take zone increased the density of commercial fishes within the reserve compared with outside; whereas the size of the buffer zone has the opposite effect. Moreover, positive effects of marine reserve on commercial fish species and species richness are linked to the time elapsed since the establishment of the protection scheme (Claudet et al. 2008).

The importance of MPA size and age was also found in the Pacific Ocean. Palau Protected Areas Network was created in 2003, comprising of numerous MPAs with differences in age, size, level of management, and habitat (Gruby et al. 2013). Friedlander et al. (2017) found that no-take MPAs had, on average, nearly twice the biomass of resource fishes compared to nearby unprotected areas, with fivefold greater biomass of piscivorous fishes in the MPAs compared to fished areas. They also found that MPA size and years of protection were two most important factors to the success of the MPA.

Protection level, i.e., the levels of reduction in fishing mortality, matters not only for the conservation but also for the fisheries. Sève et al. (2023) found stronger protection levels generate higher biomass and observed gains in catch are not only linked to biomass gains but also to the spatial dynamics of fisheries. For all levels of fishing mortality reduction, the initial decrease in catch is short and quickly offset by the increase in biomass. Thus, after a few years, even with lower fishing pressure in the MPAs, catches are at least equivalent to what they would have been without protection (Sève et al., 2023).

Evaluation

An increasing need exists for the evaluation and understanding of the effectiveness of marine protected areas operating around the world. Management effectiveness evaluations can allow for improvement of protected area management actions through learning, adaptation, and the diagnosis of specific issues influencing whether goals and objectives are being achieved. Management effectiveness evaluations also provide a mechanism to encourage accountability in the management of a protected area (Pomeroy et al., 2005).

To meet this need, in 2000 the World Conservation Union World Commission on Protected Areas—Marine and the World Wide Fund for Nature jointly initiated the MPA Management Effectiveness Initiative (MEI) to create a methodology for planning and conducting performance evaluations of MPA management effectiveness. Pomeroy et al. (2005) provides an overview of the MPA–MEI methodology and indicators. They defined the management effectiveness as the degree to which management actions are achieving the goals and objectives of the protected area. They also proposed a four-part process for the management effectiveness evaluation, including:

(a) Indictor selection: selecting the relevant biophysical, socioeconomic, and governance indicators for the evaluation of a particular MPA.
(b) Evaluation planning: developing a process for planning for and implementing this evaluation,
(c) Evaluation plan execution: including data collection, analysis, and validation, and
(d) Communication about results and adaption of management: using the results generated to inform and adaptively manage the MPA.

Grorud-Colvert et al. (2019) reviewed and integrated decades of research to clarify the issues different definitions and practices for MPA. They proposed a science-based, policy-relevant framework to categorize, evaluate, and plan MPAs.

The first step is the establishment of MPA, which includes four stages:
(a) Proposed or committed by a governing or other organizing body;
(b) Designated, by law or other authoritative rulemaking;
(c) Implemented, with activated regulations; and
(d) Actively managed, with ongoing monitoring and adaptive management.

The second step include setting the protection levels from the following levels:
(a) Fully Protected—no impact from extractive or destructive activities;
(b) Highly Protected—minimal impact;
(c) Lightly Protected—moderate impact; and
(d) Minimally Protected—high total impact, although still an MPA by IUCN criteria.

The third stage is to enable conditions for effective and equitable MPA planning, design, governance, and management (Table 5).

Table 5. Conditions for effective MPA proposed by Grorud-Colvert et al. (2019).

Stage	Conditions
All stages	• Clearly defined vision and objectives. • Long-term political will and commitment. • Sustainable financing. • Public participation with contextual and procedural fairness. • Evidence-based decision-making. • Knowledge integration, e.g., across academic disciplines, local, indigenous partitioner domains. • Coordination with related governance institutions. • Collaboration across jurisdictions. • Transparency and communication. • Upward and downward accountability to legal mandate and to stakeholders. • Recognition and support of existing governance by indigenous people and local rights-holders, including sovereignty, self-determination, and rights of assess, use, and management. • Conflict resolution mechanisms.
Proposed or committed to designation	• All of the above, including both ecological and social design principles **Ecological design principles**: – Viability based on MPA location, size, spacing, shape and performance. – Representativeness and replication of habitats – Incorporation of habitats and species of unique conservation value. – Design for connectivity and resilience – Precautionary approach considering current and emerging threats. – Consideration of existing treats and mitigation. **Social design principles**: – Inclusion of social objectives for multi-dimensional human well-being. – Recognition of pre-existing rights, tenure, uses. – Accounting for unequal costs and benefits to different social groups.

	– Impact- and benefit-sharing with distributional fairness.
From designated to implemented	• Sufficient and properly organized staffing and funding • Appropriate and adequate administrative structures and processes. • Compliance and enforcement, including graduated sanctioning. • Education and outreach initiatives. • Clarity of rules, rights, and boundaries.
From implemented to actively managed	• Ongoing monitoring, evaluation and knowledge sharing. • Adaptive management. • Support for livelihoods, e.g., development programs, capacity building, hiring. • Effective management of broader seascape and external pressures. • Ongoing efforts to build trust, strong local leadership, partnership with local users. • Local collaboration in monitoring enforcement, and management. • Ongoing consideration of cultural values, traditions, and activities in site management.

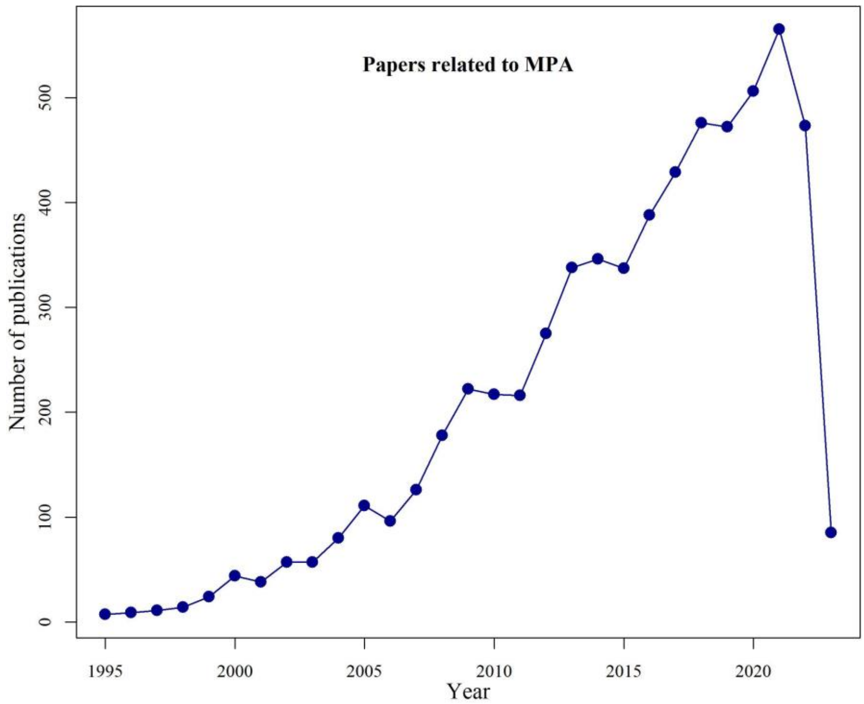


Figure 1: The number of scientific papers about marine protected areas included in the Web of Science Database from 1995 to 2023.

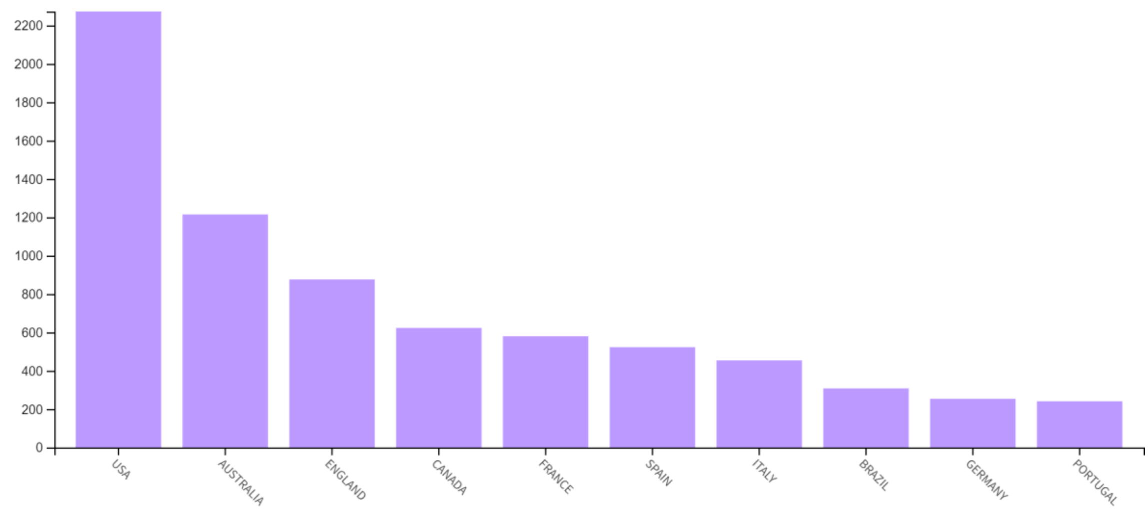


Figure 2: Bar-plot for the geographic regions where the studies about marine protected areas were conducted in the Web of Science Database from 1995 to 2023.

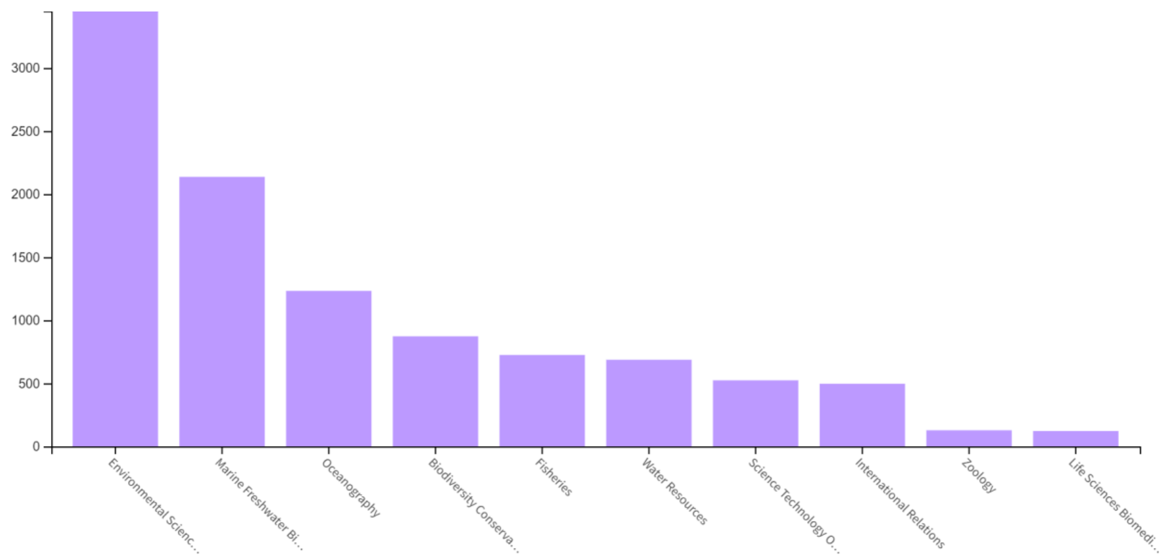


Figure 3: Bar-plot for the research areas for the scientific papers about marine protected areas included in the Web of Science Database from 1995 to 2023.

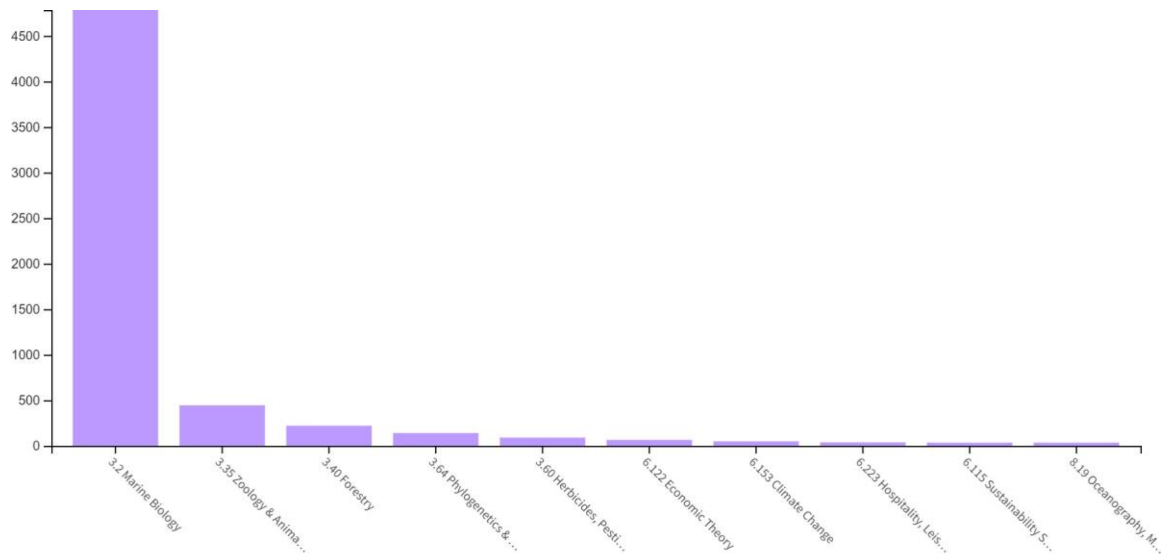


Figure 4: Bar-plot for the macro citing topics for the scientific papers about marine protected areas included in the Web of Science Database from 1995 to 2023.

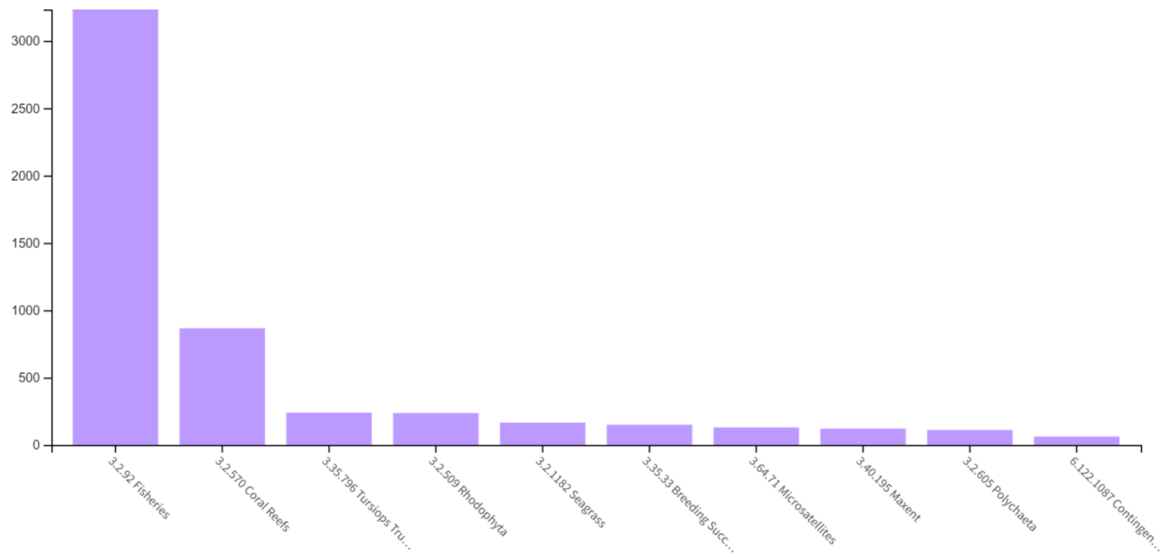


Figure 5: Bar-plot for the micro citing topics for the scientific papers about marine protected areas included in the Web of Science Database from 1995 to 2023.

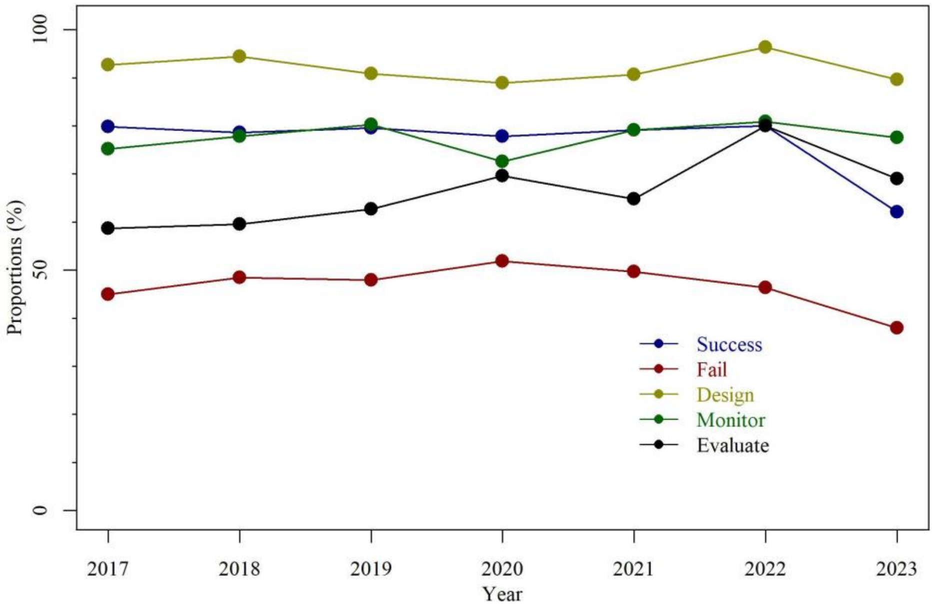


Figure 6: Proportions of keywords (blue: Success, red: fail, olive: design, green: monitor, and black: evaluate appeared in the paper.

4 Task 2. Data Review

We reviewed two types of data available for the designation and monitoring of MPAs in SIOFA's jurisdiction: bathymetric data and species composition. The former was obtained from open sources and the second type from SIOFA catch-effort and observers databases.

4.1 Bathymetric data

Bathymetric information for the study area was extracted from the ETOPO1 database available from the National Oceanic and Atmospheric Administration (NOAA) website at a resolution of 1 km, using the getNOAA.bathy function of the marmap package (Pante and Simon-Bouhet 2013) v.1.0.6. from R-project software (R Core Team 2023)

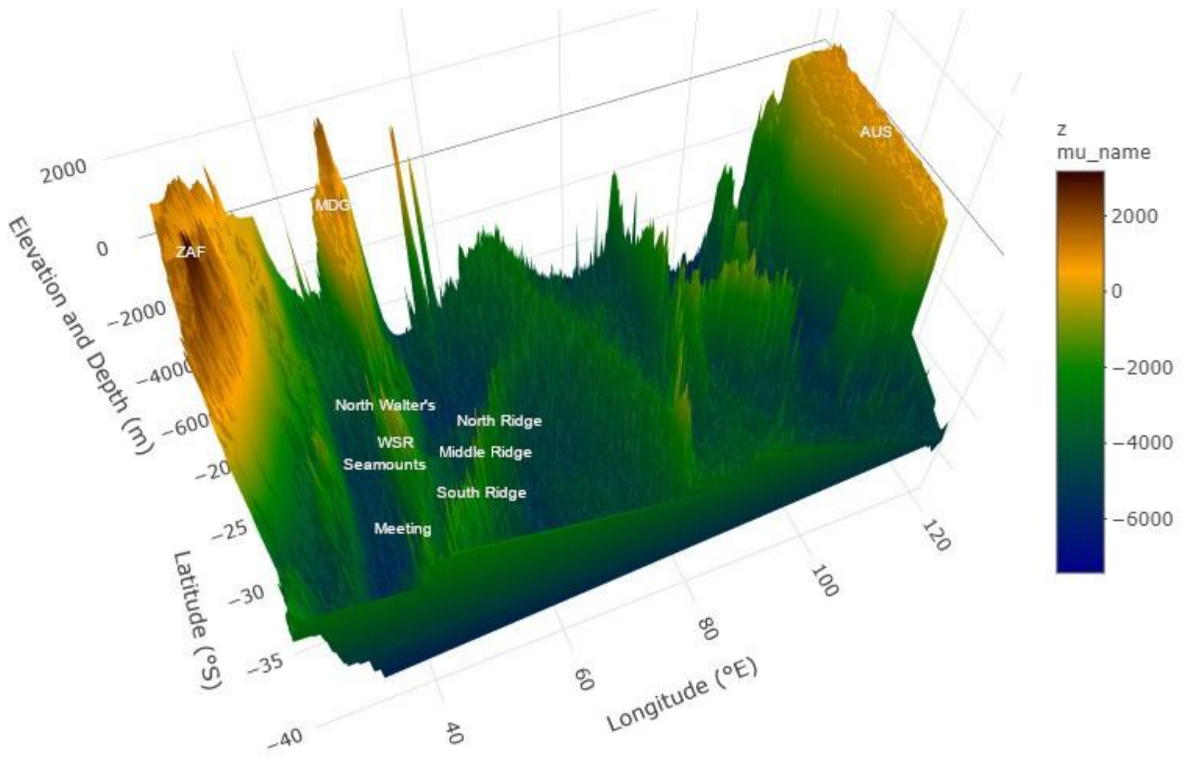


Figure 7: Compressed 3D rendering of the seabed topography of the Southern Indian Ocean. Some locations of seamounts fished by trawlers are named.

We created a 3D object with the bathymetry of the whole Southern Indian Ocean, between Easter-South Africa and Western Australia, as a 3D rotating and zooming-in object that can be examined using a regular html browser. This output is available from the SIOFA Secretariat on request.

We show in Fig. 7 this bathymetry (compressed mostly in the E-W direction), rotated to be observed from the South-East and from high altitude. The topography is characterized by a system of ridges whose highest altitudes are the islands of Madagascar and St. Denis. In the areas of trawling for demersal stocks such as orange roughy, the large scale characteristics of the habitat are two ridges, one that runs from south to north up to Madagascar (Madagascar Rideg) and another ridge that extends from south-west to north-east (SW Indian Ridge). Although this map has been compressed in Fig. 7 to fit the whole region, the original object delivered separately retains the original 1 km resolution. Thus, it can be used to examine quite fine detail of the seabed when using the 3D object in a browser.

4.2 Observer data

In this section we deliver a descriptive analysis of benthic species diversity registered as bycatch in commercial fishing operations in the SIOFA Area. Maps were generated for effort, in number of hauls, taxa at phylum level, and vulnerable marine ecosystem taxa indicators. Variables were grouped into SIOFA one-degree square quadrants according to Ramiro-Sanchez and B. Leroy (2023). All spatial polygons for SIOFA were taken from SIOFA's repository. The fishing logbook available from SIOFA secretariat contained the following attributes:

A) CCP: is a numerical code from Members belonging to SIOFA and that have registered commercial fishing operations.
B) Gear: contains the names of used fishing gears.
C) Date of fishing
D) Latitude and Longitude. Some data are reported as point data and other are grouped into 1 degree quadrants.
E) species3Acode corresponding to taxa in 3-alpha code.
F) catchWeightkg is the catch per taxon in kilograms.
G) Database.of.Origin contains HBH which identifies catches at the haul level from 2017 to 2022 and OBS which identifies data with biological sampling collected by observers between 2003 and 2023.

The fishing effort, in number of hauls, and catches were analyzed by fishing gear categorized as 'Trawls' and 'Hooks and Lines' according to the standard classification of fishing gears.

Benthic organisms were analyzed at the phylum level, given the aggregation already established in the available database. The 3-alpha code, ranging from phylum to species, revealed that only 0.1% of the registers were classified at the species level, while the remaining were assigned to a higher taxonomic level such as phylum or class. This classification precludes the application of species-level community analyses, such as diversity, species richness, and dominance, as well as other grouping statistical techniques, such as hierarchical clustering.

In addition, taxa that serve as indicators for Vulnerable Marine Ecosystems (VME) were identified following the SIOFA VME taxa classification guide 2021, available from the SIOFA Secretariat web (https://siofa.org/management/bf-interim)

4.2.1 Data curating

A total of 2,590 catch records with benthic organisms were available in the database. Seven percent contained repetitions of rows or lacked spatial location information. These records were removed.

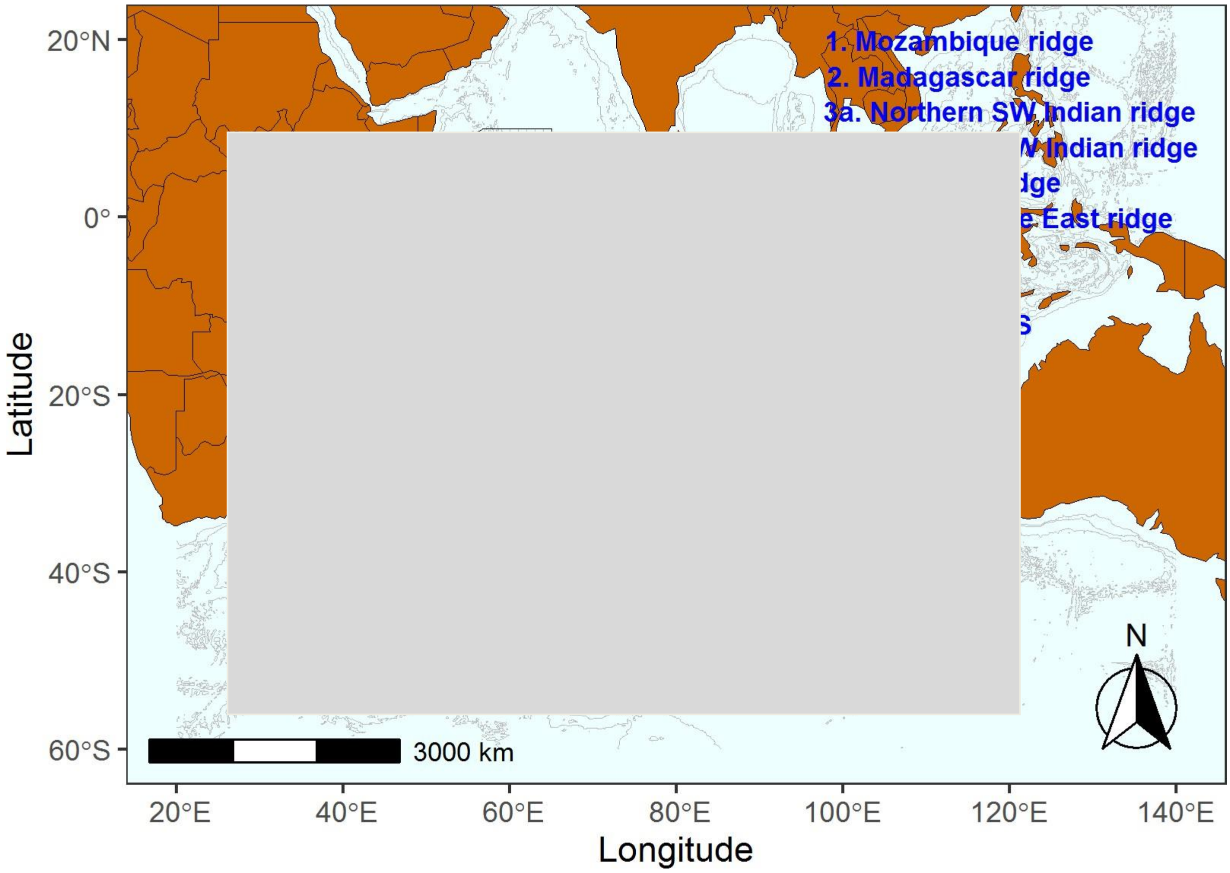


Figure 8: Spatial distribution of bycatch of benthic organisms (black crosses) in the SIOFA. Grid of 1°x1° used in SIOFA are in grey lines.

Only 23% of the data collected provides spatial point data (exact latitude and longitude), while in the remaining hauls, the position is aggregated to 1 degree. Unfortunately, the latitude and longitude value assigned to the original data located the haul in the vertices at the vertices of four SIOFA quadrants. This precludes the identification of the true SIOFA quadrant of these hauls which in turn affects some protocols to be presented below. To resolve this issue, at the cost of introducing a small amount of statistical uncertainty, we applied jittering to the latitude and longitude, thus leading to randomly assigning the ambiguous data to just one SIOFA quadrant.

4.2.2 Fishing effort and bycatch

A total of 1,216 hauls were reported between 2003 and 2023, with 91% of the fishing effort concentrated between 2018 and 2022. Additionally, 89% of the records with benthic taxa were reported during this period. In the spatial context, 41% and 23% of the fishing effort was concentrated on the Southern SW Indian Ridge (Subarea 3b) and Madagascar Ridge (Subarea 2), respectively (Fig. 8).

Eight different types of fishing gears are reported, but only four of them account for a total of 97.4% of the database. The most prevalent gears in terms of occurrence were Set longlines (46.0%), Trawls nei (18.9%), Single boat bottom otter trawls (17.5%), and Bottom trawls nei (15.0%) (Figure 9).

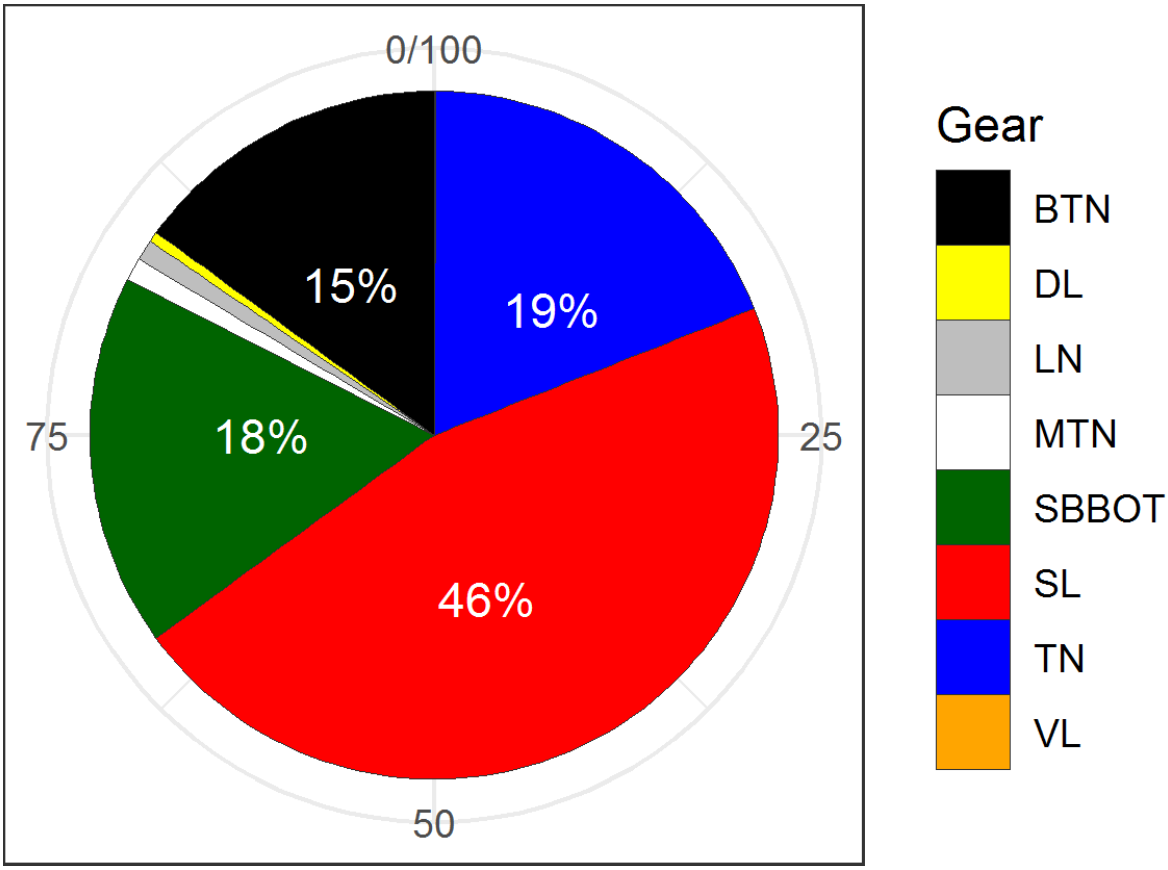


Figure 9: Percentage of composition of fishing gears reported in the SIOFA. BTN, Bottom trawls nei; DL, Demersal longlines; LN, Longlines nei; MTN, Midwater trawls nei; SBBOT, Single boat bottom otter trawls; SL, Set longlines; TN, Trawls nei; VL, Vertical lines.

The spatial distribution of fishing effort (number of hauls) by gear type categorized as 'Trawls' and 'Hooks and Lines' can be found in Fig. 10. The use of Hooks and Lines was reported in five subareas, with 56.1% of the fishing effort displayed in the Southern SW Indian Ridge (Subarea 3b). Fishing vessels labelled as 'Trawls' were located in six subareas (Fig. 10), although 86.5% of the fishing effort was accumulated in the Southern SW Indian Ridge (Subarea 3b), Madagascar Ridge (Subarea 2), and North of 20°S (Subarea 8).

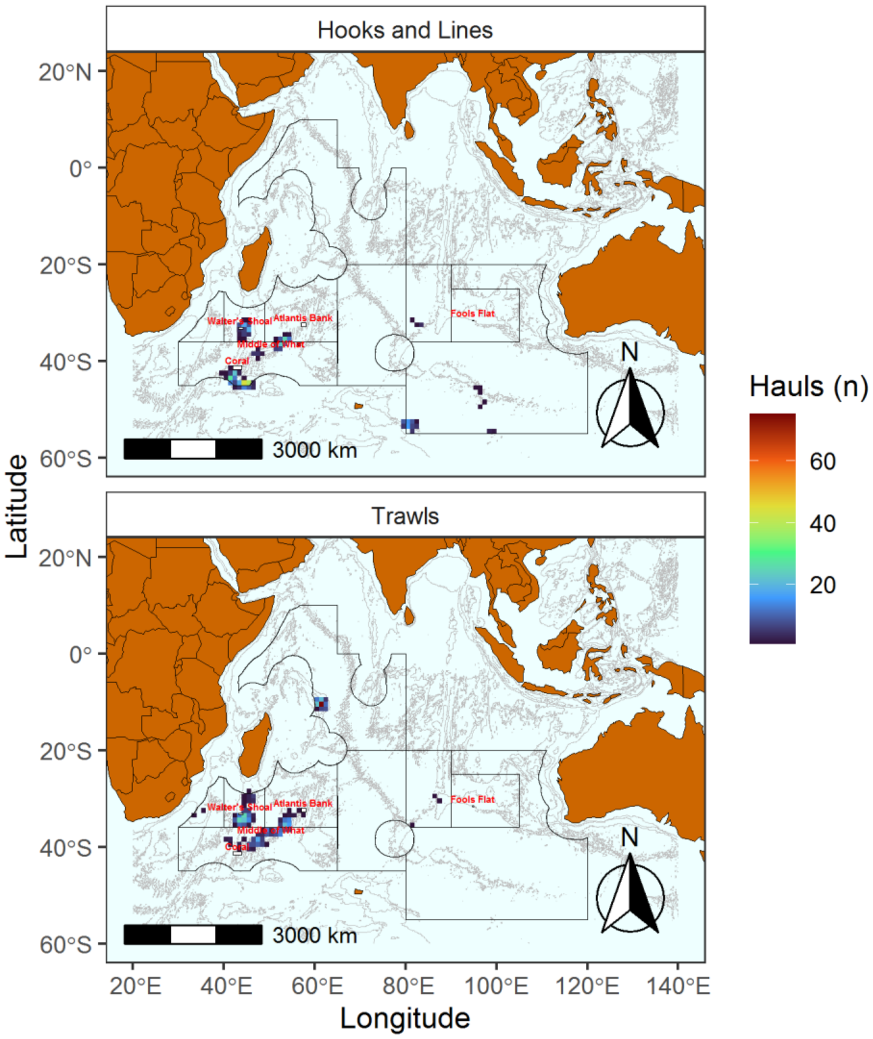


Figure 10: Spatial distribution of fishing effort, in number of hauls, for fishing gears labelled as 'Hooks and lines' and 'Trawls'. Data grouped in 1° x 1° squares. Names and white rectangles indicate the SIOFA protected areas.

A total of 13,307 kg of bycatch of benthic organisms were reported in SIOFA between 2003 and 2023. Four SIOFA subareas accumulated 92.5% of the total: Northern SW Indian Ridge (Subarea 3a), Southern SW Indian Ridge (Subarea 3b), and Northern of 20°S (Subarea

8), as shown in Fig. 11. The vast majority of the reported benthic bycatch (96%) corresponds to Trawls, with only the remaining 4% reported from Hooks and Lines in the SE Indian (Subarea 7), as depicted in Fig. 11.

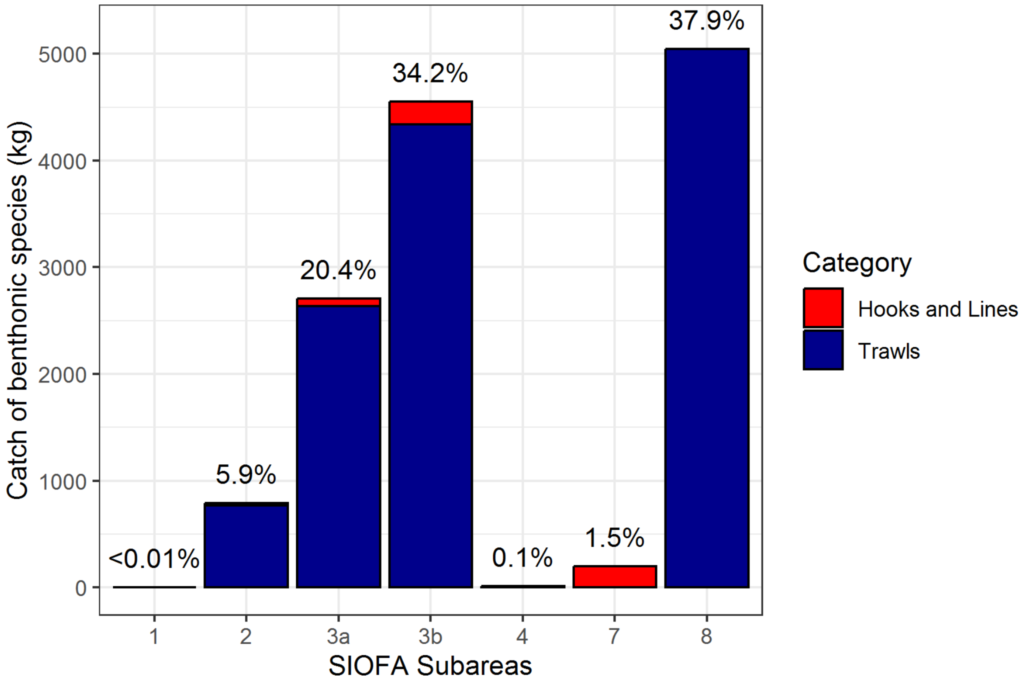


Figure 11: Bycatch of benthic species (Kg) by fishing gear and SIOFA subarea. The percentages on top of the bars correspond to the relative importance on the subarea.

4.2.3 Spatial distribution of benthic bycatch

Out of the 48 taxa reported with 3-alpha codes from OBS and HBH sources, Cnidaria accounted for 41.7%, while Echinoderm constituted 27.1%. Furthermore, Cnidaria were reported in 65.8% of the hauls, and Porifera were reported in 19.6% (see Table 6). Therefore, for further analyses, we focused on four groups: Cnidaria, Echinoderm, Porifera, and others Fig. 12 depicts the frequency of occurrence of taxonomic groups per SIOFA quadrant.

Bycatch of Cnidaria occurred in 123 quadrants, but only seven of them accumulated 18.7%. These seven quadrants are situated between 37.5 − 35.5°S and 51.5 − 54.5°E, at the southern limits of the Northern SW Indian Ridge (Subarea 3a) and northward of the Southern SW Indian Ridge (Subarea 3b). Additionally, the occurrence of Cnidaria was observed in 23 quadrants of the Madagascar Ridge (Subarea 2), but only six of them accumulated 8.4% of the total occurrence of this taxon (see Fig. 12).

Bycatch of Porifera was reported in 65 quadrants across six SIOFA subareas. Notably, a high occurrence of this taxon (≥18 quadrants) was registered on the Madagascar Ridge

Table 6: Bycatch of benthic taxa reported in SIOFA between 2003 and 2023. Taxon status and Scientific Name accepted were updated from World Register of Marine Species (WoRMS).

FAO 3-alpha Code	Scientific Name	Rank	Taxon Status	Scientific Name accepted	VME taxa	Frequency (n)	Catch (kg)
ADQ	*Antipathes dichotoma*	Species	Accepted	*Antipathes dichotoma*	No	16	33.0
AJH	Anthozoa	Class	Accepted	Anthozoa	No	4	3.5
AJZ	Alcyonacea	Order	unaccepted	Octocorallia	Yes	68	26.3
AQZ	Antipatharia	Order	Accepted	Antipatharia	Yes	67	68.8
ATX	Actiniaria	Order	Accepted	Actiniaria	Yes	67	33.7
AXT	Stylasteridae	Family	Accepted	Stylasteridae	Yes	86	41.1
AZN	Anthoathecata	Order	Accepted	Anthoathecata	No	22	11.4
BDX	*Bohadschia similis*	Species	unaccepted	*Bohadschia vitiensis*	No	2	13.9
BHZ	Brisingidae	Family	Accepted	Brisingidae	No	1	0.0*
BVH	Brachiopoda	Phylum	Accepted	Brachiopoda	Yes	1	0.0*
BWV	Paragorgiidae	Family	Jss	Coralliidae	Yes	4	2.3
BWY	Bathylasmatidae	Family	Accepted	Bathylasmatidae	Yes	7	0.2
BZN	Bryozoa	Phylum	Accepted	Bryozoa	Yes	28	9.6
CNI	Cnidaria	Phylum	Accepted	Cnidaria	No	45	39.4
COR	*Corallium spp*	Genus	Accepted	*Corallium*	Yes	60	4899.2
CRU	Crustacea	Phylum	Accepted	Crustacea	No	12	0.3
CSS	Scleractinia	Order	Accepted	Scleractinia	Yes	614	2773.3
CUX	Holothuroidea	Class	Accepted	Holothuroidea	No	8	180
CVD	Cidaridae	Family	Accepted	Cidaridae	No	15	5.0
CWD	Crinoidea	Class	Accepted	Crinoidea	Yes	23	4.7
DMO	Demospongiae	Class	Accepted	Demospongiae	Yes	204	1162.6
ECH	Echinodermata	Phylum	Accepted	Echinodermata	No	52	8.6

Continuation of Table 6

FAO 3-alpha Code	Scientific Name	Rank	Taxon status	Scientific Name accepted	VME taxa	Frequency (n)	Catch (kg)
GGW	Gorgoniidae	Family	Accepted	Gorgoniidae	Yes	316	187.8
GKX	Galatea spp	Genus	Accepted	Galatea	No	1	0.0*
QZ	Hydrozoa	Class	Accepted	Hydrozoa	Yes	9	13.1
HXY	Hexactinellida	Class	Accepted	Hexactinellida	Yes	47	47.8
INV	Invertebrata				No	21	7.1
IQO	Isididae	Family	Accepted	Isididae	Yes	110	64.7
JEL	*Rhopilema spp*	Genus	Accepted	*Rhopilema*	No	36	30.0
KCX	Lithodidae	Family	accepted	Lithodidae	No	2	1.5
KRH	*Cirrhipathes spp*	Genus	accepted	*Cirrhipathes*	No	1	0.1
NTW	Pennatulacea	Order	superseded rank	Pennatuloidea	Yes	52	9.7
NYZ	Nephtheidae	Family	accepted	Nephtheidae	No	1	0.1
OEQ	Euryalida	Order	accepted	Euryalida	No	56	11.3
OOY	Ophiurida	Order	accepted	Ophiurida	Yes	32	10.5
OWP	Ophiuroidea	Class	accepted	Ophiuroidea	No	3	1.5
PFR	Porifera	Phylum	accepted	Porifera	No	131	2488.6
PWJ	Pycnogonida	Class	accepted	Pycnogonida	No	2	0.1
QCX	*Gorgonocephalus spp*	Genus	accepted	*Gorgonocephalus*	No	7	2.8
QFY	Chrysogorgiidae	Family	accepted	Chrysogorgiidae	Yes	3	0.1
SPO	Spongiidae	Family	accepted	Spongiidae	Yes	92	1129.0

Continuation of Table 6

FAO 3-alpha Code	Scientific Name	Rank	Taxon status	Scientific Name accepted	VME taxa	Frequency (n)	Catch (kg)
SSX	Ascidiacea	Class	accepted	Ascidiacea	Yes	8	2.3
STF	Asteroidea	Class	accepted	Asteroidea	No	19	13.6
SZS	Serpulidae	Family	accepted	Serpulidae	Yes	1	1.1
URX	Echinoidea	Class	accepted	Echinoidea	No	50	18.5
WBX	*Holothuria spp*	Genus	accepted	*Holothuria*	No	1	0.4
WOR	Polychaeta	Class	accepted	Polychaeta	No	1	0.0*
ZOT	Zoantharia	Order	accepted	Zoantharia	Yes	10	2.1

jss: junior subjective synonym; (*) <0.1 kg

(Subarea 2) and the Southern SW Indian Ridge (Subarea 3b). The highest abundance of Porifera (9.3% in 9 quadrants) was recorded in the North of 20°S (Subarea 8), where only 3 quadrants accumulated 6.2% of the Porifera bycatch (Fig. 12).

In the case of Echinoderms, they were found in 65 quadrants distributed across seven SIOFA subareas. The Southern SW Indian Ridge (Subarea 3b) accumulated 29 of these quadrants, yielding 5.9% of the total hauls (refer to Figure 12). The rest of the species labelled as 'others' were registered in 29 quadrants distributed across four SIOFA subareas. A higher presence of this group was located in the Southern SW Indian Ridge (Subarea 3b), although it only accounted for 1.8% of the total hauls (Fig. 12).

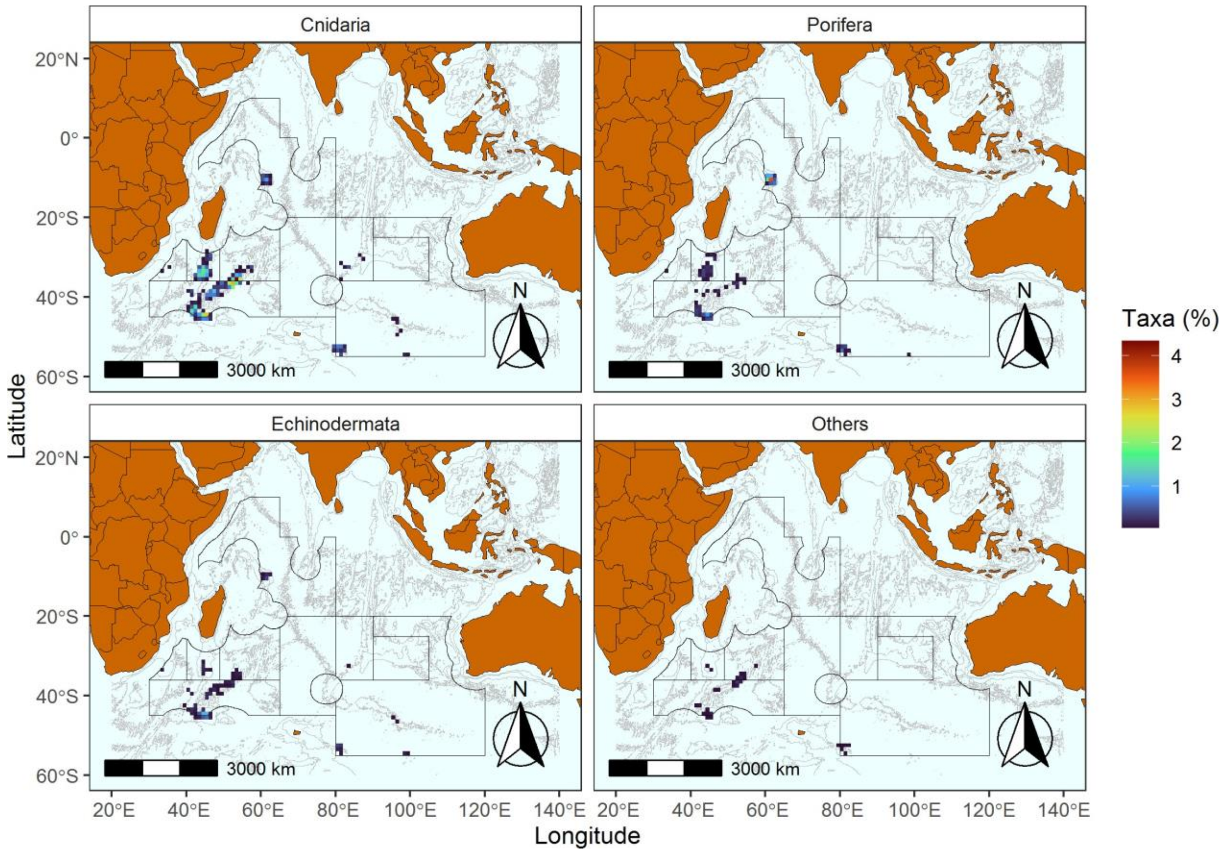


Figure 12: Spatial distribution of the frequency of occurrence of benthic organisms. Data grouped in 1° x 1° squares.

4.2.4 Spatial distribution of taxa indicators for vulnerable marine ecosystems (VME)

The frequency of occurrence and relative catch of each taxa indicator of Vulnerable Marine Ecosystems (VMEs) are depicted in Fig. 13 and 14, respectively. Taxa indicators of VMEs were registered in 110 quadrants (96%) out of all quadrants with the presence of benthic organisms. The most important areas with VME indicator species were the Southern SW Indian Ridge (Subarea 3b) with 36.2% occurrence, Madagascar Ridge (Subarea 2) with 16. 2%, and the Northern SW Indian Ridge (Subarea 3a) with 11.8% (Fig. 13) However, in terms of relative catches, the indicator taxa for VMEs were concentrated in the Southern SW Indian Ridge (Subarea 3b, 33.7%), Northern SW Indian Ridge (Subarea 3a, 20.2%), and North of 20°S (Subarea 8, 17.9%) (Fig. 14).

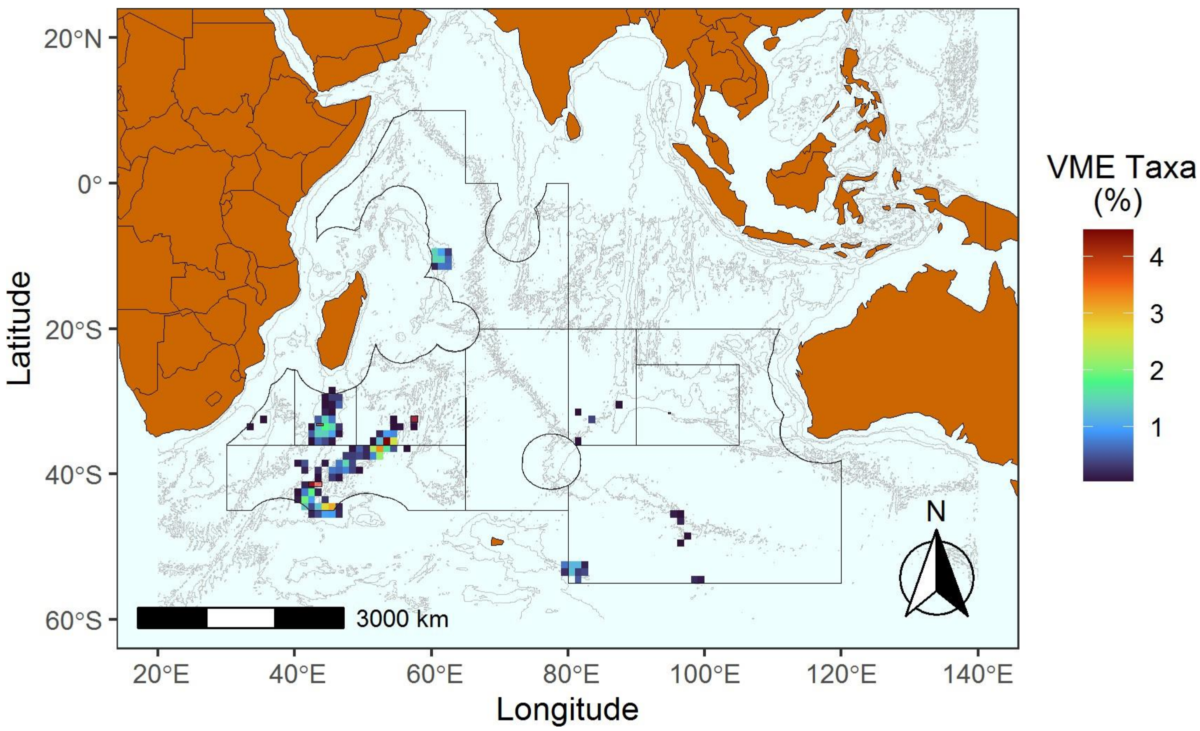


Figure 13: Spatial distribution of VME indicator taxa occurrence. Data grouped in 1° x 1° squares

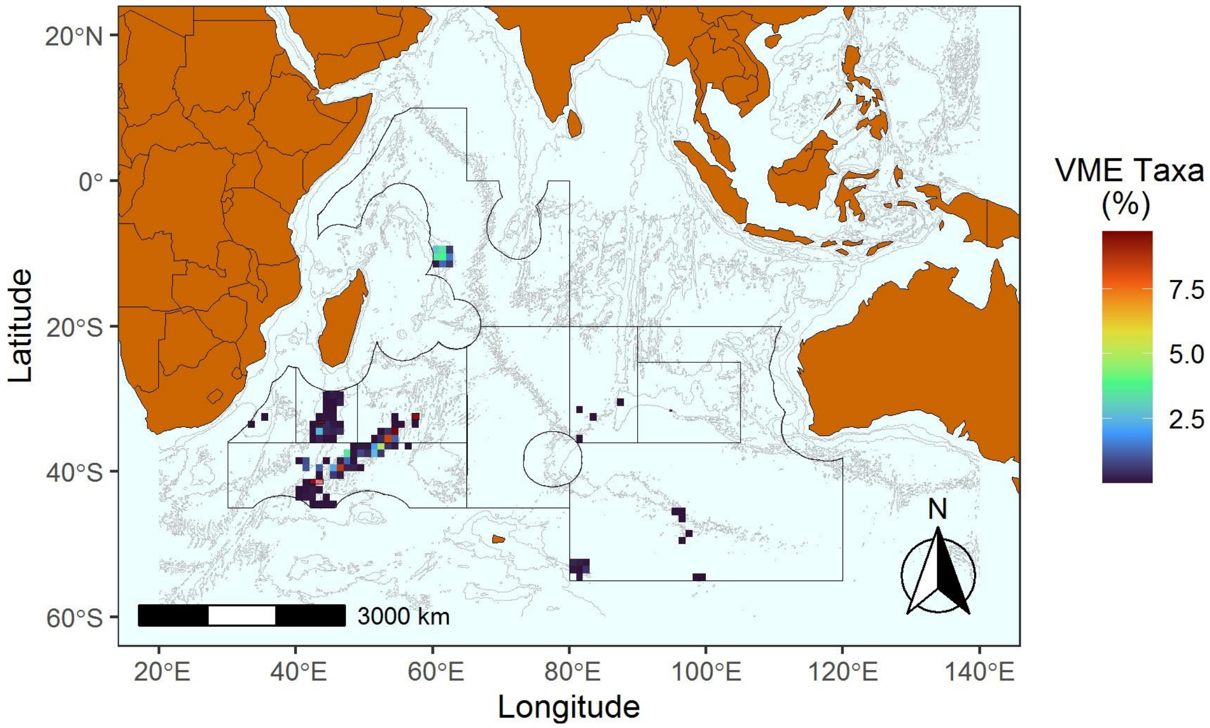


Figure 14: Spatial distribution of relative occurrence of VME indicators taxa. Data grouped in 1° x 1° squares.

4.3 Catch effort data

The catch-effort database has a number of issues that required careful curating. These database was needed for one of the presented evaluation and monitoring methods (SGLM, see below) that required point spatial data. We implemented curating procedures by:

1. removal of unrealistic coordinate records (for example, records longitude reading of 502 and 847), as well as records from outside the SIOFA Area (e.g., a record with 36°N latitude);
2. excluding records with empty coordinate values, as they provide no information about the spatial distributions of sensitive organisms;
3. checking the known distribution areas of recorded organisms with public available database, such as FishBase for the Teleost and Chondrichthyes and removed those records with unlikely presence, such as the Malawi tilapia (*Oreochromis karongae*) which is endemic in Lake Malawi.

5 Task 3. Evaluation and Monitoring

5.1 Species Archetype Model

Evaluation and monitoring of MPAs require quantitative approaches in order to glean the most information from data in an objective manner. So our approach in this task has been to develop statistical models that could be used regularly as new data are compiled into SIOFA databases.

From a biological point of view, the definition of spatially homogeneous ecological units is what matters when designing and applying spatial management plans. The definition of these spatial units requires the identification of different groups of species or assemblages, which correlate with environmental variables. These homogeneous regions with distinct features of their species assemblages are called bioregions Woodly et al. (2020). Bioregions are the fundamental concept underpinning the definitions of marine protected areas because MPAs should be ecologically representative to effectively conserve biodiversity.

Statistical models for assessing bioregions usually incorporate species and environmental information. According to Woodly et al. (2020) the analytical approach for assessing bioregions can be broadly classified into two-stage or one-stage approaches. The two-stage process is more common in marine sciences, in which either the species assemblages are first determined and then related to the environment, or single species are related to their environments, and then species assemblages are identified. For example, it is common in fisheries science to identify species indicators for vulnerable marine ecosystems (VME) to model the single species distribution using geostatistics and then correlate predicted abundance or occurrence with environmental variables.

Here we present two methodologies for the evaluation and monitoring of MPAs in SIOFA's jurisdiction. The first methodology is a one-stage methods while the second one is a more conventional two-stages method. In addition to being adequate methodologies for defining bioregions, these methodologies present the advantage of using already existing data in SIOFA's databases, thus facilitating the construction of time series of status evaluations, i.e. continued and straightforward monitoring.

5.1.1 The SAM methodology

In a one-stage approach, the set of species and their relationship with the environment is analyzed simultaneously in a single model, where all parameters are estimated at once. Advantages of one-stage models include the direct ecological interpretation of bioregions and an adequate treatment of statistical uncertainty (Hill et al. 2017, 2020). Limited methods are currently available for one-stage approaches, including multivariate regression trees (De'Ath 2002) species archetype models (Dunstan et al. 2011), and regression of common profile models (Hill et al 2002, Foster et al. 2013). Here, we propose the application of the species archetype model (SAM) as a tool to evaluate and monitor the status of SIOFA MPAs.

The Species Archetype Models are a variant of Mixture-of-Regressions used to describe how homogeneous groups of species vary with the environment. These groups are referred to as Species Archetypes, as described by Dunstan et al. (2011). Each Archetype represents a group of species that jointly respond to environmental data in the model treated as covariates, including linear, quadratic, spline, and interaction terms. This provides a general framework for modelling species responses to the environment, with general applications to spatial management planning, including the proposal of Marine Protected Areas.

Benthic organisms' data were mapped in space (Fig.15) Given the sparsity of spatial data, we defined the green shared area in Fig. (15) to demonstrate the application of SAM to SIOFA data.

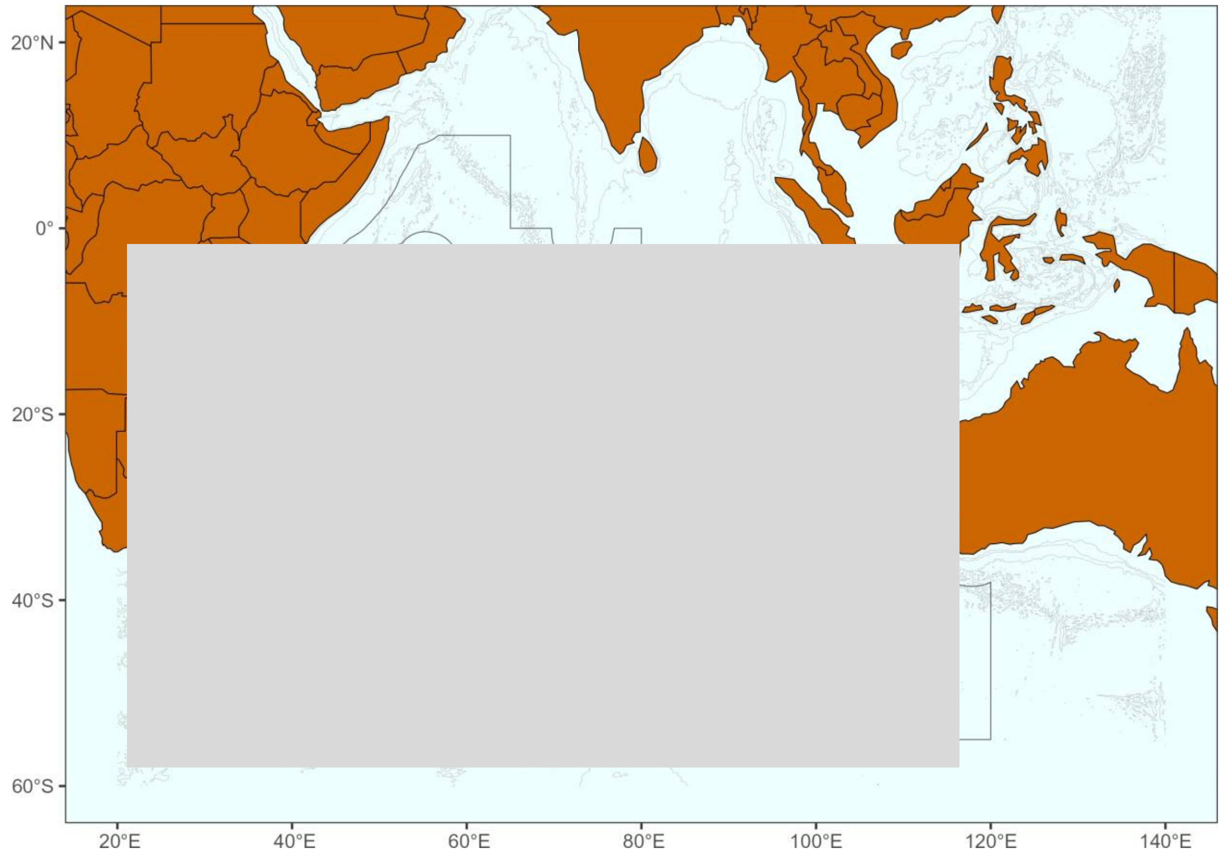


Figure 15: Map of the Study area showing the SIOFA convention with bathymetric contours. Blue dots are representing fishing locations from observer data and the chosen area for modelling in green rectangle.

The number of taxa occurrences across all sites (SIOFA quadrants) provides information regarding rare species. Following Hui et al. (2013), we removed the rare taxon with fewer than 10 occurrences across all sites (red vertical line in Fig. 16) Although these species could potentially be included in the model, they are likely to introduce noise and unexplained variance, making the model harder to fit and estimate. Removing rare species is usually recommended since these have insufficient information to be modeled well regardless of the method used (Hui et al 2013).

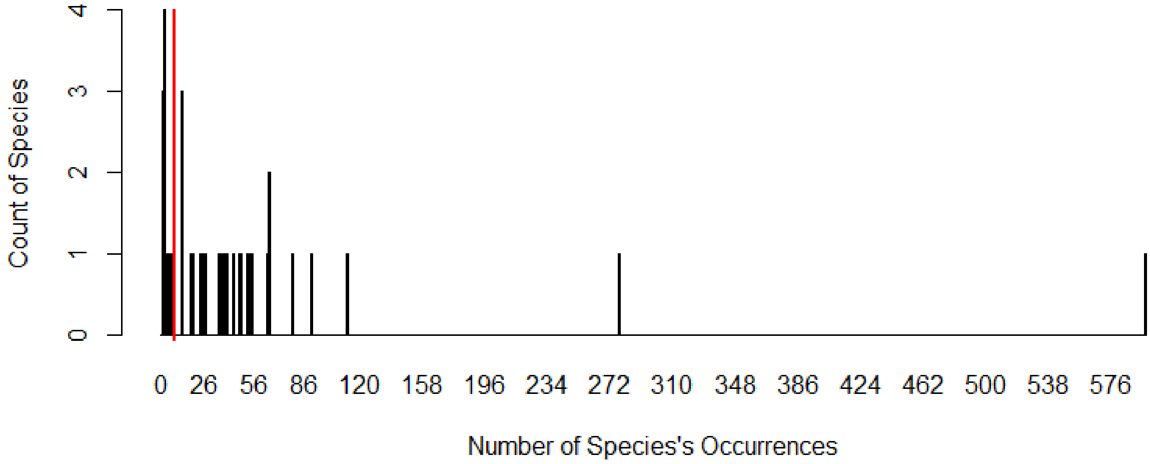


Figure 16: The occurrences of taxa across observation sites (SIOFA quadrant). Red lines indicate less than 10 presences across all sites.

The SAMs are a variant of Mixture-of-Regressions. We can describe the data as $i = 1...n$ sampling sites, $j = 1...S$ species (or taxonomic unit) and $k = 1...K$ Archetypes. The model conditional mean observations (occurrence on this case) of species is, $E(y_{ij}$ | archetype group_k) on $gk(Xi)$ Archetype covariates. The applied SAM can be described as follows:

$$h[E(y_{ij} \mid \phi k)] = a_j + g_k(X^\top \beta_k) + \nu_i$$

where $Pr(\phi_k) = \pi_k$, and $\sum_{k=1}^{K} \pi_k = 1$. The functional form of $g_k(\cdot)$ can be specified to be any function commonly used within a Generalized Linear Model framework. Including linear, quadratic, spline and interaction terms. Additionally, an offset term ν_i can be included to account for fishing effort.

We use the mean and standard deviation of the depth of the SIOFA quadrant as covariates in the SAM model, employing a quadratic function. Bathymetric data were imported from the NOAA server using the function getNOAA.bathy. To evaluate the possible effect of spatio-seasonal variation in fishing activity on the species archetypes, we include the quarters of each year as a fixed effect in the SAM. The model was implemented using the ECOMIX package in R (Woolley et al. 2024).

5.1.2 Results

Different variants of the proposed model were implemented, considering the stepwise removal of environmental covariates. One challenge in developing SAMs is selecting the number of archetypes, denoted as k, in the model. We can estimate the optimal number of archetypes based on the most parsimonious fit to the data. The final number of best-fitting archetypes was selected using the Bayesian Information Criteria (BIC; Dunstan et al. 2011). We implemented models considering between 2 and 6 archetypes. The optimal model consists of 2 archetypes, and the following results refer only to the best-selected model.

To assess the fit of the selected model, we used random quantile residuals versus the fitted values. In Fig. 17 it is evident that at the species-by-species level, the residuals are approximately randomly distributed along the fitted line. This suggests that the selected SAM models adequately fit the data.

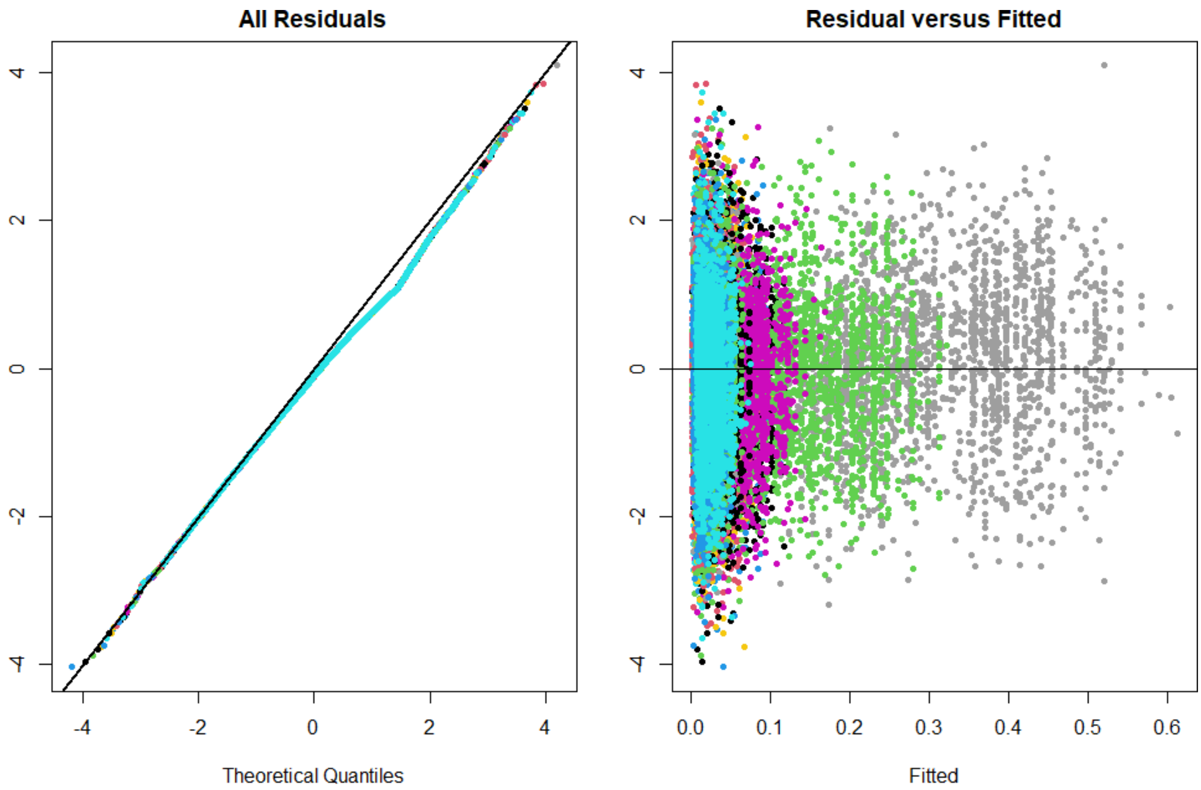


Figure 17: Random quantile residuals for all species (separated colors) in the fitted model.

The two identified archetypes show different responses to the mean and standard deviation of the depth in an SIOFA quadrant (Fig. 18) A higher probability for archetype 2 is found in deeper waters, whereas archetype 1 shows the opposite response to the mean depth. Likewise, archetype 2 has a higher probability in the average standard deviation of depth of the SIOFA quadrant. There is an increasing probability of both archetypes according to the quarter of the year. Archetype 2 shows a lower probability and does not exhibit a clear spatial pattern.

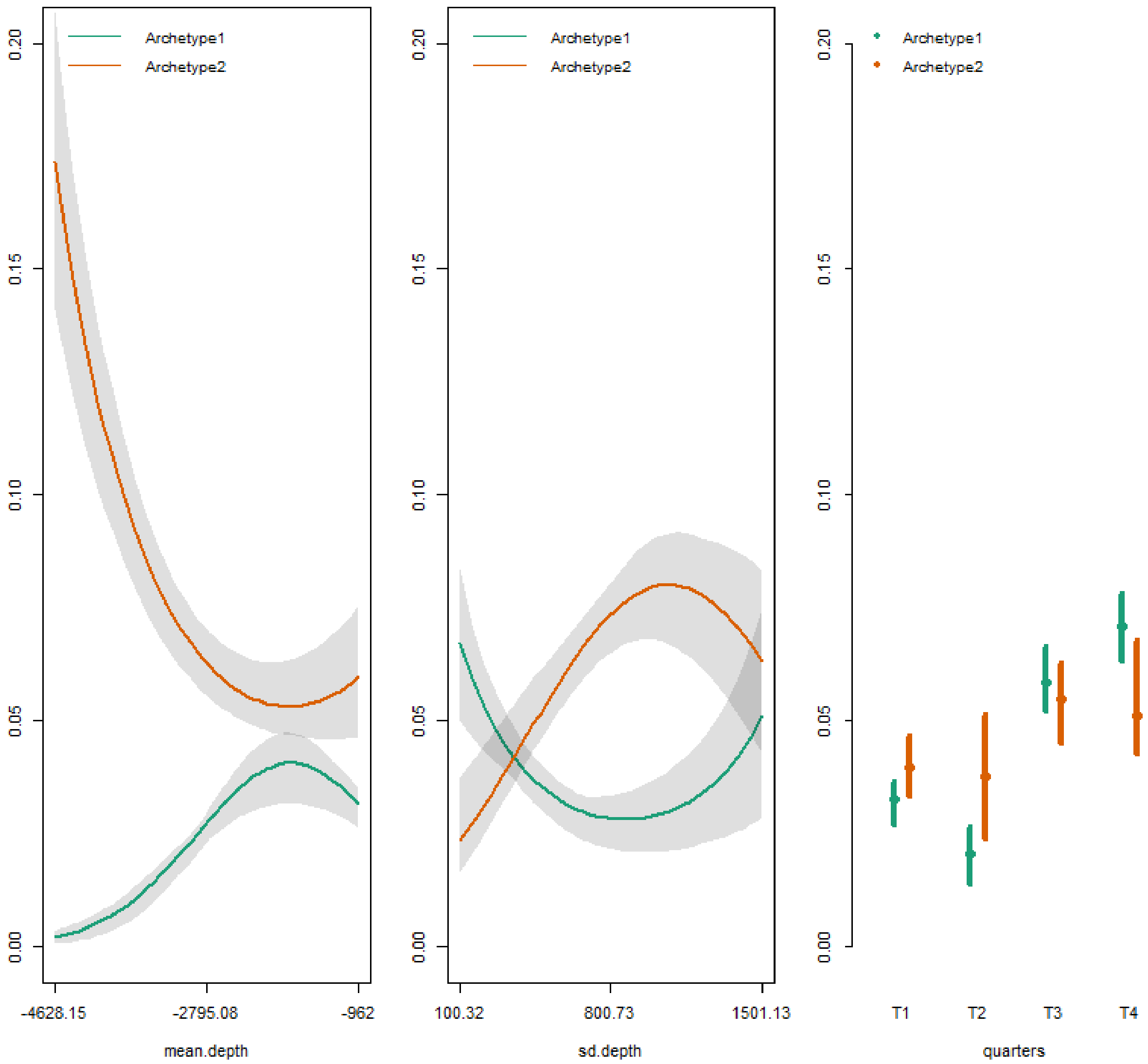


Figure 18: Partial response plots for each covariate in the model.

The probability of each archetype in space can be computed using SAM and the environmental covariates. In Fig. 19, we show the spatial predictions of the probability of finding either of the two archetypes and the standard error of the spatial prediction by SIOFA quad- rant. Although the prediction probability for both archetypes is relatively low (< 0.3), there is a high relative probability of finding archetype 1 south of Madagascar Island and along the southern-western border of the SIOFA polygon (Fig. 19).

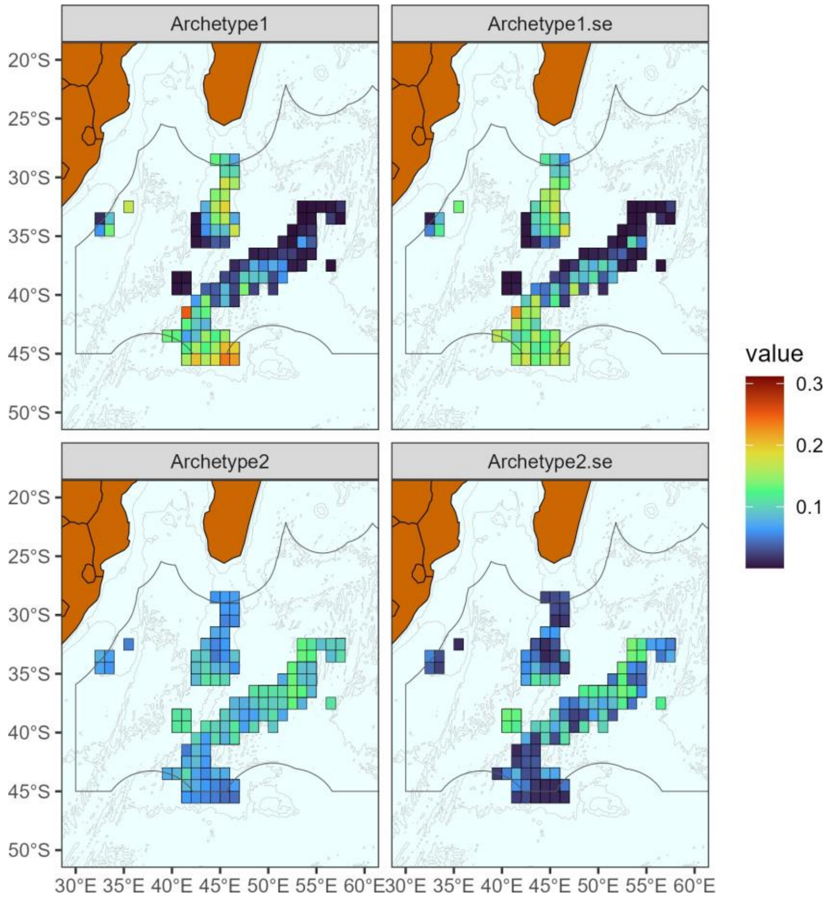


Figure 19: The predicted probability of each species archetype and the standard error of the predictions generated based on resampling. Data grouped in 1° x 1° squares.

5.1.3 Recommendations

- Most of the data provided was already grouped in 1° x 1° polygons. Therefore, provide point spatial data when possible to facilitate exploration of smaller bio-regions than those already established by SIOFA (1-degree square)
- When aggregating spatial data, provide the mid-spatial point of the aggregation quadrat. This will facilitate the unequivocal classification of each data point within a single polygon.
- Provide a database that includes all species registered in hauls without prior separation. Emphasize the species composition of the entire community, as bio-regions revolve around the diversity within the community.
- Future SAM approaches should explore the incorporation of addition environmental data. Some, such as sea surface temperature or chlorophyll-a, are already available from satellite data and can be used as proxies for the inhabited environment.

- Given most of data provided was grouped in polygons, detailed measure of fishing effort was not available. For example, in longliners, this could include total the number of hooks and soaking time. In trawlers, it could involve the total trawling time or an approximation of the trawled area. This information can be used to weigh the occurrence data.
- Considering that only 0.1% of the benthic organisms were classified at the species level, improvements in the collection and reporting of VME data is essential for any application of species-level community analyses.

5.2 Spatial Generalized Linear Model

In contrast with the one-stage approach presented in the above section, analytical approaches to bioregions are usually conducted in two stages. These consist of first determining biological groups and then relating them to the environment. This two-stage process is also known as 'group first, then predict'. A second option for two-stage models is to relate species to the environment first and then identify biological groups ('Predict first, then group').

In order to assess the applicability of a two-stage analytical approach to evaluating bioregions in the SIOFA Area, we applied the spatial generalized linear model (SGLM) to model the probability of the presence of selected organisms using the R package glmmfields (Anderson and Ward, 2019). We assumed a Matern spatial correlation structure, half-t distributions for the priors of parameters, and a run of 5,000 iterations, which are the standard settings for fitting these models. Given that the organisms in this two-stage approach are selected beforehand, this model is categorized as 'group first, then predict'.

5.2.1 Target groups

We used the catch and effort data (Fig. 20) from SIFOA to create maps of sensitive organisms using spatial generalized linear models.

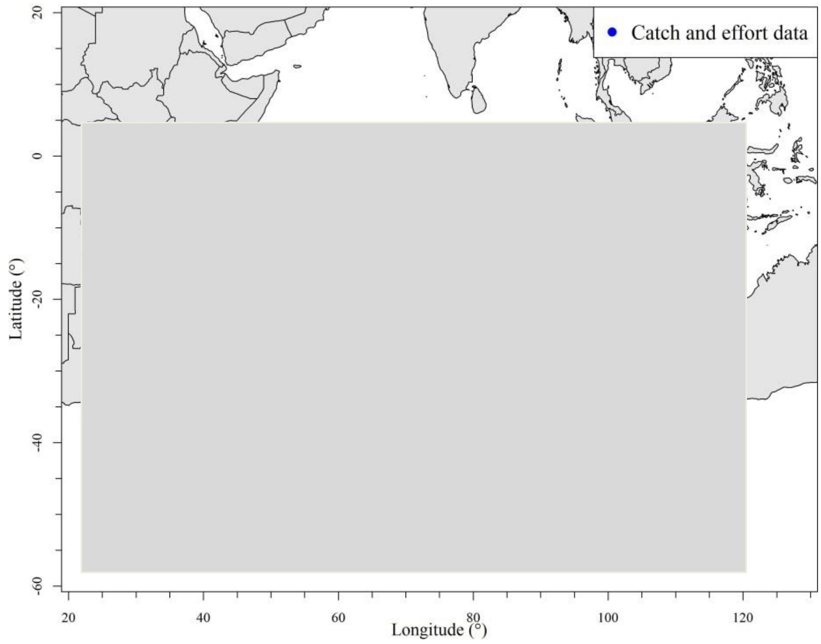


Figure 20: Distribution map of points where catch and effort data are available (blue solid circles).

The groups of organisms included in this analysis was defined as the set of species which:

1. were listed by IUCN Red List such as near threatened (NT, 9 species), vulnerable (VU, 14 species), endangered (EN, 9 species), and critically endangered (CR, 7 species);
2. sharks, rays, and chimaeras that are important in maintaining the health of marine ecosystem (Chapman et al. 2006, Field et al. 2006, MacKeracher et al. 2020) ;
3. groupers and emperors that are of high commercial importance for catch and effort data, and habitat forming organisms for observer data (Lin et al. 2022)

5.2.2 Results

Spatial generalized linear models were successfully fit using the catch and effort data on the presence of pre-defined groups of protected organisms, i.e., organisms listed in the IUCN Red List, other sharks and rays, and commercially important groupers and emperors (Table 1 in Appendix 1). Figs. 21 and 22 demonstrated the estimated probability of presence for those protected species. There are two hotspots of high probabilities of presence locating in the area between South Africa offshore and South of Madagascar (Fig. 21). The hotspot overlaps with one existing SIOFA protected area, Walter's shoal (Fig. 22).

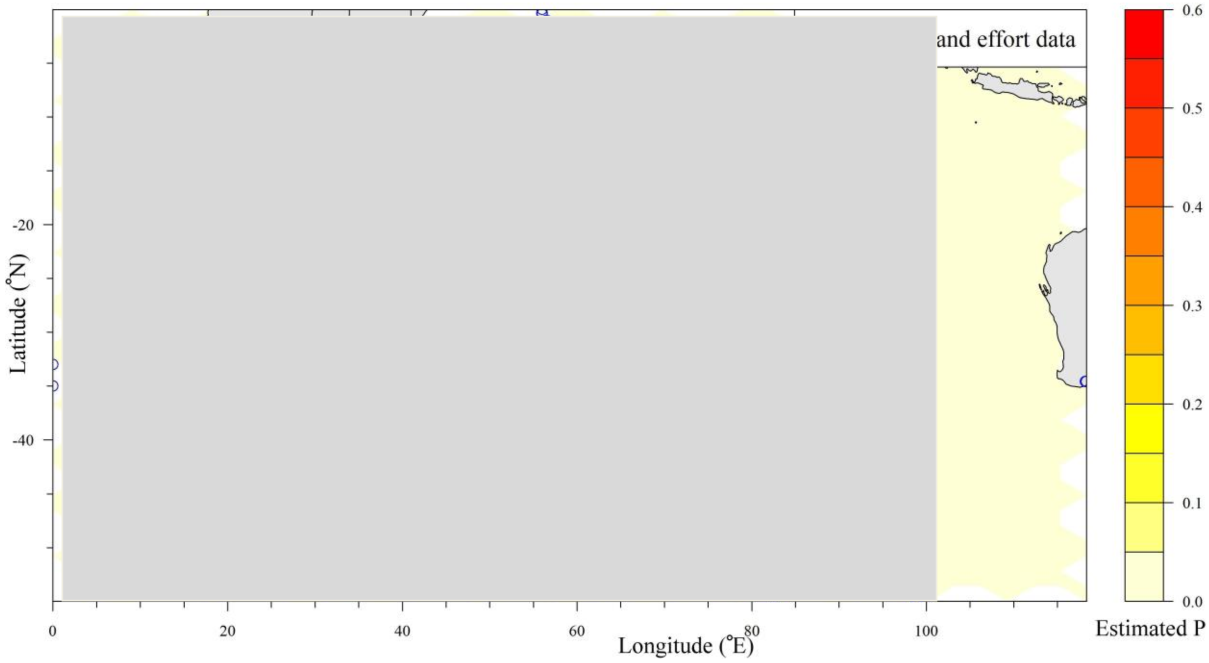


Figure 21: Estimated probabilities of presence (P) of protected organisms with catch and effort data (open blue circles).

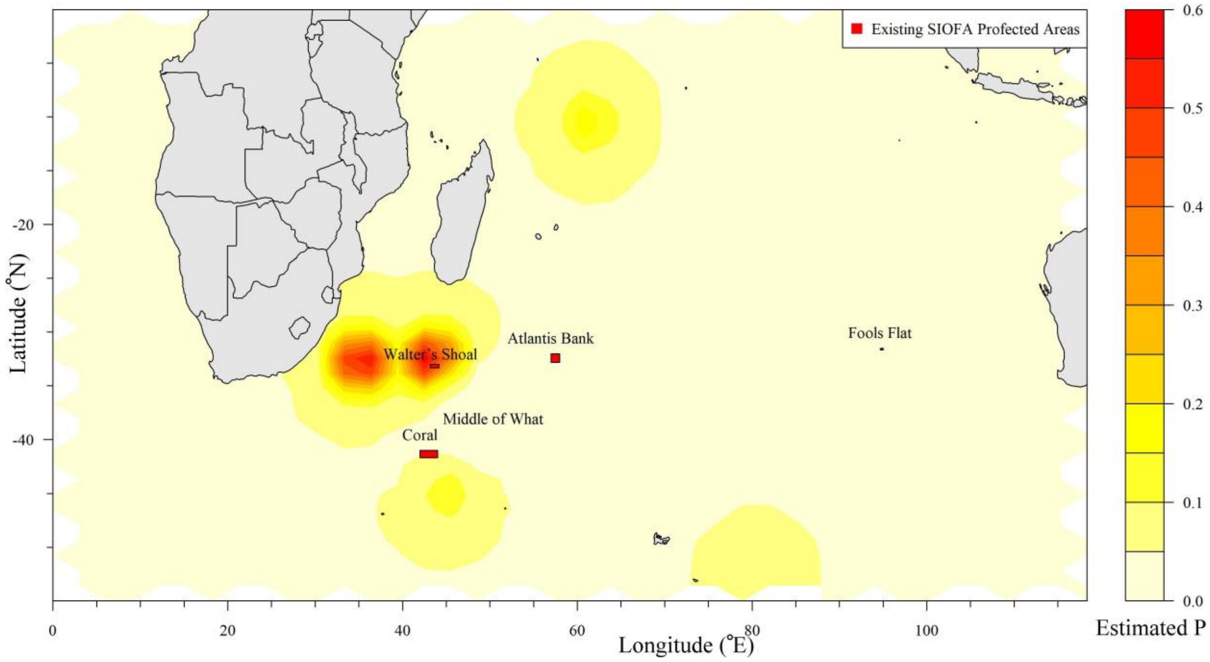


Figure 22: Estimated probabilities of presence (P) of protected organisms with existing SIOFA protected areas (red rectangles).

5.3 Discussion

We illustrate the application of SAM to benthic data provided by SIOFA. SAM offers a potentially powerful tool for evaluating bioregions by considering species and their responses to the environment in an integrated and single-stage modeling approach. The SAM presented here could be improved. For example, the general bioregion definition should consider the majority of the species in the ecosystem. However, the benthic data is a subset of the species and taxa available in SIOFA. Catch and effort data, along with benthic data, cannot be cross-referenced using the available fields in both databases, which precludes the use of all species available of each SIOFA quadrant. Another way to refine SAM is by incorporating new environmental covariates, such as sea surface temperature and chlorophyll-a, which are already available in satellite data. This could be particularly important given that the delineation of bioregions, especially in the open ocean, is challenging, and using physical or biological surrogates to infer the distribution of more complex assemblages has been discussed (Woolley et al. 2020).

In section 5.2 we demonstrate the implementation of a two-stage approach to defining bioregions. In this two-stage approach, a group of species was predefined as indicators of VME, and spatial predictions were subsequently made. This approach could be extended by correlating spatial predictions with environmental variables. The advantage of the two- stage approach lies in incorporating prior knowledge about species and how to group them in VME. However, in the two-stage approach, the grouping of species is decoupled from each other and often from the original data, necessitating additional post-hoc analyses to interpret the bioregions (Hill et al. 2020).

In contrast, one-stage approaches offer the advantage that information regarding the bioregion is recoverable directly via estimated model parameters, with variances that explicitly account for estimating bioregional groups (Foster et al. 2013). An important feature of the one-stage model is its ability to provide a formal definition of bioregions and their relationship with the environment. This explicitly ensures transparency and repeatability ((Hill et al. 2020) essential attributes for defining Marine Protected Areas (MPAs).

Preliminary results for both the one-stage and two-stage approaches show similar out- comes. Both approaches indicate that the south of the Madagascar region could be characterized as a bioregion by the SAM model or as an area with a high probability of finding a VME, as demonstrated in the two-stage approach in section 5.2. Therefore, these two approaches can complement each other, providing a comprehensive definition for proposing Marine Protected Areas in the SIOFA.

Options from the SAM methodology for evaluating the performance of protected areas in the SIOFA Area, as defined in CMM2020/01 Annex C, and the corresponding advice to the Scientific Committee on developing area specific data collection and evaluation plans for each existing protected area, are as follows:

1. Introduce cross-referencing columns (such as individual haul identifier) into the catch-effort and observers' databases, in order to use both databases in statistical analyses.
2. Introduce environmental variables available in commercial satellite data such as sea surface temperature and chlorophyll-a for more informative mappings of hotspots of biodiversity and the existing MPAs.
3. Introduce environmental variables that can be recorded from normal fishing operations of each fishing haul in the observers' database such as depth, water temperature and meteorological condition. These can be used to weight the quality of evidence of presence of protected and benthic species.

We do not anticipate any contingency precluding the implementation of these recommendations and their costs is minimal. These recommendations can be started to be implemented as soon as they are deemed acceptable by the Scientific Committee, although cross-referencing the catch-effort and observers' databases imply a large quantity of man-hours in order to include cross-referencing variables into the legacy databases, not just the updating from this date onwards.

6 Task 4. Acquisition of New Data

We found the databases informative and complete enough to conduct quantitative analyses leading to the definition of bioregions and from there to MPAs, and their evaluation and monitoring. This means that expanded efforts directed to gather additional information may not be necessary. What matters most in these databases is the addition of a few variables to cross-reference data in different databases and recording of simple environmental information connected to each haul, most importantly depth of fishing.

Data curating was a significant task during the revision of available data from observers. For instance, the duplication of data between HBH and OBS was detected, along with other issues such as hauls without spatial position or spatial data containing only the vertex of SIOFA quadrants. The latter posed a significant challenge for assigning the data to a unique SIOFA quadrant.

Additionally, as some of the data was aggregated in quadrants, it became impossible to cross-reference information with the Catch and Effort database, limiting the ability to add other attributes to the bycatch benthic database, such as other species in the catch of the target species. Remedial measures could consider adding haul identifiers to cross-reference the observers and catch-effort databases.

In addition to the above mentioned spatial issues, there are some hauls registered outside the SIOFA Area. Likewise, some of the 3-alpha taxonomic names in the database, as well as in the guidelines provided by the SIOFA Secretariat, are outdated in comparison to the guidelines in the World Register of Marine Species (Worms). The database also registers species such as the seabird *Macronectes giganteus* (3-alpha 'MAI'), which may introduce another source of error in further analysis and interpretation for designing Marine Protected Areas (MPA).

Some of the issues identified here have already been reported in the project SEC2021-05 (SIOFA 2023). These recommendations propose the merging of AggregatedCatchEffort, HBHCatch- Effort, and SIOFA Observer data into a single, unified database. We emphasize this recommendation, as well as including variables commonly used for identifying hauls, such as date and time of fishing, and a unique number for each haul.

We propose the following regarding curating and merging the SIOFA databases:

- Develop a computing platform for the automatic upload and preliminary validation of observer information.

- Ensure that the three available databases (AggregatedCatchEffort, HBHCatchEffort, and SIOFA Observers) share common fields, such as date and time of fishing or haul numbers, facilitating cross-referencing of information among databases.

- Continuously review and update the taxon name and 3-letter taxonomic code in the database and the Vulnerable Marine Ecosystem Taxon Identification Guide, as some names are not accepted by WoRMS or the code is not recognised in the FAO 3-letter taxonomic code (see Table 5).

- Conduct continuous training for scientific observers to enhance the identification of individuals at the lowest taxonomic classification possible for all recorded catches, enabling more refined community analyses.

- Depth of fishing was not included in the available data. This is an important characteristic for correlating this data with other environmental factors.

- Fine measures of fishing effort were not included in the available. For example, in longlines, this could include the number of hooks and soaking time. In trawlers, it could involve trawling time or an approximation of the trawled area. This information can be used to weigh the occurrence data.
- Re-assure all SIOFA parties of the confidentiality of all data provided to contracted analysts, in order to provide point spatial data for all records in the catch-effort database.

The last recommendation is made to avoid having a large proportion of the haul-by-haul data aggregated to 1 geographical degree blocks (35.4% of all records of the catch-effort database provided to us). This is not an issue with the data available to SIOFA, as they are all recorded with point resolution, but it is a very important issue for contracted analysts. Building confidence in all SIOFA parties regarding confidentiality clauses of the contracts with analysts will go a long way in solving this obstacle to more refined and spatially explicit mapping for MPA designation and monitoring.

7 Task 5. Protocols for designation and evaluation of protected areas

7.1 IUCN protocol

The IUCN protocol (Dudley 2008) defines a marine protected area and categorizes marine protected areas through six management types and four governance types. IUCN defines a marine protected area as a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. This definition is expanded by six management categories (one with a sub-division), whose names, short descriptions, and primary objectives are summarized in Table 7. Four government types are summarized in Table 8.

Table 7. Summary of six management categories of MPA suggested by IUCN

Category	Name	Description	Primary objective
Ia	Strict nature reserve	Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use, and impacts are controlled and limited to ensure the protection of the conservation values.	To conserve regionally, nationally, or globally outstanding ecosystems, species (occurrences or aggregations), and/or geodiversity features: these attributes will have been formed mostly or entirely by non-human forces and will be degraded or destroyed when subjected to all but very light human impact.
Ib	Wilderness area	Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition.	To protect the long-term ecological integrity of natural areas that are undisturbed by significant human activity, free of modern infrastructure and where natural forces and processes predominate, so that current and future generations have the opportunity to experience such areas.
II	National park	Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.	To protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation
III	Natural monument or feature	Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove.	To protect specific outstanding natural features and their associated biodiversity and habitats.

IV	Habitat/ species management area	Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category.	To maintain, conserve and re- store species and habitats.
V	Protected landscape or seascape	Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.	To protect and sustain important landscapes/seascapes and the associated nature conservation and other values created by interactions with hu- mans through traditional management practices.
VI	Protected areas with sustainable use of natural resources	Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims.	To protect natural ecosystems and use natural resources sustainably, when conservation and sustainable use can be mutually beneficial.

Table 8. Four governance types

Governance type	Description
Shared governance	Collaborative management (various degrees of influence); joint management (pluralist management board; transboundary management (various levels across inter- national borders).
Private governance	By individual owner; by non-profit organizations (NGOs, universities, cooperatives); by for-profit originations (individuals or corporate).
Governance by indigenous peoples and local communities	Indigenous peoples' conserved areas and territories; community conserved areas - declared and run by local communities.

IUCN suggests to consider only those sites where the main goal or outcome is conserving nature. When facing conflicts from other aspects, such as cultural or spiritual goals, nature conservation has to be the priority. Removal, modification, extraction, or collection of resources, particularly those on the industrial scale, are either completely prohibited or strongly regulated under certain circumstances (e.g., sustainable resource use by indigenous people to conserve their traditional, spiritual, and cultural values, and small-scale local fishing and aquaculture practices, and non-extractive recreational activities and nature tourism).

IUCN recommends that an MPA should seek to meet the following standards:

1. Conservation focuses on nature as the priority.
2. Defined goals and objectives which reflect these values
3. Suitable size, location, and design that will enable the conservation of values
4. Defined and agreed upon boundary
5. Management plan or equivalent, which addresses the need for conservation of the site's major values and achievement of its social and economic goals and objectives.
6. Resources and capacity to implement.

The key difference between MPAs and other area-based measures, such as fishery management areas, is that, whatever form the MPAs take, the primary focus is the conservation of biodiversity. Area-based measures where the primary goals are something else, such as sustainable fishing, do not qualify as an MPA. If fishing or other extractive activities are compatible with an MPA's objective(s) and are permitted within the MPA, they must have a low ecological impact, be sustainable, be well managed as part of an integrated approach to management, and fit within the definition and category of an IUCN protected area. Any industrial activities and infrastructural developments (e.g. mining, industrial fishing, oil and gas extraction) are not compatible with MPAs and should be excluded from such areas if they are to be considered as MPAs (Day et al. 2019).

7.2 OSPAR

OSPAR, named after Oslo and Paris Conventions (OS for Oslo and PAR for Paris), is the mechanism by which 15 Governments and the EU cooperate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources of marine pollution and the offshore industry by the Paris Convention of 1974. These two conventions were unified to become a commission, updated and extended by the 1992 OSPAR Convention.

The objective of the Commission is to take the necessary measures to protect and conserve the ecosystems and the biological diversity of the maritime area which are or could be, affected as a result of human activities, and to restore, where practicable, marine areas which have been adversely affected. The Commission promotes the establishment of a network of marine protected areas to ensure the sustainable use, protection, and conservation of marine biological diversity and ecosystems.

The aims of the OSPAR MPA Network include:

1. To protect, conserve and restore species, habitats, and ecological processes which are adversely affected as a result of human activities.
2. To prevent degradation of and damage to species, habitats and ecological processes, following the precautionary principle.
3. To protect and conserve areas that best represent the range of species, habitats and ecological processes in the OSPAR maritime area.

One of the characteristics of the OSPAR protocol (OSPAR 2003) is the emphasis on the linkages between marine ecosystems and the dependence of some species and habitats on processes that occur outside the MPA concerned. These relationships are often more complex, and occur on a larger scale, than those of terrestrial ecosystems. To take these linkages into account, OSPAR suggest to form an ecologically coherent network of well-managed MPAs. This is particularly important for highly mobile species, such as certain birds, mammals and fish, to safeguard the critical stages and areas of their life cycle (such as breeding, nursery and feeding areas).

OSPAR MPA protocol (OSPAR 2003) suggests a two-stage process of identification and selection of MPAs:

Stage 1. Identification of possible sites. For this stage, the ecological criteria/considerations listed below should be applied:

1. Threatened or declining species and habitats/biotopes.
2. Important species and habitats/biotopes.
3. Ecological significance.
4. High natural biological diversity.
5. Being representative.
6. Sensitivity.
7. Naturalness.

In some cases, this stage will identify several possible sites, for example, to protect a certain species, and it may not be possible to establish them all as MPAs. On the other hand, it may be necessary to select priority sites from several possible sites that each meet one or several, but not the same, ecological criteria. For these reasons, sites that meet the ecological criteria or considerations need to be further prioritized at Stage 2.

Stage 2: Prioritization of sites for designation. In this second stage of the process, the ecological criteria/considerations listed in Stage 1 should be reapplied to help prioritize the identified sites. For example, an area that holds a higher population of the species concerned, or that meets additional ecological criteria, may warrant a higher priority. In addition, at this stage, the following practical criteria/considerations below should be considered in developing a prioritized list of sites: (1) size, (2) potential for restoration, (3) degree of acceptance, (4) potential for the success of management measures, (5) potential damage to the area by human activities, and (6) scientific value.

For instance, an area with a comparatively higher level of support from stakeholders and political acceptability will be more suitable to be established as an MPA. Table (9) summarizes the OSPAR guidance on which criteria should be used to select areas as components of the MPA Network in relation to the identified aims given above. Information to support the selection of an MPA within the national jurisdiction of the signed members should be compiled on the proforma and submitted to the OSPAR Commission. Any proposals for action by the OSPAR Commission in respect of areas outside national jurisdiction should be submitted in the same way (OSPAR 2003) (Table 9).

Table 9. Summary of the correlation between the ecological and practical criteria/considerations and the aims of the OSPAR MPA Network

Aims	Protect, conserve and restore species, habitats and ecological processes which are adversely affected as a result of human activities	Prevent degradation of and damage to species, habitats and ecological processes following the precautionary principle	Protect and conserve areas which best represent the range of species, habitats and ecological processes in the maritime area
Ecological considera-tions	High priority habitats and species which meet the Texel-Faial criteria of decline.	1. High priority habitats and species which meet the Texel-Faial criteria of high probability of a significant decline. 2. Important habitats and species which meet the other Faial criteria (global importance, local (species)/regional (habitats) importance, rarity, sensitivity, key-stone species, ecological significance). 6.Sensitivity.	3. Ecological significance. 4. High natural biological diversity (of species within a habitat and of habitats in an area). 5. Representativity, including the biogeographic regions. 7. Naturalness.

Practical Considerations	1. Size. 2. Potential for restoration. 3. Degree of acceptance. 4. Potential for success of management measures. 6.Scientific value.	1. Size. 3. Degree of acceptance. 4. Potential for success of management measures. 5. Potential damage to the area by human activities. 6. Scientific value. 7. Naturalness.	1. Size. 4. Degree of acceptance. 5. Potential for success of management measures. 6. Scientific value.

7.3 USA protocol

The MPA Center, NOAA, uses the definition of a marine protected area from MPA Executive Order 13158: ...any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein. To ensure that MPA reporting is aligned with international definitions, the US also refers to the IUCN definition of the marine protected area mentioned earlier.

In line with these global targets, the U.S. has indicated a strong interest in employing existing and new MPAs to conserve vital marine habitats and resources and help sustain a healthy ocean and provide social and ecological benefits, including climate change resilience (Sullivan-Stack et al. 2022). A target of conserving at least 30% of U.S. waters was proclaimed at the Federal level in January 2021 (Conserving and Restoring America the Beautiful, 2021; Executive Order 14008) (U.S. Department of the Interior 2021), accompanied by similar targets and support among various Tribal leaders (Allen et al. 2021) and states (e.g., California Executive Order N-82-20; the Hawaii Governor's Sustainable Hawaii Initiative). Over the past several decades, a variety of legal authorities and programs have been established at all levels of government resulting in a dramatic increase in the number of MPAs. Nearly 1,000 such federal and state/territorial sites exist today, covering 26% of U.S. marine waters (U.S. Department of the Interior 2020),.

In the U.S., MPAs span a range of habitats including the open ocean, coastal areas, inter- tidal zones, estuaries, and the Great Lakes with various purposes, legal authorities, agencies, management approaches, levels of protection, and restrictions on human uses. Some areas that are not MPAs can make important contributions to conservation outcomes, particularly when managed in coordination with a broader MPA network. The primary intent of different area types varies widely, for example, to ensure human health and safety (e.g., a Military Closed Area) or to preserve cultural resources (e.g., a closure around a historic shipwreck, Sullivan-Stack et al. 2022).

Table 10. Types of area-based management in U.S. waters

Type	Examples	Primary Conservation Intent
MPA	Marine Reserves, Marine National Monuments, National Marine Sanctuaries, National Parks, National Wildlife Refuges, National Estuarine Research Reserves, similar state-managed areas	Conservation of nature with associated ecosystem services and cultural values.
Fishery Management Areas	Essential Fish Habitat, Habitat Areas of Particular Concern, Deep Sea Coral Protections	Sustainable production.
De Facto MPAs	Military Closed Areas, Vessel Traffic Areas	Health and human safety.
Others	Shipwrecks, war graves, permanent fishery closures	Various.

The MPA center applies the following five key functional characteristics to describe any MPA: 1. Conservation focus; 2. Level of protection. 3. Permanence of protection. 4. Constancy of protection. 5. Scale of protection (U.S. Department of the Interior 2020):

1. Conservation focus.

Effective MPAs should have legally established goals and conservation objectives. Common examples include MPAs created to conserve biodiversity in support of research and education and to protect and interpret shipwrecks for maritime education. These descriptors of an MPA are reflected in the site's Conservation Focus, which represents the characteristics of the area that the MPA was established to conserve. The Conservation Focus, in turn, influences many funda- mental aspects of the site, including its design, location, size, scale, management strategies, and potential contribution to surrounding ecosystems. U.S. MPAs generally address one or more of these areas of Conservation Focus: Natural Heritage and Cultural Heritage.

Natural Heritage:

MPAs or zones established and managed wholly or in part to sustain, conserve, restore, and understand the protected area's natural biodiversity, populations, communities, habitats, and ecosystems; the ecological and physical processes upon which they depend; and, the ecological services, human uses and values they provide to this and future generations. Examples: Natural Heritage MPAs include most national marine sanctuaries, national parks, national wildlife refuges, and many state MPAs.

Cultural Heritage:

MPAs or zones established and managed wholly or in part to protect and understand the legacy of physical evidence and intangible attributes of a group or society which is inherited and maintained in the present and bestowed for the benefit of future generations. Examples: Cultural Heritage MPAs include some national marine sanctuaries, national and state parks, and national historic monuments.

2. Level of protection.

MPAs in the US can be characterized by one of the following six levels of protection, which will directly influence its effects on the environment and human uses:

Uniform Multiple-Use:

MPAs or zones with a consistent level of protection, allowable activities or restrictions throughout the protected area. Extractive uses may be restricted for natural or cultural resources. Examples: Uniform multiple-use MPAs are among the most common types in the U.S., and include many sanctuaries, national and state parks, and cultural resource MPAs.

Zoned Multiple-Use:

MPAs that allow some extractive activities throughout the entire site, but that use marine zoning to allocate specific uses to compatible places or times in order to reduce user conflicts and adverse impacts. Examples: Zoned multiple-use MPAs are increasingly common in US waters including some marine sanctuaries (such as Monterey Bay), national parks, national wildlife refuges, and state MPAs.

Zoned Multiple-Use with No-Take Area(s):

Multiple-use MPAs that contain at least one legally established management zone in which all resource extraction is prohibited. Examples: Zoned no-take MPAs are emerging gradually in US waters, primarily in some national marine sanctuaries (such as Florida Keys) and national parks (such as Dry Tortugas).

No-Take:

MPAs or zones that allow human access and even some potentially harmful uses, but that prohibit the extraction or significant destruction of natural and cultural resources. This includes Papahanaumokuakea Marine National Monument, which allows very limited subsistence fishing activities by Native Hawaiians by permit. Examples: No-take MPAs are relatively rare in the US, occurring mainly in state MPAs, in some federal areas closed for the protection of endangered species, or as small special use (research) zones within larger multiple-use MPAs. Also called marine reserves or ecological reserves.

No Impact:

MPAs or zones that allow human access, but that prohibit all activities that could harm the site's resources or disrupt the ecological and cultural services they provide. Examples of activities typically prohibited in no-impact MPAs include resource extraction of any kind (fishing, collecting, or mining); discharge of pollutants; disposal or installation of materials; and alteration or disturbance of submerged cultural resources, biological assemblages, ecological interactions, physiochemical environmental features, protected habitats, or the natural processes that support them. Examples: No- impact MPAs are rare in U.S. waters, occurring mainly as small isolated MPAs or in small research-only zones within larger multiple-use MPAs. Other commonly used terms include fully protected marine (or ecological) reserves.

No Access:

MPAs or zones that restrict all human access in order to prevent potential ecological disturbance, unless specifically permitted for designated special uses such as research, monitoring or restoration. Examples: No-access MPAs are extremely rare in the US, occurring mainly as small research-only zones within larger multiple-use MPAs. Other commonly used terms for no access MPAs include wilderness areas or marine preserves.

3. Permanence of Protection.

Not all MPAs are permanently protected. Many sites differ in how long their protections remain in effect, which may in turn profoundly affect their ultimate effects on ecosystems and users:

Permanent:

MPAs or zones whose legal authorities provide some level of protection to the site in perpetuity for future generations, unless reversed by unanticipated future legislation or regulatory actions. Examples: Permanent MPAs include most national marine sanctuaries and all national parks.

Conditional:

MPAs or zones that have the potential, and often the expectation, to persist administratively over time, but whose legal authority has a finite duration and must be actively renewed or ratified based on periodic governmental reviews of performance.

4. Constancy of Protection.

Not all MPAs provide year-round protection to the protected habitat and resources:

Year-Round:

MPAs or zones that provide constant protection to the site throughout the year. Examples: Year-round MPAs include all marine sanctuaries, national parks, refuges, and monuments.

Seasonal:

MPAs or zones that protect specific habitats and resources, but only during fixed seasons or periods when human uses may disrupt ecologically sensitive seasonal processes such as spawning, breeding, or feeding aggregations. Examples: Seasonal MPAs include some endangered species closures around sensitive habitats.

5. Scale of Protection.

MPAs in the US vary widely in the ecological scale of the protection they provide. MPA conservation targets range from entire ecosystems and their associated biophysical processes, to focal habitats, species, or other resources deemed to be of economic or ecological importance. The ecological scale of a site's conservation target generally reflects its underlying legal authorities and, in turn, strongly influences the area' design, siting, management approach, and likely effects:

Ecosystem:

MPAs or zones whose legal authorities and management measures are intended to protect all of the components and processes of the ecosystem within its boundaries. Examples: Ecosystem-scale MPAs include most marine sanctuaries, national parks and national monuments. MPAs or zones that provide constant protection to the site throughout the year. Examples: Year-round MPAs include all marine sanctuaries, national parks, refuges, and monuments.

Focal Resource:

MPAs or zones whose legal authorities and management measures specifically target a particular habitat, species complex, or single resource (either natural or cultural). Examples: Focal-resource MPAs include many cultural resource sites, including some national marine sanctuaries.

7.4 Australia Protocol

Australia is committed to the protection of marine biodiversity and ecological integrity, and the sustainable use of marine resources, through the goals and principles of ecological sustainable development. This commitment has been ratified through Australia's international responsibilities and obligations under the Convention on Biological Diversity and addressed at a national level by the States and Territories under the Intergovernmental Agreement on the Environment. It is implemented through the actions of national strategies such as the National Strategy for Ecologically Sustainable Development and the National Strategy for the Conservation of Australia's Biological Diversity. The establishment of the National Representative System of Marine Protected Areas (NRSMPA) also supports the program of the World Conservation Union (IUCN) World Commission on Protected Areas to promote the establishment of a global representative system of marine protected areas. Australia's Oceans Policy further emphasizes the need to employ an integrated approach to marine management employing a range of mechanisms for the best protection of Australia's marine environment (U.S. Department of the Interior 2020).

Australia and New Zealand Environment and Conservation Council (ANZECC) has adopted the IUCN definition of a protected area to apply to MPAs as follows: An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and natural and associated cultural resources, and managed through legal or other effective means. This definition has been recently endorsed by the Commonwealth Government, ANZECC and the Ministerial Council on Forestry, Fisheries and Aquaculture for use in a variety of protected area contexts. It is also the definition used for a protected area in the Interim Scientific Guidelines for Establishing the National Reserve System.

The following secondary goals are designed to be compatible with the primary goal:

- To promote the development of MPAs within the framework of integrated ecosystem management.
- To provide a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use or extraction of resources, the impacts of which are compatible with the primary goal.

- To provide scientific reference sites.
- To provide for the special needs of rare, threatened or depleted species and threatened ecological communities.
- To provide for the conservation of special groups of organisms, e.g., species with complex habitat requirements or mobile or migratory species, or species vulnerable to disturbance which may depend on reservation for their conservation.
- To protect areas of high conservation value including those containing high species diversity, natural refugia for flora and fauna and centers of endemism.
- To provide for the recreational, aesthetic and cultural needs of indigenous and non-indigenous people.

Key characteristics define the MPAs from other managed marine areas. They are that the MPA:

- has been established especially for the conservation of biodiversity (consistent with the primary goal);
- is able to be classified into one or more of the six IUCN Protected Area Management Categories (see *IUCN protocol*) reflecting the values and objectives of the MPA;.
- must have a secure status that can only be revoked by a Parliamentary process; and
- contributes to the representativeness, comprehensiveness or adequacy of the national system.

The development of MPAs is based on the following principles:

Regional framework:

The Interim Marine and Coastal Regionalization for Australia provides the national and regional planning framework for developing the MPA, with ecosystems used as the basis for determining representativeness.

Comprehensiveness:

The MPA will include the full range of ecosystems recognized at an appropriate scale within and across each bioregion.

Adequacy:

The MPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

Representativeness:

Those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive.

Highly protected areas: The MPA will aim to include some highly protected areas (IUCN Categories I and II) in each bioregion.

Precautionary principle:

The absence of scientific certainty should not be a reason for postponing measures to establish MPAs to protect representative ecosystems. If an activity is assessed as having a low risk of causing serious or irreversible adverse impacts, or if there is insufficient information with which to assess fully and with certainty the magnitude and nature of impacts, decision-making should proceed in a conservative and cautious manner.

Consultation:

The processes of identification and selection of MPAs will include effective and high-quality public consultation with appropriate community and interest groups, to address current and future social, economic and cultural issues.

Indigenous involvement:

The interests of Australia's indigenous people should be recognized and incorporated in decision-making.

Decision making:

Decision-making processes should effectively integrate both long-term and short-term environmental, economic, social and equity considerations.

The process for the establishment of the individual MPAs which comprise the MPA is summarized in Table (11). Some of these steps may be carried out concurrently. Appropriate consultation with stakeholders should be carried out at various stages of the process. Broadly, an initial process of identification of candidate areas is carried out which is then followed by the selection of MPA sites from these candidate areas.

Table 11. Steps in designing an MPA in Australia

Step 1	Gather baseline data, including ecosystem mapping.
Step 2	Identify a list of candidate areas within The Interim Marine and Coastal Regionalization for Australia (IMCRA) regions to represent major ecosystems, using identification criteria in Table 11.
Step 3	Identify threatening processes..
Step 4	Identify gaps in the representation of ecosystems in existing MPAs within each IMCRA region.
Step 5	Develop national and regional priorities.
Step 6	Develop additional criteria for identification and selection of MPAs if required.
Step 7	Select sites for MPAs from the candidate areas, using selection criteria and any other additional criteria developed in Step 6.
Step 8	Assess the feasibility of potential MPAs and negotiate new protected areas.
Step 9	Establish MPAs and initiate management, including evaluation and review.

For the National Representative System of Marine Protected Areas, biodiversity and environmental criteria are the primary criteria for the identification of candidate areas. Sound biodiversity and other baseline data are essential to ensure that decision-making is underpinned by good science. Social, cultural and/or economic criteria are applied primarily in the selection of MPA sites from the candidate areas.

In practice, jurisdictions may apply some of the selection criteria at an earlier stage in the identification phase, e.g., socio-economic considerations. Environmental criteria and social, cultural and economic criteria should be considered as layers in the decision-making process, with criteria from each list able to be used at any stage in the processes of identification and selection as appropriate.

Table 12. Criteria for identification of MPAs in Australia

Identification criteria	Description
Representativeness	Will the area • represent one or more ecosystems within an IMCRA bioregion, and to what degree? • add to the representativeness of the existing MPAs, and to what degree?
Comprehensiveness	Does the area • add to the coverage of the full range of ecosystems recognized at an appropriate scale within and across each bioregion? • add to the comprehensiveness of the existing MPAs?
Ecological importance	Does the area • contribute to the maintenance of essential ecological processes or life-support systems; • contain habitat for rare or endangered species? • preserve genetic diversity, i.e., is diverse or abundant in species? • add to the comprehensiveness of the existing MPAs?
International or national Importance	Is the area rated, or have the potential to be listed, on the world or a national heritage list or declared as a Biosphere Reserve or subject to an international or national conservation agreement?
Uniqueness	Does the area: • contain unique species, populations, communities or ecosystems?; • contain unique or unusual geographic features?.
Productivity	Do the species, populations, or communities of the area have a high natural biological productivity ?
Vulnerability assessment	Are the ecosystems and/or communities vulnerable to natural processes?
Biogeographic importance	Does the area capture important biogeographic qualities?
Naturalness	How much has the area been protected from, or not been subjected to, human induced change?

Vulnerability assessment is part of both the identification and selection processes. In the identification phase, vulnerability can be related to natural processes. In the selection phase, vulnerability to human actions and threatening processes should be used to prioritize the selection of sites for MPAs.

Table 13. Criteria for selection of MPAs in Australia.

Selection criteria	Description
Economic interests	Does the site • make an existing or potential contribution to economic value by virtue of its protection, e.g., for recreation or tourism, or as a refuge or nursery area, or source of supply for economically important species?; • have importance for shipping and/or trade?; • have usage by traditional users including commercial fishers?; • have value due to its contribution to local or regional employment and economic development?
Scientific interests	Does the area Does the site have existing or potential value for research or monitoring?
Social interests	Does the site have existing or potential value to the local, national or international communities because of its heritage, cultural, traditional aesthetic, educational, recreational or economic values?
Practicality/feasibility	Does the site: • Is have a degree of insulation from external destructive influences?; • have social and political acceptability, and a degree of community support?; • have access for recreation, tourism, education?; • have compatibility between an MPA declaration generally and existing uses?; • have relative ease of management, and compatibility with existing management regimes?
Vulnerability assessment	Is the site vulnerable and susceptible to human induced changes and threatening processes?.
Replication	Will the site provide replication of ecosystems within the bioregion ?

The selection and declaration processes are carried out by State, Territory and Commonwealth agencies for their jurisdictions. Some cross-jurisdiction consultation will be required where proposed MPAs cross-jurisdiction boundaries.

Flexibility of application of the criteria will be required due to the variety of legislative and management frameworks within the States, Northern Territory and the Commonwealth, and the individual circumstances relating to specific sites. A potential MPA site may meet one or many of the listed criteria. Depending on the objectives of the site, one or more criteria may be considered to have greater weight in the consideration process (ANZECC

1998).

7.5 Advice

We suggest the IUCN protocol for SIOFA because (1) it offers various management categories with different degrees of protection which permits flexibility and gradual implementation; (2) current SIOFA management practices fit directly into the IUCN protocols, such as the identification of VME areas can fit into the category IV: habitat/species management area, and the requirement of monitoring fishing activities into the category VI: protected areas with sustainable use of natural resources). This means there are already foundations in SIOFA to apply the IUCN protocol; (3) it is more straightforward to apply IUCN protocol than the others.

Both USA and Australia protocol refer to the IUCN protocol for compatibility, indicating a similarity in these three protocols. Social and culture aspects included in the USA and Australia protocol seem not of high priority for SIOFA because SIOFA Convention Area are all in the Common Sea. Fisheries are important activities in SIOFA Convention Area and therefore, it is essential to consider the balance between human exploitation and conservation when developing MPA plans, which was not directly considered in the EU protocol.

8 Conclusions

1. The most recent and commonly used definition of MPA internationally is that provided by the International Union for Conservation of Nature (IUCN): a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.
2. The area of the Southern Indian Ocean Fisheries Agreement (SIOFA) covers the open ocean/high seas between eastern Africa and Western Australia and therefore, the methods for designating, monitoring, and evaluating the MPAs in the open ocean/high seas are directly relevant to this project.
3. The SIOFA advice to monitor protected areas can be summarized by the following practices: (1) Vessel Monitoring System (VMS) to track the location of the fishing vessel, (2) log-book systems to record the presence of targeted organisms in the monitoring program, and (3) on-board observer programs to record targeted organisms in the monitoring program from the fisheries catch and collect other required information.
4. Scientific papers related to MPAs have increased steadily in numbers, currently

producing about 500 studies each year. The term "design" is the keyword with the highest appearance in the scientific studies related to MPA, followed by the term "monitor" and "success".

5. SIOFA databases appear sufficient to conduct quantitative spatial analysis leading to the spatial definition, evaluation and monitoring of MPAs thereof, although the currently existing databases need inclusion of a few additional variables and improvements in data quality and completeness.

6. Bioregions are the fundamental concept underpinning the definitions of marine protected areas and there are recent methodological advances to define bioregions.

7. Species Archetype Model for block data in the Observer database and Spatial Generalized Linear Models for point data are two recent statistical methods for the evaluation and monitoring of MPAs. Both these methods were applied yielding new insights into benthic and demersal species assemblages.

8. Two hot-spots of organisms of special interest were mapped south of Madagascar.

9. The IUCN protocol for designation of MPAs is referenced as a standard in some countries with advanced marine management and it offers flexibility for gradual implementation.

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10 Appendix

Appendix 1. Table 1. Summary of the catch and effort data, including the 3-alphabet code, scientific name, English name, type of the organisms, listed in the IUCN Red List, remarks, and their frequencies being observed.

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
CYO	Centroscymnus.coelolepis	Portuguese.dogfish	Shark	Yes	NT		2129
SCK	Dalatias.licha	Kitefin.shark	Shark	Yes	VU		1985
EEP	Epinephelus.morrhua	Comet.grouper	Teleost	Yes		Grouper	1954
DCA	Deania.calceus	Birdbeak.dogfish	Shark	Yes	NT		1389
TRK	Triakidae	Houndsharks.smoothhounds.nei	Shark	Yes			1243
GUP	Centrophorus.granulosus	Gulper.shark	Shark	Yes	EN		1086
SUN	Squatina.tergocellatoides	Ocellated.angelshark	Shark	Yes	EN		1014
ETM	Etmopterus.granulosus	Southern.lanternshark(Lucifer)	Shark	Yes			837
CWZ	Carcharhinus.spp	Carcharhinus.sharks.nei	Shark	Yes			811
GUQ	Centrophorus.squamosus	Leafscale.gulper.shark	Shark	Yes	EN		737
RFA	Amblyraja.taaf	Whiteleg.skate	Ray	Yes			623
SHL	Etmopterus.spp	Lanternsharks.nei	Shark	Yes			576
EWU	Epinephelus.multinotatus	White.blotched.grouper	Teleost	Yes		Grouper	466
CVX	Carcharhiniformes	Ground.sharks	Shark	Yes			408
GPX	Epinephelus.spp	Groupers.nei	Teleost	Yes		Grouper	382
EFT	Cephalopholis.sonnerati	Tomato.hind	Teleost	Yes		Grouper	271

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
SPN	Sphyrna.spp	Hammerhead.sharks.nei	Shark	Yes	VU		210
SDV	Mustelus.spp	Smooth_hounds.nei	Shark	Yes			201
GTF	Rhinobatidae	Guitarfishes.nei	Shark	Yes			133
STT	Dasyatidae	Stingrays.butterfly.rays.nei	Ray	Yes			124
RJG	Amblyraja.hyperborea	Arctic.skate	Ray	Yes			110
BHY	Bathyraja.spp	Bathyraja.rays.nei	Ray	Yes			105
CAR	Chondrichthyes	Cartilaginous.fishes.nei	Shark	Yes			102
DGX	Squalidae	Dogfish.sharks.nei	Shark	Yes			97
EEA	Epinephelus.fasciatus	Blacktip.grouper	Teleost	Yes		Grouper	93
SRX	Rajiformes	Rays.stingrays.mantas.nei	Ray	Yes			91
CMO	Chimaera.monstrosa	Rabbit.fish	Chimaera	Yes	VU		89
RAJ	Rajidae	Rays.and.skates.nei	Ray	Yes			67
SKH	Selachimorpha.Pleurotremata	Various.sharks.nei	Shark	Yes			60
DGZ	Squalus.spp	Dogfishes.nei	Shark	Yes			55
BYR	Bathyraja.irrasa	Kerguelen.sandpaper.skate	Ray	Yes	VU		50
HOL	Chimaeriformes	Chimaeras.nei	Chimaera	Yes			49
NTC	Notorynchus.cepedianus	Broadnose.sevengill.shark	Shark	Yes	VU		40

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
ALS	Carcharhinus.albimarginatus	Silvertip.shark	Shark	Yes	VU		34
EIF	Epinephelus.septemfasciatus	Convict.grouper	Teleost	Yes		Grouper	29
SOR	Somniosus.rostratus	Little.sleeper.shark	Shark	Yes			27
ASK	Squatinidae	Angelsharks.sand.devils.nei	Shark	Yes			24
RRY	Rhina.ancylostomus	Bowmouth.guitarfish	Shark	Yes	CR		24
DOP	Squalus.megalops	Shortnose.spurdog	Shark	Yes			18
SKA	Raja.spp	Raja.rays.nei	Ray	Yes			17
TIG	Galeocerdo.cuvier	Tiger.shark	Shark	Yes	NT		14
BZN	Bryozoa	Bryozoans	Bryozoan	Yes		Habitat	14
SKX	Elasmobranchii	Sharks.rays.skates.nei	Shark	Yes			13
ETF	Etmopterus.lucifer	Blackbelly.lanternshark	Shark	Yes			12
CWD	Crinoidea	Feather.stars.and.sea.lilies	Echinderm	Yes		Habitat	10
PTM	Pseudotriakis.microdon	False.catshark	Shark	Yes			9
CLD	Loxodon.macrorhinus	Sliteye.shark	Shark	Yes	NT		9
BET	Thunnus.obesus	Bigeye.tuna	Teleost	Yes	VU	Tuna	9
PTH	Alopias.pelagicus	Pelagic.thresher	Shark	Yes	EN		8
CCF	Carcharhinus.amboinensis	Pigeye.shark	Shark	Yes	VU		8

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
HYD	Hydrolagus.spp	Ratfishes.nei	Chimaera	Yes			7
ETE	Etmopterus.compagnoi	Brown.lanternshark	Shark	Yes			6
HAG	Bythaelurus.lutarius	Mud.catshark	Shark	Yes			6
RCD	Rhynchobatus.djiddensis	Giant.guitarfish	Shark	Yes	CR		6
HXN	Hexanchus.nakamurai	Bigeyed.sixgill.shark	Shark	Yes	NT		6
CZI	Centroscymnus.spp	Sleeper.shark	Shark	Yes			5
QUK	Squalus.mitsukurii	Shortspine.spurdog	Shark	Yes	EN		5
SPL	Sphyrna.lewini	Scalloped.hammerhead	Shark	Yes	CR		4
RBI	Rhinobatos.irvinei	Spineback.guitarfish	Shark	Yes	CR		4
GAG	Galeorhinus.galeus	Tope.shark	Shark	Yes	CR		4
SMA	Isurus.oxyrinchus	Shortfin.mako	Shark	Yes	EN		4
SON	Somniosus.pacificus	Pacific.sleeper.shark	Shark	Yes	NT		4
HXT	Heptranchias.perlo	Sharpnose.sevengill.shark	Shark	Yes	NT		4
RZZ	Somniosus.antarcticus	Southern.sleeper.shark	Shark	Yes			3
BSH	Prionace.glauca	Blue.shark	Shark	Yes	NT		3
CCE	Carcharhinus.leucas	Bull.shark	Shark	Yes	VU		3
SUE	Squatina.tergocellata	Ornate.angelshark	Shark	Yes			2

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
APX	Apristurus.microps	Smalleye.catshark	Shark	Yes			2
RYE	Aetomylaeus.vespertilio	Ornate.eagle.ray	Ray	Yes	EN		2
SBF	Thunnus.maccoyii	Southern.bluefin.tuna	Teleost	Yes	EN		2
SPZ	Sphyrna.zygaena	Smooth.hammerhead	Shark	Yes	VU		2
CWM	Chimaera.spp		Chimaera	Yes			1
RBY	Gymnura.spp	Butterfly.rays.nei	Ray	Yes			1
SUU	Squatina.australis	Australian.angelshark	Shark	Yes			1
EZT	Etmopterus.viator	Blue_eye.lanternshark	Shark	Yes			1
CWO	Centrophorus.spp	Gulper.sharks.nei	Shark	Yes			1
CSF	Apristurus.longicephalus	Longhead.catshark	Shark	Yes			1
RSK	Carcharhinidae	Requiem.sharks.nei	Shark	Yes			1
AKG	Achoerodus.gouldii	Western.blue.groper	Teleost	Yes			1
SPK	Sphyrna.mokarran	Great.hammerhead	Shark	Yes	CR		1
RME	Mobula.eregoodoo	Longhorned.mobula	Ray	Yes	EN		1
SBL	Hexanchus.griseus	Bluntnose.sixgill.shark	Shark	Yes	NT		1
RMV	Mobula.spp	Mantas.devil.rays.nei	Ray	Yes	VU		1
RTE	Taeniurops.meyeni	Round.ribbontail.ray	Ray	Yes	VU		1

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
HCM	Chaenogaleus.macrostoma	Hooktooth.shark	Shark	Yes	VU		1
DGS	Squalus.acanthias	Picked.dogfish	Shark	Yes	VU		1
BYS	Beryx.splendens	Splendid.alfonsino	Teleost	No			14797
MZZ	Actinopterygii	Marine.fishes.nei	Teleost	No			4907
ORY	Hoplostethus.atlanticus	Orange.roughy	Teleost	No			4239
TOP	Dissostichus.eleginoides	Patagonian.toothfish	Teleost	No			3397
SEY	Schedophilus.velaini	Violet.warehou	Teleost	No			2819
THB	Nemipterus.spp	Threadfin.breams.nei	Teleost	No			2598
SZX	Saurida.spp	Lizardfish	Teleost	No			2597
GRV	Macrourus.spp	Grenadiers.nei	Teleost	No			2437
SDX	Decapterus.spp	Scads.nei	Teleost	No			2409
EDR	Pseudopentaceros.richardsoni	Pelagic.armourhead	Teleost	No			2347
BWA	Hyperoglyphe.antarctica	Bluenose.warehou	Teleost	No			2204
EPI	Epigonus.telescopus	Black.cardinal.fish	Teleost	No			2104
PFM	Pristipomoides.filamentosus	Crimson.jobfish	Teleost	No			1995
AVR	Aprion.virescens	Green.jobfish	Teleost	No			1994
SBX	Sparidae	Porgies.seabreams.nei	Teleost	No			1835

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
BIS	Selar.crumenophthalmus	Bigeye.scad	Teleost	No			1821
RIB	Mora.moro	Common.mora	Teleost	No			1702
BIG	Priacanthus.spp	Bigeyes.nei	Teleost	No			1639
ONV	Neocyttus.rhomboidalis	Spiky.oreo	Teleost	No			1573
GOX	Upeneus.spp	Goatfishes	Teleost	No			1367
ANT	Antimora.rostrata	Blue.antimora	Teleost	No			1316
BAR	Sphyraena.spp	Barracudas.nei	Teleost	No			1122
AMX	Seriola.spp	Amberjacks.nei	Teleost	No			1020
ETC	Etelis.coruscans	Deepwater.longtail.red.snapper	Teleost	No			884
NGX	Carangoides.spp	Travelly	Teleost	No			884
LUB	Lutjanus.sebae	Emperor.red.snapper	Teleost	No			792
SNA	Lutjanus.spp	Snappers.nei	Teleost	No			784
IAX	Sepia.spp	Cuttlefishes.nei	Cephalopod	No			706
WHA	Polyprion.oxygeneios	Hapuku.wreckfish	Teleost	No			689
WRF	Polyprion.americanus	Wreckfish	Teleost	No			689
ETA	Etelis.carbunculus	Deep_water.red.snapper	Teleost	No			621
RPX	Parupeneus.spp	Goatfishes	Teleost	No			579

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
UPM	Upeneus.moluccensis	Goldband.goatfish	Teleost	No			532
KCS	Paralithodes.spp	King.crabs	Crustacean	No			466
HAU	Polyprion.spp	Hapuka	Teleost	No			448
PRP	Promethichthys.prometheus	Roudi.escolar	Teleost	No			438
BOR	Caproidae	Boarfishes.nei	Teleost	No			398
RAX	Rastrelliger.spp	Indian.mackerels.nei	Teleost	No			380
APO	Apogonidae	Cardinalfishes.nei	Teleost	No			351
BOE	Allocyttus.niger	Black.oreo	Teleost	No			337
SSO	Pseudocyttus.maculatus	Smooth.oreo.dory	Teleost	No			306
BXD	Beryx.decadactylus	Alfonsino	Teleost	No			304
RYG	Plagiogeneion.rubiginosum	Rubyfish	Teleost	No			302
LTQ	Lethrinus.mahsena	Sky.emperor	Teleost	No			300
ANF	Lophiidae	Anglerfishes.nei	Teleost	No			295
LJL	Lutjanus.lutjanus	Bigeye.snapper	Teleost	No			294
LZX	Lethrinus.spp	Emperors	Teleost	No			274
HFR	Helicolenus.percoides	Red.gurnard.perch	Teleost	No			250
RAG	Rastrelliger.kanagurta	Indian.mackerel	Teleost	No			243

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
PBX	Plectorhinchus.spp	Sweetlips.rubberlips.nei	Teleost	No			216
BRF	Helicolenus.dactylopterus	Blackbelly.rosefish	Teleost	No			187
COX	Congridae	Conger.eels.nei	Teleost	No			163
TAK	Nemadactylus.macropterus	Tarakihi	Teleost	No			157
OIL	Ruvettus.pretiosus	Oilfish	Teleost	No			140
BSF	Aphanopus.carbo	Black.scabbardfish	Teleost	No			127
VLO	Palinuridae	Spiny.lobsters.nei	Crustacean	No			119
ALF	Beryx.spp	Alfonsinos.nei	Teleost	No			110
YTC	Seriola.lalandi	Yellowtail.amberjack	Teleost	No			110
YRB	Sphyraena.obtusata	Obtuse.barracuda	Teleost	No			109
DPX	Perciformes	Demersal.percomorphs.nei	Teleost	No			108
RTX	Macrouridae	Grenadiers.rattails.nei	Teleost	No			107
LWX	Pristipomoides.spp	Jobfishes.nei	Teleost	No			90
GEM	Rexea.solandri	Silver.gemfish	Teleost	No			82
SFS	Lepidopus.caudatus	Silver.scabbardfish	Teleost	No			82
SQU	Loliginidae.Ommastrephidae	Various.squids.nei	Cephalopod	No			80
CEN	Centrolophidae	Ruffs.barrelfishes.nei	Teleost	No			75

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
CDL	Epigonus.spp	Cardinal.fishes.nei	Teleost	No			71
BSX	Serranidae	Groupers.seabasses.nei	Teleost	No		Grouper	66
HPR	Hoplostethus.mediterraneus	Mediterranean.slimehead	Teleost	No			65
ALT	Aluterus.spp	Leatherjacket.filefishes	Teleost	No			59
ROK	Helicolenus.spp	Rosefishes.nei	Teleost	No			58
SXB	Pagellus.affinis	Arabian.pandora	Teleost	No			56
GUX	Triglidae	Gurnards.searobins.nei	Teleost	No			55
GRX	Haemulidae.or.Pomadasyidae	Grunts.sweetlips.nei	Teleost	No			48
EMP	Lethrinidae	Emperors.nei	Teleost	No		Emperor	44
PCX	Muraenesox.spp	Pike_congers.nei	Teleost	No			43
CDX	Sciaenidae	Croakers.drums.nei	Teleost	No			42
SCO	Scorpaenidae	Scorpionfishes.redfishes.nei	Teleost	No			42
PUX	Tetraodontidae	Puffers.nei	Teleost	No			39
CTL	Sepiidae.Sepiolidae	Cuttlefish.bobtail.squids.nei	Cephalopod	No			38
GRN	Macruronus.novaezelandiae	Blue.grenadier	Teleost	No			37
TRI	Balistidae	Triggerfishes.durgons.nei	Teleost	No			36
LRI	Pristipomoides.multidens	Goldbanded.jobfish	Teleost	No			34

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
CUT	Trichiuridae	Hairtails.scabbardfishes.nei	Teleost	No			33
CVY	Coryphaenoides.spp	Grenadiers.whiptails.nei	Teleost	No			30
CRA	Brachyura	Marine.crabs.nei	Crustacean	No			29
LBR	Gymnocranius.spp	Largeeye.breams	Teleost	No			28
CRU	Crustacea	Marine.crustaceans.nei	Crustacean	No			27
OEQ	Euryalida	Basket.stars	Echinderm	No			27
XSX	Scorpaeniformes	Scorpionfishes.gurnards.nei	Teleost	No			27
FIT	Fistularia.spp	Flutemouth	Teleost	No			26
PZU	Pterois.russelii	Plaintail.turkeyfish	Teleost	No			25
RRU	Elagatis.bipinnulata	Rainbow.runner	Teleost	No			25
TRZ	Pseudocaranx.dentex	White.trevally	Teleost	No			22
OCT	Octopodidae	Octopuses.nei	Cephalopod	No			21
DIA	Actinopterygii	Diadromous.fishes.nei	Teleost	No			21
LHN	Lethrinus.nebulosus	Spangled.emperor	Teleost	No			21
RNJ	Seriolina.nigrofasciata	Blackbanded.trevally	Teleost	No			20
HCZ	Holocentridae	Squirrelfishes.nei	Teleost	No			20
XAX	Anguilliformes	Eels.morays.congers.nei	Teleost	No			19

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
PAZ	Neoachiropsetta.milfordi	Finless.flounder	Teleost	No			17
MOR	Moridae	Moras.nei	Teleost	No			17
ENE	Pentaceros.capensis	Cape.armourhead	Teleost	No			16
WLX	Latridopsis.spp	Trumpeters	Teleost	No			16
MCH	Macrourus.holotrachys	Bigeye.grenadier	Teleost	No			15
JOD	Zeus.faber	John.dory	Teleost	No			15
LEF	Bothidae	Lefteye.flounders.nei	Teleost	No			15
LEV	Lepidion.spp	Lepidion.codlings.nei	Teleost	No			15
ORD	Oreosomatidae	Oreo.dories.nei	Teleost	No			15
TVX	Thenus.spp	Flathead.lobsters.nei	Crustacean	No			14
EMT	Emmelichthyidae	Bonnetmouths.rubyfishes.nei	Teleost	No			14
YBS	Sphyraena.forsteri	Bigeye.barracuda	Teleost	No			13
SNK	Thyrsites.atun	Snoek	Teleost	No			13
ALL	Allocyttus.verrucosus	Warty.dory	Teleost	No			13
CRW	Palinurus.spp	Palinurid.spiny.lobsters.nei	Crustacean	No			12
MAX	Scombridae	Mackerels.nei	Teleost	No			12
IJP	Helicolenus.mouchezi	Rosefish	Teleost	No			12

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
MAC	Scomber.scombrus	Atlantic.mackerel	Teleost	No			11
CGX	Carangidae	Carangids.nei	Teleost	No			11
TOA	Dissostichus.mawsoni	Antarctic.toothfish	Teleost	No			10
OAV	Pomacanthus.asfur	Arabian.angelfish	Teleost	No			10
OPH	Ophidiidae	Cusk_eels.brotulas.nei	Teleost	No			10
TRU	Latridae	Trumpeters.nei	Teleost	No			10
SVY	Synaphobranchidae	Cutthroat.eels.nei	Teleost	No			9
HMG	Trachurus.declivis	Greenback.horse.mackerel	Teleost	No			9
LJB	Lutjanus.bohar	Two_spot.red.snapper	Teleost	No			9
CUX	Holothuroidea	Sea.cucumbers.nei	Sea.cucumber	No			8
HWH	Sargocentron.rubrum	Redcoat	Teleost	No			8
DCK	Decapterus.kurroides	Redtail.scad	Teleost	No			8
ERY	Erythrocles.schlegelii	Japanese.rubyfish	Teleost	No			7
KGX	Scomberomorus.spp	Seerfishes.nei	Teleost	No			7
BNS	Benthosema.suborbitale	Smallfin.lanternfish	Teleost	No			7
SLN	Palinurus.delagoae	Natal.spiny.lobster	Crustacean	No			6
DCP	Natantia	Natantian.decapods.nei	Crustacean	No			6

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
OCZ	Octopus.spp	Octopuses.nei	Cephalopod	No			5
JCX	Maja.spp	Maja.spider.crabs.nei	Crustacean	No			5
JSP	Jasus.paulensis	St.Paul.rock.lobster	Crustacean	No			5
SDC	Diastobranchus.capensis	Basketwork.eel	Teleost	No			5
WLF	Latridopsis.forsteri	Bastard.trumpeter	Teleost	No			5
CLP	Clupeidae	Herrings.sardines.nei	Teleost	No			5
KAW	Euthynnus.affinis	Kawakawa	Teleost	No			5
NDG	Nototodarus.gouldi	Goulds.flying.squid	Cephalopod	No			4
DSD	Distorsio.decussata	Decussate.distorsio	Gastropod	No			4
BAT	Platax.spp	Batfishes	Teleost	No			4
COE	Conger.conger	European.conger	Teleost	No			4
FIN	Actinopterygii	Finfishes.nei	Teleost	No			4
NGS	Carangoides.malabaricus	Malabar.trevally	Teleost	No			4
SOX	Soleidae	Soles.nei	Teleost	No			4
SQC	Loligo.spp	Common.squids.nei	Cephalopod	No			3
THQ	Thenus.orientalis	Flathead.lobster	Crustacean	No			3
CRS	Portunus.spp	Portunus.swimcrabs.nei	Crustacean	No			3

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
OOY	Ophiurida	Brittle.and.snake.stars	Echinderm	No			3
CVD	Cidaridae	Pencil.urchins	Echinderm	No			3
SEM	Seriolella.brama	Common.warehou	Teleost	No			3
XPX	Antennariidae	Frogfishes.nei	Teleost	No			3
ZCT	Cyttus.traversi	King.dory	Teleost	No			3
MOW	Nemadactylus.spp	Morwongs	Teleost	No			3
CHP	Sardinops.sagax	Pacific.sardine	Teleost	No			3
DGV	Acanthurus.blochii	Ringtail.surgeonfish	Teleost	No			3
SIL	Atherinidae	Silversides.or.Sand.smelts.nei	Teleost	No			3
PJJ	Projasus.parkeri	Cape.jagged.lobster	Crustacean	No			2
JEL	Rhopilema.spp	Jellyfishes.nei	Jellyfish	No			2
BDX	Bohadschia.similis	Brownspotted.sandfish	Sea.Cucumber	No			2
MAI	Macronectes.giganteus	Antarctic.giant.petrel	Seabird	No			2
POA	Brama.brama	Atlantic.pomfret	Teleost	No			2
HYW	Hyperoglyphe.perciformis	Barrelfish	Teleost	No			2
AMB	Seriola.dumerili	Greater.amberjack	Teleost	No			2
TRE	Caranx.spp	Jacks.crevalles.nei	Teleost	No			2

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
REL	Regalecus.glesne	King.of.herrings	Teleost	No			2
MRL	Muraenolepis.spp	Moray.cods.nei	Teleost	No			2
PRC	Percoidei	Percoids.nei	Teleost	No			2
CUS	Genypterus.blacodes	Pink.cusk_eel	Teleost	No			2
SKJ	Katsuwonus.pelamis	Skipjack.tuna	Teleost	No			2
AJS	Abalistes.stellaris	Starry.triggerfish	Teleost	No			2
AXQ	Acanthurus.spp	Surgeionfish	Teleost	No			2
SEU	Seriolella.caerulea	White.warehou	Teleost	No			2
TUZ	Trachurus.novaezelandiae	Yellowtail.horse.mackerel	Teleost	No			2
YFT	Thunnus.albacares	Yellowfin.tuna	Teleost	No		Tuna	2
BWY	Bathylasmatidae	Barnacle	Barnacle	No			1
GER	Chaceon.spp	Chaceon.geryons.nei	Crustacean	No			1
KCU	Paralomis.aculeata	Red.stone.crab	Crustacean	No			1
SVX	Stomatopoda	Stomatopods.nei	Crustacean	No			1
SLV	Panulirus.spp	Tropical.spiny.lobsters.nei	Crustacean	No			1
STF	Asteroidea	Starfishes.nei	Echinderm	No			1
WOR	Polychaeta	Marine.worms	Invertebrates	No			1

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
SZS	Serpulidae	Serpulid.tube.worms	Invertebrates	No			1
WBX	Holothuria.spp	Sea.cucumber	Sea.cucumber	No			1
TDO	Tripterodon.orbis	African.spadefish	Teleost	No			1
PQR	Priacanthus.arenatus	Atlantic.bigeye	Teleost	No			1
CWA	Clupeonella.spp	Black_Caspian.Sea.sprats.nei	Teleost	No			1
AYV	Aphyonus.brevidorsalis	Blidfish	Teleost	No			1
EMM	Emmelichthys.nitidus	Cape.bonnetmouth	Teleost	No			1
CBH	Bassanago.hirsutus	Deep.sea.conger.eel	Teleost	No			1
JDX	Notacanthidae	Deep_sea.spiny.eels.nei	Teleost	No			1
ZEX	Zeidae	Dories.nei	Teleost	No			1
DGW	Acanthurus.mata	Elongate.surgeonfish	Teleost	No			1
GUY	Trigla.spp	Gurnards.nei	Teleost	No			1
JAX	Trachurus.spp	Jack.and.horse.mackerels.nei	Teleost	No			1
LXX	Myctophidae	Lanternfishes.nei	Teleost	No			1
MWG	Melanostigma.gelatinosum	Limp.eelpout	Teleost	No			1
MOX	Mola.mola	Ocean.sunfish	Teleost	No			1
LAP	Lampris.spp	Opahs.nei	Teleost	No			1

Code	ScientificName	EnglishName	Organism	Protected	IUCN	Remark	Freq
CDD	Nemadactylus.douglasii	Porae	Teleost	No			1
PLZ	Pleuronectidae	Righteye.flounders.nei	Teleost	No			1
TST	Taractichthys.steindachneri	Sickle.pomfret	Teleost	No			1
SEP	Seriolella.punctata	Silver.warehou	Teleost	No			1
GES	Gempylus.serpens	Snake.mackerel	Teleost	No			1
GEP	Gempylidae	Snake.mackerels.escolars.nei	Teleost	No			1
MAP	Magnisudis.prionosa	Southern.barracudina	Teleost	No			1
SPI	Siganus.spp	Spinefeet(=Rabbitfishes).nei	Teleost	No			1
URA	Uranoscopus.spp	Stargazers	Teleost	No			1
BBY	Batrichthys.albofasciatus	White_ribbed.toadfish	Teleost	No			1

Terms of Reference (ToR) for the provision of scientific services to SIOFA Scientific Committee

Project title: Protocols to designate and evaluate MPAs in the SIOFA Area

Project Code: PAE2022-MPA1

1. INTRODUCTION

SIOFA CMM2020/01 requires the SIOFA Scientific Committee to provide advice to the Meeting of Parties (MoP) on a standard protocol for future protected areas designation (paragraph 5d) and research and management plans (paragraph 6e) for each of the protected areas listed in CMM2020/01 Annex 3.

This document describes the project Terms of Reference (ToR), milestones, and administrative matters for a consultancy to develop proposals for evaluating and monitoring protected areas in the SIOFA Area. Once appointed, the Consultant should direct any questions and clarifications to the SIOFA Science Officer (Marco Milardi, marco.milardi@siofa.org) who will coordinate the project and its interactions with the project advisory panel, the relevant SC HoDs and the SIOFA Scientific Committee Chair, as appropriate.

This project will provide options for consideration by the SIOFA Scientific Committee for evaluating and monitoring protected areas in the SIOFA Area.

2. TERMS OF REFERENCE

The project objectives and tasks are described below. The Consultant shall undertake these tasks and consult with the project coordinator to ensure that the project objectives are met.

A project advisory panel consisting of the SIOFA Scientific Committee Chair, selected members of the SIOFA Scientific Committee, and the SIOFA Secretariat will meet periodically with the consultant to assist the consultant access and interpret reports, data, and to provide advice on relevant analyses or data interpretation for the project.

2.1 Overall objectives

Objective 1: Provide advice to the SIOFA Scientific Committee on the options for evaluating and monitoring current protected areas (CMM2020/01 Annex C) in the SIOFA Area.

Objective 2: Provide advice to the SIOFA Scientific Committee on approaches to developing protocols for designating new protected areas (as per CMM2020/01 paragraph 5d) in the SIOFA Area.

2.1.1 Task 1: Literature review

Review SIOFA reports and publications, reports from other regional marine management organisations, the general scientific literature, and other relevant information sources, that will summarise previous SIOFA advice and advice for other management organisations approaches to monitoring protected areas and the protocols for designating protected areas.

2.1.2 Task 2: Review of fisheries, research, and other relevant data

Review the relevant fisheries, research, and any other data held by SIOFA or is publicly available to develop an understanding of benthic organism diversity and the fish catch composition in the protected areas in the SIOFA Area. This will also include consideration of potential linkages with areas in the Indian Ocean sector of the CCAMLR Convention and IOTC Areas.

2.1.3 Task 3: Options for evaluating and monitoring protected areas

Develop options for evaluating the performance of protected areas in the SIOFA Area, as defined in CMM2020/01 Annex C, and provide advice to the SIOFA Scientific Committee on developing area specific data collection and evaluation plans for each existing protected area. An overview of potential contingencies, timelines, and relative costs involved should also be described.

2.1.4 Task 4: Develop options to optimise the acquisition of new data

Develop options for approaches and method to acquire the data and information required to evaluate and monitor the protected areas. and provide advice to the SIOFA Scientific Committee.

2.1.5 Task 5: Options for protocols for designating new protected areas

Develop options for protocols for the evaluation and designation of new protected areas in the SIOFA Area and provide advice to the SIOFA Scientific Committee on these options.

2.2 Reporting requirements

1. Provide updates and engage with the project advisory panel that will assist the consultant access and interpret reports, data, and to provide advice on relevant analyses or data interpretation for the project

2. Provide a draft report detailing the methods, outcomes of reviews, conclusions, and recommendations to the SIOFA project advisory panel for review by 31 November 2023.

3. Update the draft report in (2) by considering any comments and advice from the project advisory panel and submit this report to SIOFA Secretariat for submission to the SIOFA Scientific Committee meeting in 2023 by 15 January 2024.

4. Present the draft report in (3) to the SIOFA Scientific Committee to its meeting in March 2024 by videoconference.

5. Provide an amended final report to the SIOFA Secretariat, considering any comments made at the SIOFA Scientific Committee meeting in March 2024, by 15 April 2024

6. Provide all the information collected to the SIOFA Secretariat (including that sourced from the Secretariat) before the final payment of the contract is made to the consultant. Such information includes electronic data files, analysis codes, biological samples, and other relevant data if applicable.

2.3 Confidentiality and distribution of project outcomes

The Consultant shall not release confidential data provided for conducting this study to any persons nor any organisations, other than SIOFA Secretariat. The consultant shall delete all the confidential data after the completion of the contract. Any arrangements for ownership, storage, or disposal of physical samples shall be agreed by SIOFA as a part of the contract.

All Intellectual Property generated as a part of this contract shall become the property of SIOFA unless otherwise excluded in the proposal and agreed by SIOFA in the contract.

All reports and presentations will be reviewed by the SIOFA Secretariat prior to any form of further distribution. The Consultant will revise the report according to comments received from the review process before the report or presentation is accepted as a submission against the requirements in the Terms of Reference.

2.4 Relevant SIOFA information

1. SIOFA data (provided by the SIOFA Secretariat upon request)
2. SIOFA reports:
    a. SIOFA SC reports and National Reports. Scientific Committee Meeting | SIOFA (siofa.org)
    b. MoP reports. Meeting of the Parties | SIOFA (siofa.org)
    c. SIOFA technical and scientific reports (public reports available from siofa.org, and restricted reports available from the SIOFA Secretariat to the project consultant)

3. WORK PLAN AND PAYMENT SCHEDULE

The funds for this project are budgeted under Task 1 of the SIOFA-SEAs EU Grant Agreement, for a total allocated budget of 18,000 euro (including all costs and including any travel related expenses). Any communication activity funded by the grant must acknowledge EU support and display the European flag (emblem) and the funding statement (translated into local languages, if applicable).

The consultant shall follow the timeline described in Table 1 below.

Table 1: Timeline for payments, milestones, and report submission

Milestone	Date	Activities
Initiation of contract	1 February 2023	First instalment payment (30% of the total contract sum)
Delivery of draft report	31 November 2024	Submission of draft report to SC8
Delivery of final report	15 April 2024	Submission of final report and project information to SIOFA. Final instalment payment (70% of the total contract sum) on acceptance of the final report and the submission of project information
Presentation		Present the report to a meeting of the SC or working group of SC

4. SUBMISSION OF APPLICATIONS

The applicants should have appropriate experience and knowledge of developing stock structure hypotheses and preferably on the stock dynamics and life cycle of Patagonian toothfish. The applicants should submit a proposal to the project coordinator (SIOFA Science Officer - Marco Milardi, marco.milardi@siofa.org) containing the following items:

1. A current CV that summarises the applicant(s) relevant educational background and professional experience
2. A brief proposal (indicatively 1-2 pages) outlining the proposed methods and analyses, including a description of how the objectives of the ToRs will be achieved
3. Any proposed exclusions to the intellectual property clause
4. The proposed consultancy price (including all consultant expenses and project related costs), noting that the available budget for this work is a maximum of €18,000
5. Identification of any project risks and associated mitigation and management required to successfully complete the project
6. A statement that identifies any perceived, potential, or actual conflicts of interest of the applicant(s), including those described in paragraph 4 of the SIOFA recruitment procedure (see Box 1), and
7. Any additional relevant information the applicant(s) wish to submit.
8. We note that similar projects for alfonsino and orange roughy in the SIOFA Area are also available, and we encourage consultants to submit combined proposals for these projects if appropriate.

Applications received before 12 AM (9 AM UTC) on Monday the 16th of January 2023, Reunion Island time, will be considered in the following selection process.

5. EVALUATION CRITERIA FOR THE SELECTION OF CANDIDATES

The selection criteria will be developed by the evaluation panel along with the project manager, the Secretariat, and the Chairpersons of the relevant subsidiary bodies. The criteria may include following items:

1. Adequate submission of information to allow the panel to evaluate the candidate
2. Evaluation of the proposal from the candidate, including the proposed contract price
3. Ability to undertake and complete the analyses or work required in the ToR
4. The candidate's agreement with confidentiality provisions required for the project
5. Acceptable conflict of interest statement
6. Agreement with the data submission and intellectual property terms required in this ToR, and
7. Financial and resourcing considerations.

6. CONFLICTS OF INTEREST. PARAGRAPH 4 OF SIOFA'S RECRUITMENT PROCEDURE

To ensure that situations relating to potential and actual conflict of interests are avoided, persons falling into the following categories may not normally be considered for SIOFA consultancy: (i). any person designated as a designated representative or alternate representative of a CCP to the Meeting of Parties (MOP) as per Rule 3.1 of the Rules of Procedure, and to the SC and any other subsidiary bodies of the MOP, as per Rule 21.3 of the Rules of Procedure; (ii). Any person fulfilling the function of Chair or Vice-Chair of the MOP or Chair or Vice-Chair of a SIOFA subsidiary body or working group; (iii). Any person acting as a member of a delegation involved in the SIOFA decision-making process resulting in recommendations and/or approval for the SIOFA work requiring the engagement of a consultant; and (iv). Individuals who were SIOFA Secretariat staff members at the time when the recommendations and/or approval for the SIOFA works were adopted or who are members of immediate family (e.g., spouse or partner, father, mother, son, daughter, brother, or sister) of any Secretariat staff member or of the persons identified in 4 (i), (ii), and (iii).

7. CONTACTS

Project Coordinator – SIOFA Science Officer (Marco Milardi, marco.milardi@siofa.org)

Administration – SIOFA Executive Secretary (Thierry Clot, thierry.clot@siofa.org)

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